

Colour Stability of Temporary Restorations with Different Thicknesses Submitted to Artificial Accelerated Aging

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Abstract - This study evaluated the colour stability of temporary prosthetic restorations with different thicknesses submitted to artificial accelerated aging. The occlusal surfaces of 40 molars were grinded to obtain flat enamel surfaces. Twenty acrylic resin specimens [Polymethyl methacrylate (Duralay) and Bis-methyl acrylate (Luxatemp)] were made with two different thicknesses, 0.5mm and 1.0mm. Temporary restorations were fixed on enamel and CIE L*a*b* colour parameters of each specimen were assessed before and after artificial accelerated aging. All groups showed colour alterations above the clinically acceptable limit. Luxatemp showed the lowest colour alteration regardless its thickness and Duralay showed the greatest alteration with 0.5mm.

KEYWORDS: Temporary dental restorations, Acrylic resins, Colour stability, Artificial accelerated aging, Thermal cycling.

INTRODUCTION

Aesthetic temporary restorations are often used for several months, requiring them to be well made and stable with distinct functions and purposes¹. Temporary restorations have become a vital diagnostic and assessment tool in evaluating function, colour, shape, contour, occlusion, periodontal response, implant healing, and overall aesthetics¹. A critical step during prosthetic rehabilitation is temporisation of the prepared teeth. Temporary restorations are meant to protect both the tooth structure and the surrounding soft tissue. In addition, they help to determine the size, position, colour, and texture of final restorations². In aesthetically critical areas, a temporary restoration must remain colour-stable during the length of treatment³, which can last an extended period of time⁴. The literature on the colour stability of resins used for temporary restorations is limited^{5,7}. Nevertheless, it is known that temporary restorations show colour changes over time, jeopardizing the success of any type of cosmetic treatment^{5,8}.

Colour is the result of light waves reflected by restorative materials, which may be opaque or translucent⁹. Several factors are involved in determining the colour of an object: the characteristics of the light source under which the object is observed; the way light waves are absorbed; reflected, or transmitted; and environmental influences on the observer^{10,11}. Colour is also related to the distribution and absorption of light emitted by the source¹². While in opaque objects, light is more intensely dispersed, in translucent objects, more transmission and less dispersion occur¹³.

Therefore, knowledge of the fundamentals of colour and light would help dentists to select the appropriate tooth colour for restorative materials in aesthetic restorations¹⁰.

Temporary restorations are most often made of polymethyl methacrylate (PMMA), which has been used in dentistry for over 70 years due to its aesthetic qualities and its easy handling and repair¹⁴. Clinically, however, they have low impact and fracture resistance¹¹ and poor colour stability over time¹⁵. Other materials indicated for temporary restorations have been tested based on bis-methyl acrylate (Bis-Ac), which, according to some authors, presents proper colour stability over time within clinically acceptable limits^{16,17}.

Artificial accelerated aging (AAA) is a method that produces, in a relatively short period, degradation similar to that restorative materials would undergo during their clinical life^{18,19}. AAA promotes variations in physicochemical conditions, such as visible light, ultraviolet radiation, temperature, and humidity²⁰. As colour perception is subjective²¹, the use of objective methods and specific equipment to perform accurate colour analysis of restorative materials is essential. The CIE L*a*b* colour space²² has been widely used in dentistry research^{19,23,24,25}, as it defines colour in terms of 3 coordinate values (L*, a*, and b*). Axes a* and b* are at right angles and represent the shade or colour dimension. The third axis, perpendicular to the a* and b* planes, is lightness L*, which represents the amount of light reflected from the object and is expressed in numeric values ranging from 0 (black) to 100 (white). Since different materials with different thicknesses may show different appearances and colour stability, this study aimed at evaluating the effect of AAA on the colour stability of two types of temporary restorations (PMMA and Bis-Ac) with different thicknesses. The null hypotheses tested were that the thinner the restoration, the higher the colour alteration and that no difference in colour would appear between either temporary material after AAA.

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MATERIALS AND METHODS

The present study was approved by the Research Ethics Committee (Process No. 2010.1.1399.58.8) and used 40 sound human molars. Teeth with white spot lesions, signs of demineralisation, fractures, abrasions, or cracks were excluded from the study.

After prophylaxis with a rubber cup in a slow-speed hand-piece, the teeth were embedded in PVC cylinders (15 mm in diameter) with self-cured acrylic resin up to the cemento-enamel junction. Following acrylic resin polymerization, a flat enamel surface was obtained by grinding the occlusal surface with a polishing machine using abrasive sandpaper discs in decreasing granulations (P100, P320, P600, P800, and P1000). Forty temporary restoration samples were produced according to the manufacturer's guidelines (6 mm diameter): 20 of PMMA (Duralay acrylic resin - Shade 66), and 20 of Bis-Ac (Luxatemp - Shade A3) (see Table 1). They were then subdivided into two thickness groups (0.5 mm and 1.0 mm, n=10), simulating temporary restorations for ceramic laminate veneers.

After polymerization, specimens were manually polished to a thickness of 0.5 mm and 1.0 mm with water-cooled sandpaper discs in decreasing order of granulation (P600, P1000, and P1200). The thickness of the samples was constantly assessed using a digital calliper. The temporary restorations were then fitted to the tooth surface with composite (Z250, shade A3) applied to the central portion of the enamel surface after acid etching (37% phosphoric acid) for 30 seconds. A load of 380 grams was used to ensure the standardisation of the luting procedure. This procedure was used after the determination that a load with a minimum of 380 g allows for the sufficient flow of composite excesses, resulting in the thinnest possible cementing line. The composite was light-activated by a LED device for 20 seconds, and specimens were kept in distilled water at 37 °C for 24 hours. After luting the temporary restorations, initial colour readings were taken with a dental spectrophotometer (Vita Easyshade), according to the CIE L*a*b* colour space, excluding the specular component, which simulates a measurement of 45/0 geometry, standard illuminant D65, and observer pattern of 2°. The excluded specular component is related to the colour measurement on the sample surface meant to prevent interference by surface brightness^{26,27}. Specimens were then subjected to AAA (Accelerated Aging System for Non-Metallic UV-C) for 40 hours, simulating a period of one month of clinical use²⁸. To do this, specimens were placed on aluminium plates and exposed to 8 UV-B light sources with a radiation of 280/320 nm and steam condensation. The working program was set to 4 hours of exposure to UV-B at 50°C and 4 hours of condensation at 50°C²⁸. After AAA, new colour readings were taken, and colour alteration (ΔE) was calculated using the following formula¹⁹:

$$\Delta E = \sqrt{(\Delta L')^2 + (\Delta a')^2 + (\Delta b')^2}$$

Where:

ΔE = colour alteration

$\Delta L^* = L^*_F - L^*_I$

$\Delta a^* = a^*_F - a^*_I$

$\Delta b^* = b^*_F - b^*_I$

The subscript "F" corresponds to the final reading performed after AAA, while the subscript "I" corresponds to the initial reading. ΔL represents the lightness difference, Δa the red-green parameter difference ($-a^*$ = Green and $+a^*$ = red), and Δb the yellow-blue parameter difference ($-b^*$ = blue and $+b^*$ = yellow)¹⁹. Colour alteration values greater than 3.3 were considered clinically unacceptable²⁹. The results obtained were subjected to statistical analysis (2-way ANOVA, Bonferroni, $p < 0.05$) using GraphPad Prism 4.0 software.

RESULTS

Table 2 presents the results for colour stability (ΔE). All groups showed colour alteration above the clinically acceptable limit ($\Delta E > 3.3$). However, changes occurred in Luxatemp with a statistically significant difference as compared to those for Duralay ($p < 0.05$) (thickness-independent).

When comparing the thickness influence for the same material, no significant difference ($p > 0.05$) was observed for Luxatemp. However, Duralay showed a statistically significant difference between the two thicknesses. Thinner specimens (0.5 mm) showed higher colour alteration ($p < 0.05$).

DISCUSSION

The present study aimed at evaluating the colour stability of temporary prosthetic restorations with different thicknesses submitted to AAA. The null hypotheses tested were that the thinner the restorations, the higher the colour alteration and that there would be no difference in colour between either temporary material after the AAA. Based on the results obtained, the null hypotheses were rejected: The colour stability was different in the tested materials, and thickness had no influence on the colour stability of the bis-acrylate-based material.

Several authors have suggested that materials such as Bis-Ac have adequate colour stability over time^{16,17}. However, other studies have reported that such materials still have lower colour stability when compared to that achieved with PMMA-based acrylic resins^{8,30,31}. These conflicting findings may be explained by the technique used to verify colour

Table 1. Materials used in the study.

Product	Resin type	Composition
Duralay	Polymethyl methacrylate	Powder: copolymer of methyl methacrylate and pigments Liquid: methyl methacrylate, EDMA*, inhibitors
Luxatemp	Bis-acryl methacrylate	Matrix of Bis-methyl acrylate, catalysts, stabilizers, additives and pigments

* EDMA- Ethylene Glycol Dimethacrylate

Table 2. Mean values for colour stability (ΔE)

Thicknesses	Groups	
	Duralay Mean (SD)	Luxatemp Mean (SD)
0.5 mm	37.21 (2.86) ^{aA}	11.82 (2.83) ^{bA}
1.0 mm	26.27 (2.55) ^{aB}	11.36 (2.56) ^{bA}

SD= Standard Deviation

Different letters, lowercase in lines and uppercase in columns, show a statistically significant difference (2-way ANOVA, Bonferroni ($p < 0.05$)).

stability. When the chosen technique is immersion cycles in dye solutions, PMMA behaves better and exhibits less colour alteration^{8,30,31}. However, when the UV irradiation with AAA technique is used, composites such as Bis-Ac show greater resistance to discolouration⁸. Subjecting materials to extreme conditions in an effort to speed up the natural aging process, AAA is a suitable method for estimating the useful life span of a product^{18,19}. Thus, if a restorative material shows better colour stability after being subjected to AAA, it is expected to have higher resistance and better clinical performance in the oral environment.

In the present study, specimens were subjected to AAA for 40 hours, a period that simulates the clinical use of temporary restorations for a month²⁸ and the average time that a temporary restoration is used³². AAA has been widely used^{5,8,32,33}, especially for materials based on acrylic resins^{5,15}. Aging processes attempt to reproduce the hydrolytic degradation occurring in polymers, since these materials are susceptible to absorption, from the oral environment³⁴, solvents that can change their chemical and physical properties, including colour alteration³⁵.

Colour alteration produced by hydrolytic and hygroscopic effects depends on polymer composition and chemical structure, as well as the number of free unreacted monomers in carbon chains, the polymer chains, and the presence of porosities in cross-linked networks³⁴. Thus, these changes will be different in materials with different chemical compositions and structures³⁵, as demonstrated in this study. Surface smoothness is also an important factor when selecting a temporary material. According to Young *et al.*³⁵, Bis-Ac resins have greater smoothness when compared to PMMA-based materials, and materials with smoother homogeneous surfaces have a less extrinsic staining capacity.

In contrast to previous studies^{16,17}, values found for colour change in the present study were above the clinically acceptable limit ($\Delta E > 3.3$) for both materials. However, despite the clinically unacceptable values for bis-acrylate-based restorations, the present results showed that colour stability was not influenced by the material's thickness. Bis-Ac resins are composites of fluid viscosity, fast polymerization, high abrasion resistance, and small polymerization shrinkage^{8,30,35}. Due to chemical structure polarity³³, most Bis-Ac resins have higher affinity for water and other liquids than do PMMA-based resins, which could explain the higher values of colour change once the material was subjected to water condensation cycles during AAA. In this study, although Bis-Ac has greater water affinity, observed colour alteration was lower than in PMMA-based restorations. This shows that the hydrolytic degradation in the polymer chain of tested materials could not be responsible for the colour changes observed.

The monomer conversion rate of the polymeric network is directly related to the staining ability and chemical characteristics of resin systems³⁴. Resins with a high monomer conversion rate exhibit advantageous features: They have suitable optical properties and experience less degradation susceptibility by oral environment substances³⁴ when compared to others. However, insufficient monomer conversion and the presence of carbonic unconverted double bonds render the material more susceptible to degradation reactions⁶, resulting in colour stability reduction due to the lixiviation of subproducts, such as methacrylic acid, formaldehyde, and certain molecules of methacrylate³⁶. Moreover, Bis-Ac resins possess a special feature: The presence of cross-linked bonds in their polymeric structure promote greater mechanical strength, reduce polymerization shrinkage³⁷, and make the material more degradation resistant than PMMA-based acrylic resins³⁰.

CONCLUSION

Material selection for temporary restorations should be based on the strengths and limitations of each material and the specific purposes of the treatment phase. Despite the limitations of this study, one can conclude that both bis-methyl acrylate-based and PMMA-based restorations exhibit colour alteration above the clinically acceptable limit over time; however, colour alteration is lower for bis-methyl acrylate-based materials (thickness-independent), and colour alteration for PMMA is inversely proportional to restoration thickness.

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MANUFACTURERS DETAILS

- Slow-speed Handpiece - Dabi Atlante, Ribeirão Preto, SP, Brazil
- Self-cured acrylic resin - Vipi Flash, Vipi, Pirassununga, SP, Brazil
- Mechanical polisher - Polipan-U, Panambra, São Paulo, SP, Brazil
- Sand paper discs - Norton, São Paulo, SP, Brazil
- Bis-Ac - Luxatemp, DMG Hamburg, Germany
- PMMA - Duralay, Reliance Dental Mfg, Worth, IL, EUA
- Phosphoric acid 37% - SS White, Rio de Janeiro, RJ, Brazil
- Composite Z250 shade A3 - 3M ESPE, Sumaré, SP, Brazil
- LED curing light - FLASHlite 1401, Discus Dental, Culver City, CA, EUA 460-480 nm, 1100 mW/cm
- Digital caliper - Digimess, São Paulo, SP, Brazil
- Spectrophotometer - Vita Easys shade - VITA Zahnfabrik, Bad Säckingen, Germany

- AAA - Accelerated Aging System for Non-Metallic UV-C, Comexim Matérias Primas Ltd., São Paulo, SP, Brazil
- Statistical software - GraphPad Prism 4.0, La Jolla, CA, EUA

REFERENCES

- Ruyter, I.E., Nilner, K. and Moller B (1987) Color stability of dental composite resin materials for crown and bridge veneers. *Dent. Mat.*, 1987; **3**: 246-251.
- Lodding, D.W. Long-term esthetic provisional restorations in dentistry. *Curr. Opin. Cosmet. Dent.*, 1997; **4**:16-21.
- Small, B.W. Pretreatment wax-ups and provisionals for restorative dentistry. *Gen. Dent.*, 2005; **53**:98-100.
- Doray, P. G., Wang, X., Powers, J. M. and Burgess, J. O. Accelerated aging affects color stability of provisional restorative materials. *J.Prostbodont.*, 1997; **6**: 183-188.
- Derbabian, K., Marzola, R., Donovan, T.E. and Arcidiacono, A. The science of communicating the art of esthetic dentistry. Part III: precise shade communication. *J. Esthet. Restor. Dent.*, 2001; **13**:154-162.
- Doray, P.G., Wang, X., Powers, J.M. and Burgess, J.O. Accelerated aging affects color stability of provisional restorative materials. *J. Prostbodont.*, 1997; **6**: 183-188.
- Scotti, R., Mascellani, S.C. and Forniti, F. The in vitro color stability of acrylic resins for provisional restorations. *Int. J. Prostbodont.*, 1997; **10**:164-168.
- Lang, R., Rosentritt, M., Leibrock, A., Behr, M. and Handel, G. Colour stability of provisional crown and bridge restoration materials. *Br. Dent. J.*, 1998; **185**:468-471.
- Givens, E.J., Neiva, G., Yaman, P. and Dennison, J.B. Marginal adaptation and color stability of four provisional materials. *J. Prostbodont.*, 2008; **17**:97-101.
- Johnston, W.M. and Reisbick, M.H. Color and translucency changes during and after curing of esthetic restorative materials. *Dent. Mater.*, 1997; **13**:89-97.
- Schanda, J.D. Colorimetry. In DeCusatis C. (Eds):Handbook of applied photometry. New York: Optical Society of America Springer-Verlag, 1998; 324.412.
- Janda, R., Roulet, J.F., Kaminsky, M., Steffin, G. and Latta, M. Color stability of resin matrix restorative materials as a function of the method of light activation. *Eur. J. Oral. Sci.*, 2004; **112**:280-285.
- Vichi, A., Fraioli, A., Davidson, C.L. and Ferrari, M. Influence of thickness on color in multi-layering technique. *Dent. Mater.*, 2007; **23**:1584-1589.
- Lee, Y.K., Lim, B.S., Rhee, S.H., Yang, H.C. and Powers, J.M. Color and translucency of A2 shade resin composites after curing, polishing and thermocycling. *Oper. Dent.*, 2005; **30**:436-442.
- Pires-de-Souza, F de C., Panzeri, H., Vieira, M.A., Garcia, L da F. and Consani, S. Impact and fracture resistance of an experimental acrylic polymer with elastomer in different proportions. *Mater. Res.*, 2009; **12**:415-418.
- Doray, P.G., Li, D. and Powers, J.M. Color stability of provisional restorative materials after accelerated aging. *J. Prostbodont.*, 2001; **10**:212-216.
- Rutkunas, V., Sabaliauskas, V. and Mizutani, H. Effects of different food colorants and polishing techniques on color stability of provisional prosthetic materials. *Dent. Mater. J.*, 2010; **29**:167-176.
- Sham, A.S., Chu, F.C., Chai, J. and Chow, T.W. Color stability of provisional prosthodontic materials. *J. Prosthet. Dent.*, 2004; **91**:447-452.
- Melo, M.A.V., Moyses, M.R., Santos, S.G., Alcantara, C.E.P. and Ribeiro, J.C.R. Effects of different surface treatments and accelerated artificial aging on the bond strength of composite resin repairs. *Braz. oral res.* [online]. 2011; **25**:485-491.
- Pires-de-Souza, F de C., Casemiro, L.A., Garcia, L da F. and Cruvinel, D.R. Color stability of dental ceramics submitted to artificial accelerated aging after repeated firings. *J. Prosthet. Dent.*, 2009; **101**:13-18.
- Pires-de-Souza F.C., Garcia, L. F., Hamida, H.M. and Casemiro, L.A. Color stability of composites subjected to accelerated aging after curing using either a halogen or a light emitting diode source. *Braz. Dent. J.*, 2007; **2**: 119-123.
- Ren, Y.F., Feng, L., Serban, D. and Malmstrom, H.S. Effects of common beverage colorants on color stability of dental composite resins: the utility of a thermocycling stain challenge model in vitro. *J. Dent.* CIE (Commission Internationale de l'Éclairage). Colorimetry Technical Report. CIE Pub. 2004; **15**: 1-79
- Heydecke, G., Zhang, F. and Razzoog, M.E. In vitro color stability of double-layer veneers after accelerated aging. *J. Prosthet. Dent.* 2001; **85**:551-557.
- Douglas, R.D., Steinhauer, T.J. and Wee, A.G. Intraoral determination of the tolerance of dentists for perceptibility and acceptability of shade mismatch. *J. Prosthet. Dent.* 2007; **97**:200-208.
- Ertan, A.A. and Sahin, E. Colour stability of low fusing porcelains: an in vitro study. *J. Oral. Rehabil.* 2005; **32**:358-361.
- Devigus, A. and Lombardi, G. Shading Vita In-ceram YZ sub-structures: influence on value and chroma, part II. *Int. J. Comput. Dent.*, 2004; **7**:379-388.
- ASTM Standards G154-00A. Standard practice for operating fluorescent light apparatus for UV exposure of nonmetallic materials. Annual Book of ASTM Standards, 2006; 646.654.
- Wang, R.L., Moore, B.K., Goodacre, C.J., Swartz, M.L. and Andres, C.J. A comparison of resins for fabricating provisional fixed restorations. *Int. J. Prostbodont.*, 1989; **2**:173-184.
- Haselton, D.R., Diaz-Arnold, A.M. and Vargas, M.A. Flexural strength of provisional crown and fixed partial denture resins. *J. Prosthet. Dent.*, 2002; **87**:225-228.
- Yannikakis, S.A., Zissis, A.J., Polyzois, G.L. and Caroni, C. Color stability of provisional resin restorative materials. *J. Prosthet. Dent.*, 1998; **80**:533-539.
- Hoshiai, K., Tanaka, Y. and Hiranuma, K. Comparison of a new autocuring temporary acrylic resin with some existing products. *J. Prosthet. Dent.*, 1998; **79**:273-277.
- Passos, S.P., Ozcan, M., Vanderlei, A.D., Leite, F.P., Kimpara, E.T. and Bottino, M.A. Bond strength durability of direct and indirect composite systems following surface conditioning for repair. *J. Adhes. Dent.*, 2007; **9**:443-447.
- Ferracane, J.L. Hygroscopic and hydrolytic effects in dental polymer networks. *Dent. Mater.*, 2006; **22**:211-222.
- Young, H.M., Smith, C.T. and Morton, D. Comparative in vitro evaluation of two provisional restorative materials. *J. Prosthet. Dent.*, 2001; **85**: 129-132.
- Santerre, J.P., Shajii, L. and Leung, B.W. Relation of dental composite formulations to their degradation and the release of hydrolyzed polymeric-resin-derived products. *Crit. Rev. Oral. Biol. Med.*, 2001; **12**:136-151.
- Diaz-Arnold, A.M., Dunne, J.T. and Jones, A.H. Microhardness of provisional fixed prosthodontic materials. *J. Prosthet. Dent.*, 1999; **82**:525-528.