EVALUATION OF DISCOLORATION AND MECHANICAL PROPERTIES OF PROVISIONAL RESINS AFTER IMMERSION IN DIFFERENT MOUTHWASHES

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Abstract

Introduction. This study aimed at evaluating the effects of mouthwash solutions upon color stability, surface roughness and microhardness of a polymethyl methacrylate (PMMA) and a bis-acryl based provisional restorative material. **Materials and methods**. Forty cylindrical specimens of each acrylic type [PreVISION® Temp (KULZER) and Temdent (Schütz-Dental Co.)] were prepared in a stainless-steel mold (10 mm diameter x 2 mm thick). The samples of each material were divided into four groups (n=10), according to the mouthwashes: Distilled water (DW), Listerine, Colgate Plax and Vinegar. Color measurements were made by a spectrophotometer. Surface roughness was measured with a profilometer and microhardness – with a Vickers microhardness tester. All test measurements were performed at two different time intervals: before immersion (T0) and after immersed in mouthwashes, for 72 hours (T1) of immersion. Data was analyzed by Paired simple t-test, ANOVA, Bonferroni postHoc, Spearman's Rank Correlation tests. **Results and discussion.** The highest significant roughness reduction was observed for PreVISION after immersion in Vinegar and Listerine ($p<0.05$). For Temdent, the most significant roughness change occurred after immersion in Vinegar, however no significant differences were observed among the other solutions. As to microhardness, both acrylics' immersion in Vinegar showed the highest microhardness value reduction, with a statistically significant difference ($p<0.05$). The highest ΔE values were observed in Listerine and Vinegar for PreVISION and Vinegar for Temdent, respectively. **Conclusions.** The higher color stability of specimens was shown by polymethylmethacrylate, compared to bis-acryl resins. Mouthwashes promote a significant change in surface roughness increase and microhardness reduction of acrylic resin.

Keywords: *provisional resins, discoloration, mechanical properties, mouthwashes.*

1. INTRODUCTION

Interim restorations are fixed prostheses used for a limited period of time until the final prosthesis is made, to maintain aesthetics and function during fixed prosthetic treatment and even to support a specific treatment plan. Providing the occlusion, the gum form and preservation of the pulp of the prepared tooth are among the important benefits of interim restoration [1].

Temporary crown materials should be preferred, if considering the mechanical and aesthetic features of the treatment-specific requirements, as they provide the opportunity to establish a relationship with the patient, to better fulfill his aesthetic expectations, to create his hygiene skills and habits, and to learn ideal phonetic and aesthetic treatment plan for patients in occlusion [2]. Temporary restorations require assessment of the mechanical properties for use over the ideal period, as they are applied during endodontic treatments [3], implant treatments [4], especially long-term periodontal treatments [5]. In principle, fixed prosthesis treatment should be started after the periodontal ones are completed [6].

A wide variety of mouthwashes are recommended for the treatment of periodontal disease. Many commercial mouthwashes depend on their content for gingivitis and periodontal diseases. Among them, vinegar is used to provide oral hygiene, along with alcohol [7]. The compatibility of these mouthwashes with the temporary material will increase restoration lifespan and patient satisfaction by minimizing clinical problems such as discoloration, breakage and displacement until the use of permanent restorations.

Chemical solutions cause surface biodegradation of restoration materials, causing plaque accumulation, wear and discoloration. The type of

treatment to be performed, and the period for which the temporary restoration is intended to be used should be the reason of preference in choosing the temporary restoration material type. The acid and alcohol contents of the mouthwash solutions cause changes in the material properties of provisional resins. As a result, diversity in their hardness, surface roughness and, accordingly, color can be expected [8].

Temporary restoration color stability is especially important in long-term use of aesthetic restorations. Depending on the chemical and surface properties of the material, color stability can be affected [9].

Hardness, the resistance of a material to plastic deformation, shows the degree of resistance to plastic deformation by an indenter on the material. Also, surface hardness is proportional to density. It renders dense materials more resistant to abrasion and surface deterioration. Surface hardness can soften according to the type of fluids, so that occlusal harmony and vertical dimension will change, depending on the occlusal forces and wear on the surface [10].

Therefore, the aim of the present investigation was to evaluate the effect of mouth rinse solutions on discoloration, surface roughness and microhardness of different chemical type provisional resins. The null hypothesis tested that mouth rinse solutions would not promote changes in the properties of provisional resins.

2. MATERIALS AND METHODS

The effects of four different mouthwash solutions (Table 1) on color stability, surface roughness and microhardness of two types of provisional resin materials (Table 2) were evaluated.

Fabrication of Specimens

Forty cylindrical specimens (10 mm diameter x 2 mm thick) of each acrylic type were prepared in a stainless-steel mold, following manufacturer's recommendations, according to definition number 27 offered by the American Dental Association (ADA) [11]. Samples were polished in a polishing machine (EcoMet Grinder/ Polisher, Buehler, USA) by reducing grit numbers, 600, 800 and 1,200, respectively, with sandpapers (3M ESPE, MN, USA), and kept in distilled water at 37 °C for 24 hours in the oven (Nüve, Ankara, Turkey), to remove excess monomer.

Then, the specimens were randomly divided into four groups (n=10) according to the mouthwash solution in which they were immersed (Table 1).

All analyses were carried out at two-time intervals: before the first immersion (T0) and 72 hours (T1) after the experimental procedures began.

Table 1. Tested Mouthwash Solutions

Product name	Components*	pH	Manufacturer
Colgate Plax, alcohol-free	Sodium Fluoride total fluoride content 225ppm, Cetylpyridinium Chloride, Aqua, Glycerin, Propylene Glycol, Sorbitol, Poloxamer 407, Aroma, Sodium Saccharin, Camellia Sinensis Leaf Extract, Potassium Sorbate, Sodium fluoride, Menthol,citrus limon peel oil , Cl 19140,Cl42051	4.96	Colgate-Palmolive, Thailand
Listerine Total Care	Aqua, alcohol, sorbitol, poloxamer 407, benzoic acid, zinc chloride, eucalyptol, aroma, Sodium Saccharin, methyl salicylate, thymol, mentol, Sodium fluoride, sodium benzoate, sucralose, propylene glycol, CI 16035, CI 42090, Fluoride total fluoride content 225ppm,	3.57	Johnson and Johnson, Italy
Vinegar	%100 White apple vinegar	3	Taskobirlik, Nevşehir, Turkey
Distilled Water (DW)	Deionized water	7	BRTR Kimya, Izmir, Turkey

*Information provided by manufacturers

Table 2. Tested Acrylic Resins

Product name	Material Type	Shade	Manufacturer
Temdent	Polymethylmethacrylate	Light	Schütz-Dental Co. Germany
PreVISION Temp	Monomer (Multifunctional methacylic esters) Based on Bis-EMA	A2	Kulzer, Kanau, Germany

Color Measurements

Assessment with color measurement devices is objective, which allows even minor color variations to be identified.

Spectrophotometric and colorimetric color measurements provide numerical values even below the eye detection level, which leads to repeatable and reliable results. CIE L * a * b * (Commission Internationale de l'Eclairage), a system frequently used in instrumental color analysis, contains three coordinates [12]. The L * coordinate gives the lightness of the color, the a * and b * coordinates represent the positions on the red/ green and yellow/ blue axes. On the other hand, the +a * axis represents the red intensity of the color, the –a * axis represents the green intensity of the color, the +b * axis represents the yellow intensity of the color, and the –b * axis is the blue intensity of the color. Color difference (ΔE *) is the mathematical calculation of the direction and magnitude of the difference between two points in the three-dimensional color space.

The initial color coordinates (CIE Lab) of the samples were measured using a dental spectrophotometer (VITA Easyshade V; Vita Zahnfabrik, Bad Sackingen, Germany). Measurements were made using a white background and under the D65 standard lighting conditions, calibrating the device according to manufacturer's instructions. Average L, a, and b values were recorded by repeating the measurements three times on each sample surface.

After a 72 hour immersion in solutions, color differences were calculated using Eq.1. based on the L*, a*, b* values:

$$\Delta E = \sqrt[2]{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \quad \text{Eq.1.}$$

The values ΔL, Δa and Δb represent the differences of CIE L * a * b * values measured before and after the specimens were kept in mouthwash [13]. At the end of the test time, the specimens were removed from the liquid and washed with distilled water. It was stated that the 72 hour holding period used in the study corresponds to a 3 month usage period [13].

Surface Roughness and Vickers Hardness Measurements

Surface roughness (Ra) was measured on one side of the specimen, with a surface roughness analyzer (SJ-201 P/M, Mitutoyo, Tokyo, Japan). The cut off was set at 0.25 mm, and the total transverse length was 1.25 mm. Three measurements were made and the arithmetic averages were evaluated for statistical analysis.

Vickers hardness test was carried out with a HMV device (Micro Hardness Tester, Shimadzu, Japan) with indentations at 3 different points, under 25 g load and 30 s penetration. The average values of individual samples were considered. A minimum (as short as 10 sec) time interval of diagonal length readings was allowed to pass immediately after each recess. Due to the short time between indenting and reading, the viscoelastic healing of the diagonals after the indent is assumed to be minimal [14].

Statistical Analysis

Before and after data comparisons of the groups were made with the Paired simple t-test. T1 time comparisons were made with the One-way ANOVA test and Bonferroni postHoc. Correlations between microhardness, surface roughness and discoloration were evaluated using Spearman's Rank Correlation. The software SPSS version 25, IBM SPSS, Chicago, IL was used for statistical comparisons at 95% level of significance.

3. RESULTS

Color Analysis

Color stability (ΔE) values are presented in Table 3 and Figure 1. The highest ΔE values were observed in Listerine for PreVISION (ΔE=8.85±0.67) ($p<0.05$), and in Vinegar for Temdent (ΔE= 3.69±0.94) ($p<0.05$), respectively. Although the unpolished material showed the worst results, the results of polished bis-acryl based material were also poor (ΔE=6.35) ($p<0.00$).

Although PreVISION showed a clinically acceptable value (ΔE<3.3) [15] only after immersion in DW, Temdent showed a clinically acceptable value after immersion in Colgate, Listerine and DW. Regarding PreVISION, comparison of the effects of different mouth rinse solutions revealed statistically significant differences between the specimens immersed in Colgate and Listerine, Colgate and Vinegar ($p<0.05$), except between Listerine and Vinegar ($p>0.05$).

Table 3. Mean and Standard Deviations for ΔE Values

	PreVISION	Temdent
Colgate	5.41±1.27[a]	2.68±0.30[a]
Listerine	8.85±0.67[b]	3.21±0.27[ac]
Vinegar	8.50±1.20[b]	3.69±0.94[bc]
DW (Control)	1.97±0.70[c]	0.75±0.35[d]

The difference between the groups without the common lower case in the same material type (column) is statistically significant.

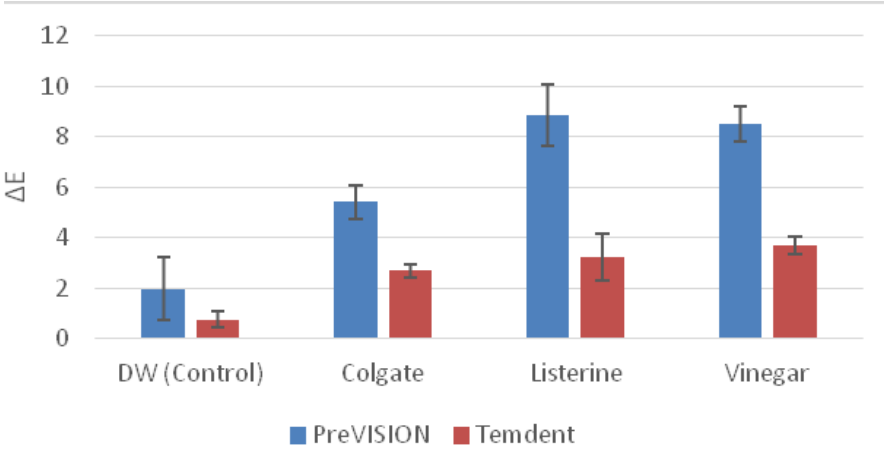

Fig. 1. Mean and standard deviations for ΔE values

Surface Roughness

The surface roughness (R_a) values are showed in Table 4.

After the acrylics were immersed in mouthwashes for 72 hours, statistically significant differences were detected in the surface roughness of PreVISION ($p=0.000$) and Temdent ($p=0.001$) restorative materials (Table 4).

When evaluated for PreVISION, it was stated that Colgate, Listerine and Vinegar ($p<0.05$) affected roughness in terms of values before and after measurements, except DW ($p>0.05$). According to the mean values, the highest change in Ra values were detected after immersion in Vinegar, followed by Listerine solutions.

No difference was observed between Colgate and DW ($p>0.05$) and Listerine and Vinegar ($p>0.05$) in terms of roughness change before and after measurements.

When evaluated for Temdent, the highest statistically significant surface roughness change was stated after immersion in Vinegar ($p<0.05$). There was no statistically significant difference between Colgate, Listerine and DW ($p>0.05$) but, according to the average values, higher changes were seen in Vinegar, then in Colgate.

A comparison of mouthwash solutions to each other stated no difference between Colgate and DW ($p>0.05$), Listerine and Colgate ($p>0.05$) and DW and Listerine ($p>0.05$) in terms of roughness change before and after measurements (Table 5).

Table 4. Changes in Surface Roughness (Ra (in µm), Mean Values ± Standard Deviation) of the Acrylic Materials Used in Each Mouth Rinse (n = 10) at Baseline and after Immersion

		DW	Colgate	Listerine	Vinegar
ProVISION	Baseline	0.10±0.02	0.13 ± 0.02	0.09±0.10	0.13±0.04
	72 h	0.12±0.03	0.27 ± 0.04	0.50±0.02	0.50±0.10
Temdent	Baseline	0.08±0.03	0.11 ± 0.02	0.13±0.04	0.10±0.05
	72 h	0.08±0.02	0.19 ± 0.12	0.13±0.04	0.43±0.04

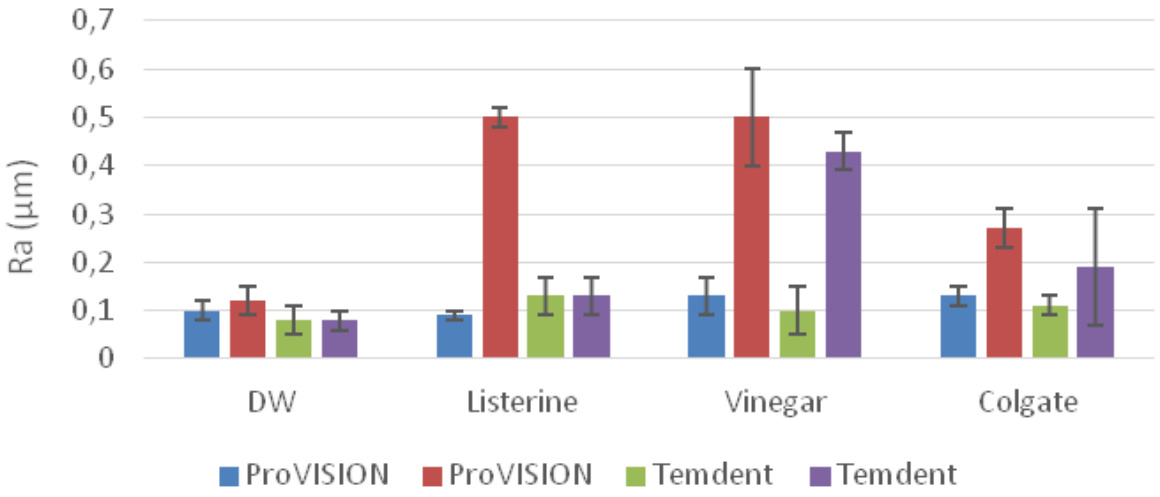

Fig. 2. Mean and standard deviations for Ra(µm) values

A statistically significant difference was found between the before and after roughness values in terms of solutions in both materials (p= 0.000).

For PreVISION, the highest change in the average values was seen in Vinegar, followed by Listerine (Table 5). There was no difference between Colgate and DW, and between Listerine and Vinegar in terms of roughness change before and after measurements (Table 5).

Table 5. Mean and Standard Deviations for R_a (%) Values

	PreVISION	Temdent
Colgate	26.28(10.50) a	21.26 (8.35) a
Listerine	108.14(24.45) b	1.52(1.20) a
Vinegar	146.76(29.34) b	111.12(35.46) b
Control	7.49(5.65) a	1.34(0.54) a

The difference between the groups without the common lower case in the same material type (column) is statistically significant (Bonferroni test (p<0.05).

Microhardness

The initial microhardness values were the same for each resin group. In all provisional resins, there was a statistically significant difference in microhardness after immersions (p<0.05). PreVISION immersion in Vinegar showed the highest microhardness value decrements with statistically significant difference concerning Colgate and DW (p<0.05) (Table 6). For Temdent, a higher microhardness value reduction occurred in Vinegar, while no difference was evidenced between Colgate and DW, Colgate and Listerine and Listerine and DW (p>0.05) (Table 6).

Table 6. Changes in Microhardness (HV, mean values ± standard deviation) of the Acrylic Materials Used in each Mouthwash Solution (n=10) at Baseline and after Immersion

	PreVISION	Temdent
Baseline	22.37±1.52a	22.07±1.44a
After immersion		
DW	12.63±2.84d	20.03±1.09b
Colgate	16.26±1.33 b	18.80±2.68b
Listerine	8.84±2.3c	19.50±2.66b
Vinegar	7.09±1.09c	15.83±2.62c

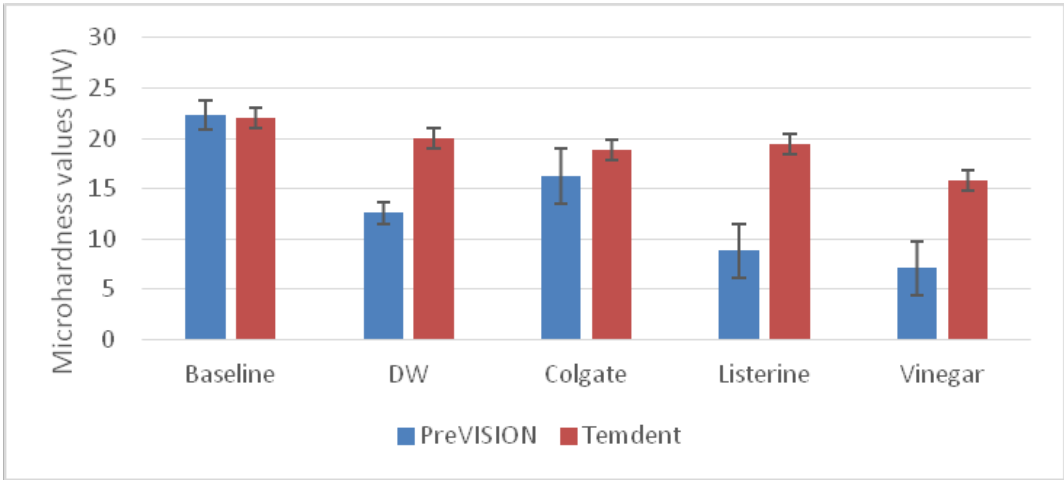

Fig. 3. Mean and standard deviations for microhardness values (HV)

Considering the correlation between microhardness, surface roughness and discoloration, a significant relationship was established for both provisional materials. The correlation between microhardness and roughness was negative, moderate but statistically significant (R = -0.489; p = 0.00) for Provision. A negative, moderate level relationship was observed between microhardness and roughness (r = -0.464; p = 0.01) for Temdent.

4. DISCUSSION

The Null hypothesis was rejected as the results of the study showed that the type of mouthwash affects temporary restoration surface roughness, microhardness and color stability, thus creating statistically significant differences.

As a result of one-way analysis of variance, the difference between the ΔE values obtained in samples kept in different mouthwashes at different times was statistically significant ($p < 0.05$). Previous studies stated that ΔE values higher than 3.3 will not be clinically acceptable [15,16]. According to this concept, in the present study, 3 mouthwash solutions showed ΔE values over the acceptable limit on PreVISION, only Vinegar showing unacceptable value on Temdent. PreVISION showed a higher color change when immersed in Listerine and, to a lesser extent, color change was observed in Vinegar, yet the difference was not statistically significant ($p > 0.05$). On the other hand, Temdent evidenced higher color change after immersion in Vinegar and, to a lesser extent, in Listerine. The ΔE values of immersion in DW for both provisional restorations, while in Listerine and

Colgate for Temdent showed clinically acceptable values.

The present study on PreVISION, based on bis-acriyl, demonstrated less color stability than in a previous study ($p<0.05$) [17]. As bis-acrylic resin polymers are more polar than the acrylic resin ones, the susceptibility of bis-acrylic resins to polar liquid molecules may occur, encouraging higher sorption of substances that interfere with the color stability of the materials. Also, a low pH and alcohol content may provoke surface roughness and related color changes during temporary restoration with the Bis-acrylic content [18]. Organic polymer matrix and anorganic fillers in Bis-acrylic based PreVISION can roughen the surface and cause more color change.

Dietary and oral hygiene habits are important factors that affect the optical properties, as water absorption demonstrates oxidation and hydrolysis, causing chemical degradation [19]. Not only the chemical properties of acrylic but also the unpolished surface properties can cause discoloration due to food adhesion, supported by surface roughness [20].

Surface roughness is an important factor facilitating the attachment of microorganisms [21]. Low pH mouthwashes, such as Vinegar and Listerine, facilitated changes in the material surface. The Listerine solution has been approved by ADA, being recommended to be used twice a day for 30 seconds. The low pH and alcohol content of Listerine are the most important factors causing changes in the surface roughness of acrylics [22]. In addition, the low pH created by acetic acid in Vinegar was similarly affected.

Under such special circumstances of the study, mouthwashes caused an increase in the surface roughness of acrylic resins, except for DW. Although mouthwash solutions are beneficial for the health of the gum, they may have negative effects on restorative materials. These disadvantages can occur not only depending on the chemical structure of the solution, but also on that of the temporary material used.

PMMA resins have advantages, such as being economical, having good marginal compatibility, and being well-polished [23]. Bis acrylics have some advantages, such as the ease of application, less laboratory requirements, low polymerization shrinkage, low exothermic heat release, which increases their usage [24].

Temporary restorations are in contact with the gum and mucosa. Rough surfaces can cause more microbial plaque to accumulate and have negative effects on oral health [25]. Surface roughness is related to the coloring of restorations, a surface roughness higher than 0.2 micrometer causing biofilm formation and coloration of restoration [26].

In the present study, after immersion in Colgate, Listerine and Vinegar solutions, PreVISION materials' surface roughness exceed 0.2 µm, but it was only after immersion in Vinegar that Temdent showed a value above 0.2 µm, which is the clinically bacterial colonization threshold [27]. Dramatic bacteria colonization would occur, beginning with 2 µm. Also, researchers cited 0.12 µm as characteristic for a smooth acrylic surface [21]. In this *in vitro* study, all test groups showed lower values than the critical surface roughness value of 2 µm.

The surface roughness values of acrylic resin Temdent were lower than those of Bis-acrylic PreVISION, as mentioned in previous studies [28,29]. This difference may be due to the homogeneous structure of the acrylic and heterogeneous distribution of bisacryl.

Vinegar is a low-toxic, inexpensive product, available as a prosthesis disinfectant with a 50% and 100% concentration of 6%-13% acetic acid content. The polymer bonds of acrylic are disrupted by the hydrogen ions from the acid and by absorption of water. Similar to the study of Kodir *et al.* [30], in the present study, vinegar affected the surface roughness of both provisional restorations.

Resin hardness will affect its durability under functional forces, thus affecting abrasive wear, surface roughness and plaque involvement. Vickers hardness evaluates a certain load strength, but it has disadvantages, such as microscope measurement, optical resolution. Vickers microhardness is the resistance value of the material to the entrance of a special tip into the material with a certain load at a certain time [31].

After 72-hour immersion, all solutions were affected in the microhardness of both temporary acrylic materials, which caused statistically significant reductions of such values.

The essential oils in Listerine are considered as potential solvents on acrylic, thereby causing softening. This reduction in final hardness values for PMMA is also caused by the plasticizing effect developed by ethanol, which penetrates the matrix, enlarges the gap between chains and changes the structure of the polymer [32].

It was observed that PreVISION's microhardness values decreased more, being more affected by the solutions. Provision, Listerine and Vinegar showed similar and excessive decreases in microhardness, while Vinegar immersion for Temdent decreased too much. The acidic structure of vinegar may have caused these low values in HV.

5. CONCLUSIONS

Depending on the material properties, the solutions produced different changes in the temporary acrylic restoration material. The choice of the mouthwash solution to be used according to the type of material will prolongue the life of the restoration and will provide a longer period of confidence in the mouth.

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