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Rahaf KURDI

Elizabeth SARKIS

Nazera SARKIS

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# A COMPARATIVE STUDY OF SOLUBILITY BETWEEN RESIN CEMENT AND SELF-ADHESIVE RESIN CEMENT

Rahaf Kurdi\* | Elizabeth Sarkis\*\* | Nazera Sarkis\*\*\*

## Abstract

Resin cements have been largely used for luting indirect restorations due to their bonding abilities to the tooth structures and the increase of the restorations stability; however their solubility can negatively affect the restoration durability. The aim of this *in vitro* study was to evaluate and to compare water solubility values of conventional resin cement with self-adhesive resin cement according to ISO 4049 specification.

Two commercial dental luting cement materials were selected: Conventional resin cement (Resicem™ /Shofu) and self-adhesive resin cement (Total Cem, Itena). Ten discs were prepared of each cement material. The discs were made according to the manufacturer's instructions using a cylindrical teflon mold of 5 mm inner diameter and 2 mm thickness.

The discs were weighed on a precision weight scale to record their individual baseline weight ( $w_1$ ), measured by a digital caliper to record their volume ( $v$ ), then immersed in 10mm distilled water at 37°C and 50rpm. After that, the specimens were desiccated then weighed ( $w_2$ ) at different interval periods (1, 14, 30 and 90 days). The solubility value was obtained based on the equation: Solubility =  $(w_1 - w_2) / v$ . Collected data was statistically analyzed for significant differences by one-way ANOVA ( $p = 0.05$ ).

The mean solubility value ( $\mu\text{g}/\text{mm}^3$ ) obtained after 90 days was  $3.86 \pm 0.36$  for Resicem™ and  $12.93 \pm 1.33$  for Total Cem.

Within the limitations of this *in vitro* study, the conventional resin cement showed the highest resistance to solubility compared to the self-adhesive resin cement.

**Keywords:** Resin cement – solubility – self-adhesive cement.

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## ÉTUDE COMPARATIVE DE LA SOLUBILITÉ ENTRE LE CIMENT À BASE DE RÉSINE ET DE CIMENT À BASE DE RÉSINE AUTOADHÉSIF

### Résumé

Les ciments en résine ont été largement utilisés pour le scellement des restaurations indirectes en raison de leur capacité à se lier aux structures dentaires et à accroître la stabilité des restaurations; cependant, leur solubilité risque d'affecter négativement la durabilité des restaurations. Cette étude *in vitro* a pour but d'évaluer et de comparer le degré de solubilité, dans l'eau, d'un ciment résine conventionnel à celui d'un ciment résine auto-adhésif, en respectant les exigences de la norme ISO 4049. Deux ciments de scellement ont été choisis: un ciment résine classique (Resicem™/Shofu) et un ciment résine auto-adhésif (Total Cem, Itena). Dix spécimens sous forme de disques ont été préparés à partir de chaque matériau. Les disques ont été réalisés conformément aux instructions du fabricant, en utilisant un moule cylindrique en téflon de 5mm de diamètre interne et de 2mm d'épaisseur. Le poids de départ ( $w_1$ ) et le volume ( $v$ ) de chaque disque ont été enregistrés en utilisant une balance et un pied à coulisse digital, respectivement. Ils ont été ensuite immergés dans 10mm d'eau distillée à 37°C et 50rpm. Les spécimens ont été desséchés et pesés ( $w_2$ ) à différents intervalles (1, 14, 30 et 90 jours). Le degré de solubilité a été évalué en appliquant l'équation: solubilité =  $(w_1 - w_2) / v$ . Les résultats ont été analysés à la recherche de différences statistiquement significatives par le test ANOVA ( $p = 0.05$ ). Les valeurs moyennes de solubilité ( $\mu\text{g}/\text{mm}^3$ ) après 90 jours pour chaque ciment étaient  $3,86 \pm 0,36$  pour Resicem™ et  $12,93 \pm 1,33$  pour Total Cem. Dans les limites de cette étude, le ciment résine classique a montré une plus grande résistance à la solubilité par rapport au ciment résine auto-adhésif.

**Mots-clés :** ciment résine – solubilité – adhésif.

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\* Masters in Restorative Dentistry  
Faculty of Dentistry  
University of Aleppo, Syria

Professor, Department of Restorative Dentistry  
Faculty of Dentistry,  
University of Aleppo, Syria  
sarkiselizabeth@yahoo.com

Professor in Food & Analytical Chemistry  
Faculty of Pharmacy  
University of Aleppo, Syria

## Introduction

Restorative dentistry is constantly undergoing changes, driven in part by new clinical applications of existing dental materials and the introduction of new materials [1]. Presently, various types of adhesive cement are used for permanent and temporary cementation of indirect restorations. These cements have different mechanical and biological characteristics [2].

Resin cements have been largely used for luting indirect restorations due to their bonding abilities to the tooth structure and their better mechanical characteristics compared to those of conventional luting agents [1]. However, many clinicians prefer to cement all-ceramic inlays and onlays with self-etching, dual-cure resin cements. These systems contain self-etching adhesive and dual-cure resin cement in the same formula; therefore, a separate bonding adhesive is not required. This significantly reduces the number of steps, leaving less room for operator error [2].

Dental cements' performance is conditioned by their adequate resistance to dissolution in the oral environment, the strong bond through mechanical interlocking and adhesion, the high strength under tension, the good manipulation properties such as acceptable working and setting times and the biologic acceptability for the substrate [3]. Failures due to deteriorated mechanical properties may be explained by the influence of moisture from the oral environment on the luting cements, leading to degradation [4] and debonding of the restoration which causes microleakage and recurrent decay [5, 6]. Therefore, resistance to solubility is an important feature in assessing the clinical durability of luting cements [7]. Thus, this study was performed to compare the solubility feature of a conventional resin cement and a self-adhesive resin cement used in current clinical dentistry.

| Cement groups | Mean ( $\mu\text{g}/\text{mm}^3$ ) |
|---------------|------------------------------------|
| Resicem™      | 3.86±0.36                          |
| Total Cem     | 12.9349±13.39674                   |

Table 1: Mean solubility values of the two tested cements.

|                | Sum of Squares | df | Mean Square | F | Sig. |
|----------------|----------------|----|-------------|---|------|
| Between Groups | 5              | 19 | 0.263       |   |      |
| Within Groups  | 0              | 0  |             |   |      |
| Total          | 5              | 19 |             |   |      |

Table 2: One-way analysis of variance (ANOVA) test.

## Materials and Methods

Two commercial dental luting cement materials were selected: Conventional resin cement (Resicem™ /Shofu) and self-adhesive resin cement (Total Cem, Itena®). Ten specimen discs were prepared for each cement material according to the manufacturer's instructions using cylindrical teflon mold (5x2mm). The resin cements were placed in the mold and pressed by plastic matrix strips under hand pressure to extrude any excess material. Then, they were light-cured by halogen light (380 mw/cm<sup>2</sup>) for 40 seconds. The discs were weighed on a precision weight scale to record the original weigh (w1) and their volume was measured by digital caliper. After that, specimens were immersed in vials containing 10mm of distilled water; the vials were wrapped in aluminum foil to exclude light and placed in an incubator at 37°C and 50rpm. After immersion, specimens were desiccated in an oven at 100°C for 2 hours and weighed (w2) at different interval periods (1, 14, 30 and 90 days). The solubility values were calculated using the equation (ISO 4049:2000):  $S = \frac{w1 - w2}{v}$ ; where w1 is the specimen mass before water immersion (mg), w2 is the specimen mass after immersion and desiccation (mg), and v is the

specimen volume before immersion (mm<sup>3</sup>). For each group, the mean for solubility was calculated.

## Statistical Analysis

Statistical analysis for cement solubility values was performed using one-way ANOVA and Bonferonni's test. The alpha error was set at 0.05.

## Results

Table 1 summarizes the solubility means of resin cement and self-adhesive resin cements, respectively in  $\mu\text{g}/\text{mm}^3$ .

Statistical analysis of data using one-way analysis of variance (ANOVA) revealed the existence of a statistically significant difference ( $p < 0.05$ ) in solubility values between the two groups (Table 2).

## Discussion

The method used for testing solubility in this study followed a modification of the section 7.12 of ISO 4049. The test requires that specimens are first placed in desiccators immediately after curing

and removal from the mold. The section 7.12 was modified by placing specimens in a solution of distilled water immediately after preparation [9]. The aim was to ensure that the results of solubility are static because desiccation of specimens immediately after fabrication might also affect their solubility results due to damage.

The rate of dissolution can be influenced by the test conditions as well as the time of dissolution, the concentration of the solute in the dissolution medium, the pH of the medium, the specimen shape and thickness [10].

In our study, distilled water served as medium; *in vitro* tests are only static, so they do not simulate the pH and temperature changes of the oral cavity [11].

The study results showed that the self-adhesive resin cement exhibited the highest mean solubility value compared to the conventional resin cement as shown in table 1. This difference

can be attributable to the hydrophilic nature and the matrixes composition of the self-adhesive resin cement [11, 12].

The resin cements are basically insoluble but may release small amounts of unpolymerized monomer constituents. The factors that influence solubility include the filler concentration, the nature of the filler particles and their mean size as well as the coupling agents [13].

Materials can exhibit different behaviors during their interaction with water (Vrochari et al. [16]). In fact, the hydrophilic constituents of the resin cements such as hydroxyethyl methacrylate (HEMA) or the resin molecules that contain hydrophilic moieties increase solubility [14, 15]. That may explain the higher solubility observed for Total Cem.

It is difficult to correlate data for solubility with those of other studies, since the results will inevitably vary due to the use of different time periods and measurement units [17]. Moreover,

comparisons are difficult due to differences in the reported specimen sizes. For small specimens, the time period for water equilibration is short; the materials that absorb more water take longer time to stabilize [14].

This study showed that solubility increased with the immersion time; similar results were reported by Yoshida et al. [8].

## Conclusion

Within the limitations of the present study, it can be concluded that the self-adhesive resin cement (Total Cem) exhibited higher values of water solubility compared to the conventional resin cement. This was attributed to the hydrophilic nature of the Total Cem as well as to the filler characteristics. Conventional resin cement appeared to meet longevity requirements more than self-adhesive resin cement.

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# EFFECT OF DIFFERENT POLISHING PROCEDURES ON COLOR STABILITY OF NANOCOMPOSITES IN DIFFERENT MOUTH RINSES

Nazish Fawad\*

## Abstract

*The aim of this in vitro study was to evaluate the effect of two polishing procedures on color stability of nanocomposites immersed in three mouth rinses.*

*One hundred twenty disc-shaped specimens (10x2mm) of nanocomposite Filtek™ Z350 XT, shade A3, were prepared. Specimens were distributed into 3 groups of 40 discs each: Group 1) Filtek™ Supreme XTE without polishing; group 2) Filtek™ Supreme XTE + Sof-Lex™ pop-on discs and group 3) Filtek™ Supreme XTE + PoGo® polishers. Initial color values were evaluated using the CIELAB scale. The discs in each group were randomly divided into 4 subgroups (n = 10). Each subgroup was immersed in 20ml of mouth rinse for 12 hours, then removed and submerged in deionized water. Color values were remeasured.*

*The results didn't show any statistical significant difference between polished and unpolished samples whether immersed in artificial saliva or in Listerine®. For the specimens immersed in Cool Mint® Listerine® or in Enziclore, a statistically significant difference was observed between polished and unpolished specimens (p < 0.05).*

*Samples polished with Sof-Lex™ discs showed lower color alteration than samples polished with PoGo® polishers. Cool Mint® Listerine® (alcohol containing-mouthwash) and Enziclore (chlorhexidine-containing mouthwash) showed the highest value of discoloration but these differences were not visually perceptible.*

**Keywords:** Nanocomposite - Sof-Lex™ discs - PoGo® polishers - color stability - mouth rinse - polishing techniques.

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# EFFET DE DIFFÉRENTES PROCÉDURES DE POLISSAGE SUR LA STABILITÉ DE LA COULEUR DES NANOCOMPOSITES DANS DIFFÉRENTS BAINS DE BOUCHE

## Résumé

Le but de cette étude *in vitro* était d'évaluer l'effet de deux techniques de polissage sur la stabilité de la couleur du nanocomposite immergé dans trois bains de bouche différents.

Cent vingt disques (10x2mm) de nanocomposite « Filtek XT™ Z350 », de teinte A3, ont été préparés. Les échantillons ont été répartis en 3 groupes de 40 disques chacun: groupe 1) « Filtek™ Supreme XTE » sans polissage; groupe 2) « Filtek™ Supreme XTE » + polissage à l'aide de disques « Sof-Lex™ » et groupe 3) « Filtek™ Supreme XTE » + polissage à l'aide des cupules « PoGo® ». Les premières valeurs de couleur ont été évaluées en utilisant l'échelle CIELAB. Les disques ont été maintenus à 37 °C tout au long de l'étude. Les disques de chaque groupe ont été divisés au hasard en 4 sous-groupes (n = 10). Chaque sous-groupe a été immergé dans 20 ml de bain de bouche pendant 12 heures, puis retiré et immergé dans de l'eau déminéralisée. Les valeurs de couleur ont été réévaluées.

Les résultats n'ont pas montré de différence statistiquement significative entre les échantillons polis et non polis immergés dans la salive artificielle ou dans la « Listerine® ». Pour les échantillons immergés dans du « Cool Mint® Listerine® » ou dans « Enziclore », une différence statistiquement significative a été observée entre les échantillons polis et non polis (p < 0.05).

Une faible altération de la couleur a été observée dans les échantillons polis avec les disques « Sof-Lex™ » comparés à ceux polis avec les disques « PoGo® ». Des altérations de la teinte ont été observées avec le « Cool Mint® Listerine® » (contenant de l'alcool) et « l'Enziclore » (contenant de la chlorhexidine), mais ces différences ne sont pas visuellement perceptibles.

**Mots-clés :** résine composite – bain de bouche – polissage.

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\* BDS, Masters in Dental Materials  
Dow University of Health Sciences, Pakistan  
nazish\_fawad@yahoo.com

## Introduction

Color stability is the ability of any material to maintain its original color [1]. Tooth-colored restorations using resin composites have been extensively used in comparison with other material even for posterior teeth with great success [2]. Resin composite is the material of choice because of its excellent strength, adequate initial esthetics and adhesion to tooth structure [3]. However, discoloration can occur by three ways [4]:

- Extrinsic discoloration due to bio-film accumulation on the restoration surface.

- Intrinsic discoloration due to physico-chemical reactions inside the body of the restoration.

- Surface or subsurface changes with slight penetration and reaction of dye agents on the superficial layer of composite resin.

Furthermore, hydrophilic resins are more prone to dye penetration and staining than hydrophobic ones [4]. The staining susceptibility may be related to a low water sorption rate of hydrophobic resins.

Proper finishing and polishing are important steps in clinical restorative dentistry that enhance both esthetics and longevity of restorations [5]. Residual surface roughness may result in excessive plaque accumulation, gingival inflammation and increased surface staining [6]. Additionally, it might directly influence the wear behavior and marginal integrity of posterior composite resin restorations [7, 8].

Finishing is required to remove excess material and to adjust the occlusion. The final polishing reduces the remaining roughness [9] and eliminates the superficial resin layer which comes in contact with oxygen and does not polymerize. This resin layer has a direct effect on the staining ability of composite resin [10].

Mouth rinses are primarily used for controlling the progression of caries and periodontal diseases. These extrinsic factors can cause discoloration of resin composite [10, 11]. Previous studies have reported the

effect of alcohol-containing, chlorhexidine gluconate-containing, and hybrid mouthwashes on the color stability of glass ionomers, compomers, and microhybrid resin-based composites [12, 13].

The aim of this *in vitro* study was to compare the effect of two polishing techniques on color stability of nanocomposites immersed in three commercially available mouth rinses.

The hypotheses tested in the study were:

- 1-The daily use of alcohol- or chlorhexidine-containing mouth rinses affects color stability of resin composite more than alcohol- and chlorhexidine-free mouth rinses.

- 2-A multistep polishing technique is better than a single-step polishing technique for color stability of nanocomposites.

## Materials and Methods

One hundred twenty disc-shaped specimens (10x2mm) of nanocomposite Filtek™ Z350 XT (3M/ESPE, USA), shade A3, were prepared. The discs had smooth texture with no visible surface voids or bubbles. The materials used in the study are listed in the table 1.

Specimens were distributed into 3 groups of 40 discs each: Group 1) Filtek™ Supreme XTE without polishing; group 2) Filtek™ Supreme XTE + Sof-Lex™ pop-on discs and group 3) Filtek™ Supreme XTE + PoGo® (Dentsply) polishers. Initial color values were evaluated using the CIELAB scale.

Three different mouth rinses were used (Table 2):

- 1-Listerine®.
- 2-Cool Mint® Listerine®.
- 3-Enziclore.

### Discs preparation

A glass slide and polyethylene sheet were placed under the mold. Unset pastes were placed in the polytetrafluoroethylene (Teflon) mold

(10x2.5mm). After filling the mold, a second polyethylene sheet and glass slides were placed over the filled mold and light pressure was applied. This method provided specimens with smooth surface. Unset material was cured with LED curing lamp Mectron, Italy (1.000mw/cm<sup>2</sup>) for 40 seconds on each side. The distance between the light and the specimen was standardized by using a 1mm glass slide.

### Polishing techniques

In the group 1, after curing, the specimens were not submitted to any kind of finishing or polishing procedure (Table 3).

In group 2, specimens were polished with aluminum oxide- impregnated Sof-Lex™ discs at a low speed with light pressure for 20 seconds each, as recommended by manufacturer. Specimens were washed with water, air dried and then polished with another lower grit disc for the same period of time.

In group 3, specimens were polished with PoGo® polishing system at a low speed with light pressure for 30 seconds each, as recommended by the manufacturer.

After polishing, specimens were stored in artificial saliva in an incubator at 37° C for 24 hours.

### Color evaluation

Baseline color measurements were performed with a spectrophotometer (Data color; SF 600; Plus-CT; USA) using CIE L\*a\*b\* (Commission International l'Eclairage) system. The analyzed color parameters were the values for L\*, a\* and b\*, where L\* is the luminosity, a\* represents the color variation between green-red and b\* represents the color variation between blue-yellow.

The spectrophotometer was calibrated before each color analysis session of specimens in accordance with manufacturer's instruction.

For color analysis, each specimen was placed inside the central orifice of the white, opaque Teflon matrix. A mortise device was placed on the white Teflon,

| Material             | Manufacturer                        | Composition  |
|----------------------|-------------------------------------|--|
| Filtek™ Z350 XT (A3) | 3M ESPE,<br>St Paul, MN, USA        | Matrix: Bis-GMA, UDMA, Bis-EMA, TEGDMA<br>Filler: zirconia/silica<br>Nanofillers of silicon (5–75 nm),<br>zircon/silicon nanoclusters (0.6–1.4 μm)<br>nanofiller 78.5% wt, 59.5% vol |
| Sof-Lex™ discs       | 3M ESPE<br>St. Paul, MN, USA        | Al2O3 flexible discs   |
| PoGo® polishers      | Dentsply Caulk,<br>Milford, DE, USA | Cured composite of urethane dimethacrylate, fine diamond powder, silicon dioxide 7 μm, Al2O3   |

Table 1: Characteristics of the materials used in the study.

| Mouth rinses          | Manufacturer              | Chemical composition  | Ph  |
|-----------------------|---------------------------|---|-----|
| Listerine®            | Johnson & Johnson         | Eucalyptol, menthol, methyl salicylate, thymol  | 5.0 |
| Cool Mint® Listerine® | Johnson & Johnson         | Water, alcohol, sorbitol, propyl alcohol, poloxamer 407, benzoic acid, sodium saccharine, eucalyptol, flavour, thymol, methyle salicylate, menthol, sodium benzoate | 3.7 |
| Enziclore             | Platinium pharmaceuticals | Benzylamine hydrochloride, chlorhexadine gluconate  | 5.8 |

Table 2: Mouth rinses used in the study.

which was positioned over the specimen to standardize the contact of the tip from the spectrophotometer to the specimen surface at a 90° angle.

Forty specimens of each group were randomly divided into 4 subgroups (n=10). Details of subgroups are given in table 4. Subgroups G1, G5, G9 were stored in artificial saliva; other subgroups were immersed in 20 ml of respective mouth rinses for 12 hours (Table 4), equivalent to the use mouthwashes twice per day for 1 year [14]. Specimens were kept at 37°C throughout the study, and mouth rinses were shaken every hour to provide homogeneity. After 12 hours, the specimens were removed, submerged in deionized water and color values were remeasured. The total color variation is ΔE. It was calculated according to the following equation:

$$\Delta E^*ab = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

## Statistical analysis

The statistical analysis was performed using a software program (SPSS for

Windows, version 16.0, Chicago, IL, USA). The alpha error was set at 0.05. Kruskal-Wallis test and Tukey's honest significance test for multiple comparisons were conducted to explore significant changes in color (ΔE) among the groups.

## Results

No statistically significant differences were found between polished (G5, G9), (G6, G10) and unpolished (G1, G2) subgroups immersed in artificial saliva and Listerine®, respectively. After immersion, there was no color alteration. Furthermore, no significant difference was observed between both polishing procedures (p>0.05) as shown in table 5.

In cool Mint® Listerine®, a statistically significance difference was found between polished (G7, G11) and unpolished (G3) subgroups (p ≤0.05). Unpolished subgroup (G3) displayed color changes after immersion whereas in polished subgroups (G7, G11) the color was stable.

In Enziclore mouthwash, all samples showed color changes after immersion and a statistically significant difference was found among unpolished (G4) and both polished subgroups (G8, G12). The subgroup polished with Sof-Lex™ discs showed lower color alteration compared to subgroup polished with PoGo® polishers. Furthermore, unpolished subgroups (G4) showed the highest degree of color alteration.

## Discussion

The present study evaluated the effect of two different polishing techniques on the color stability of nanocomposite specimens immersed in three commercially available mouth rinses. The effectiveness of surface finishing and polishing techniques is of fundamental importance for any restoration [15]. These procedures are commonly required after placement of direct composite resin-based restorations since they minimize the retention of plaque and stains and other problems result-

| Groups | N  | Polishing procedures                                      |
|--------|----|---|
| 1      | 40 | Mylar® strip (polyester matrix)                           |
| 2      | 40 | Sof-Lex™ pop-on discs ( coarse, medium, fine, extra fine) |
| 3      | 40 | PoGo®   |

Table 3: Groups distribution according to polishing procedures.

| Polishing techniques  | Immersion medium  |                 |                       |                 |
|-----------------------|-------------------|-----------------|-----------------------|-----------------|
|                       | Artificial saliva | Listerine®      | Cool Mint® Listerine® | Enziclore       |
| Mylar® strip          | G <sub>1</sub>    | G <sub>2</sub>  | G <sub>3</sub>        | G <sub>4</sub>  |
| Sof-Lex™ pop-on discs | G <sub>5</sub>    | G <sub>6</sub>  | G <sub>7</sub>        | G <sub>8</sub>  |
| PoGo® polishers       | G <sub>9</sub>    | G <sub>10</sub> | G <sub>11</sub>       | G <sub>12</sub> |

Table 4: Characteristics of the subgroups.

| Polishing procedures           | Immersion medium      | Mean ± SD   |
|--------------------------------|-----------------------|-------------|
| Mylar strip (polyester matrix) | Artificial saliva     | 1.161±0.195 |
|                                | Listerine®            | 1.124±0.181 |
|                                | Cool Mint® Listerine® | 1.918±0.091 |
|                                | Enziclore             | 2.387±0.395 |
| Sof-Lex™ pop-on discs          | Artificial saliva     | 1.124±0.181 |
|                                | Listerine®            | 1.124±0.181 |
|                                | Cool Mint® Listerine® | 1.113±0.216 |
|                                | Enziclore             | 1.124±0.181 |
| PoGo® polishing disc           | Artificial saliva     | 1.124±0.181 |
|                                | Listerine®            | 1.124±0.181 |
|                                | Cool Mint® Listerine® | 1.113±0.216 |
|                                | Enziclore             | 2.236±0.272 |

Table 5: Means of color change values observed for the different groups.

ting from the exposure of rough surfaces to the oral environment.

Surface roughness is the major contributor for extrinsic discoloration of resin composite restorations. This property is closely related to the organic matrix, inorganic filler composition of the composites in addition to the finishing and polishing techniques. In our study, unpolished sample surfaces were smoothen against the polyester matrix; they appeared more polished because these surfaces are rich in organic polymer matrix. They

tend to absorb more water and become more prone to staining [16 - 18].

The single-step PoGo® system was applied with no surface pretreatment. The corresponding specimens displayed more color changes in comparison with samples polished with Sof-Lex™ discs. Similar results were obtained by Yap et al. [13]. These authors stated that higher surface roughness values were obtained with PoGo® polishers in comparison with the Sof-Lex™ discs and that rough surfaces were more prone to staining [4].

In the multiple-step technique, polishing points or burs are used in sequential order of decreasing abrasiveness, favoring the final surface texture. This scenario does not occur with the one-step technique [1, 14].

The effect of staining solutions on color changes of composite resin-based may be material-dependent, and the staining susceptibility of a restorative material may be attributed to its resin matrix or filler type.

Asmussen [19] reported that mouth rinses with high alcohol content might soften the composite resin material.



Ethanol has a softening effect on BIS-GMA based polymers. Gürgan et al. [14] showed that irrespective of alcohol concentration, both alcohol-containing and alcohol-free mouth rinses could affect the hardness of resin-restorative materials. Our study showed statistically significant differences in color change values among alcohol-free, alcohol-containing, chlorhexidine-containing mouth rinses and artificial saliva. The color changes were mostly observed in samples immersed in the alcohol- and the chlorhexidine-containing mouth rinses.

Villalta et al. [20] have shown that low pH and alcohol concentration of solutions might affect the surface integrity of composite resins and cause staining. In the present study, there was a statistically significant difference regarding color change values between the alcohol-free mouth rinse, i.e. Listerine® and distilled water and alcohol-containing and chlorhexidine-containing mouth rinses (Cool Mint® Listerine® and Enziclore), but this difference was not visually perceptible.

Color stability of a material can be evaluated by various methods. It involves subjecting the specimens to a colorant and evaluating the change in color over a period of time. The evaluation of color can be done either by visual assessment or by instrumental methods.

Variability of the results by visual assessment can arise due to several factors including the observed object, illuminant position relative to the observer and to each other, color characteristics of the illuminant, metamerism, fatigue, aging and emotional state of the observer [21]. Since instrument measurements can eliminate subjective interpretation of visual color comparison, spectrophotometers and colorimeters are more widely used today. These instruments use the CIE L\*a\*b\* (CIELAB) color system, which was developed in 1978 by the "Commission Internationale de L'Eclairage" for characterizing color for human perception.

The CIE L\*a\*b\* (CIELAB) color space is a uniform three dimensional color order system. The color difference  $\Delta E$  represents the relative color changes that are observed for the materials after treatment or between time periods. Um and Ruyter [22] suggested that a perceptible discoloration must be referred to as acceptable up to a value  $\Delta E=3.3$  while Gulern [23] stated that a value of 3.7 should be considered as visually perceptible. The color change observed in our study was not visually perceivable since the obtained  $\Delta E^*ab$  was 3.3.

## Conclusion

Understanding the property of color stability and the comparative analysis of various restorative materials will help a clinician to choose the materials as per the diet.

Within the limitations of the study, we can conclude that:

- Nanocomposites multistep polishing procedures with Sof-Lex™ discs promoted greater staining resistance than single-step polishing technique with PoGo® polishers.

- Cool Mint® Listerine® (alcohol-containing) and Enziclore (chlorhexidine-containing) mouth rinses showed the highest value of discoloration as compared to Listerine® (non-alcohol-containing mouth rinse) and artificial saliva. However, these differences were not visually perceptible.

Furthermore, future *in vivo* studies should consider longer periods of immersion to determine the effect of the two different polishing procedures on staining potential of nanocomposites when using different types of mouth rinses.

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