

# Effect of cleanser solutions on the color of acrylic resins associated with titanium and nickel-chromium alloys

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**Declaration of Interests:** The authors certify that they have no commercial or associative interest that represents a conflict of interest in connection with the manuscript.

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DOI: 10.1590/1807-3107BOR-2014.vol28.0017  
Epub Jun 02, 2014

Submitted: Nov 29, 2013  
Accepted for publication: Feb 25, 2014  
Last revision: Apr 28, 2014

**Abstract:** This study evaluated the effect of cleanser solutions on the color of heat-polymerized acrylic resin (HPAR) and on the brightness of dental alloys with 180 immersion trials. Disk-shaped specimens were made with I) commercially pure titanium, II) nickel-chromium-molybdenum-titanium, III) nickel-chromium molybdenum, and IV) nickel-chromium-molybdenum beryllium. Each cast disk was invested in the flasks, incorporating the metal disk into the HPAR. The specimens ( $n = 5$ ) were then immersed in solutions containing: 0.05% sodium hypochlorite, 0.12% chlorhexidine digluconate, 0.500 mg cetylpyridinium chloride, a citric acid tablet, one of two different sodium perborate/enzyme tablets, and water. The color measurements ( $\Delta E$ ) of the HPAR were determined by a colorimeter in accordance with the National Bureau of Standards. The surface brightness of the metal was visually examined for the presence of tarnish. The results (ANOVA; Tukey test- $\alpha = 0.05$ ) show that there was a significant difference between the groups ( $p < 0.001$ ) but not among the solutions ( $p = 0.273$ ). The highest mean was obtained for group III (5.06), followed by group II (2.14). The lowest averages were obtained for groups I (1.33) and IV (1.35). The color changes in groups I, II and IV were slight but noticeable, and the color change was considerable for group III. The visual analysis showed that 0.05% sodium hypochlorite caused metallic brightness changes in groups II and IV. It can be concluded that the agents had the same effect on the color of the resin and that the metallic alloys are not resistant to the action of 0.05% sodium hypochlorite.

**Keywords:** Denture Cleansers; Titanium; Chromium Alloys; Acrylic Resins; Color.

## Introduction

Removable dentures can be cleaned using chemical, mechanical or combined methods.<sup>1</sup> Chemical methods mainly include soaking the dentures in a household or commercial solution. Alkaline peroxides, sodium hypochlorite and mouthwashes are agents that are frequently included in these solutions.<sup>2</sup> Alkaline hypochlorites are bactericidal and fungicidal agents, as well as stain bleaching<sup>3</sup> agents, and they have been indicated for prosthetic disinfection and for overnight soaking.<sup>4</sup> Alkaline peroxides work through an oxygen-liberating process that enables mechanical cleaning via the release of oxygen bubbles, as well

as chemical cleaning, and they have been widely used for prosthesis cleaning.<sup>5</sup> Mouthwashes are very popular, mainly due to their pleasant fragrance and fresh taste, and they have demonstrated the ability to inhibit the microbial colonization of prosthetic surfaces.<sup>6</sup> Regardless of the efficacy of such cleansers, a factor that should be taken into consideration is the presence of adverse effects on the components of the prosthetic device. The color stability of acrylic resins is of particular concern, as it is associated with the esthetic reproduction of oral mucosa. Discoloration may be caused by several factors; cleaning solutions<sup>7</sup> and hygiene habits<sup>3</sup> are extrinsic factors that must be considered. Patients often do not receive instructions about effective hygiene, and they may over-clean the prosthesis using home-care products, which can have harmful effects.<sup>8</sup>

Metal alloys may corrode or be stained as a result of surface contact with the chlorine or oxygen that are present in some commercial cleansers.<sup>9</sup> Nickel-chromium alloys may be an appropriate substitute for gold alloys because they are low cost, have a lower specific weight and have better physical properties, such as mechanical resistance, hardness, and corrosion resistance.<sup>10</sup> Titanium alloys have several advantages, including biocompatibility, corrosion resistance, a low specific weight, a low elastic modulus, low thermal conductivity, and high mechanical resistance,<sup>11</sup> and they are well accepted by patients. However, there have been reports of titanium alloy tarnishing (surface discoloration)<sup>12</sup> and corrosion (surface pitting).<sup>13</sup>

Previous studies have evaluated color alterations in acrylic resins treated with 0.5% and 1% hypochlorite alkaline solutions,<sup>7,14,15,16</sup> as well as with alkaline peroxide solutions,<sup>7,17,18</sup> and they have revealed that the type of sanitizer, the immersion time, and the period of use are factors to be considered. In relation to the metal surface, it was determined that tarnish and spot corrosion on Co-Cr alloys are deleterious effects of immersion in cleansing solutions. However, commercially pure titanium was not evaluated.<sup>19</sup>

The purpose of this study was to evaluate the effects of six cleansing solutions on the color stability of heat-polymerized acrylic resin and on the surface brightness of four dental alloys. The null hypothesis

tested was that immersion in disinfection solutions would not influence the color stability of the acrylic resin or the surface brightness of the dental alloys.

## Methodology

Disk-shaped (12 × 3 mm) wax patterns (GEO, Renfert GmbH, Hilzingen, Germany) were used as a sprue to cast disks of each of the following alloys: I) Commercially pure titanium (Tritan, Dentaureum Inc., Pforzheim, Germany), II) Ni-Cr-Mo-Ti (Vi-Star, Talladium do Brasil, Curitiba, Brazil), III) Ni-Cr Mo (Fit Cast-SB Plus, Talladium do Brasil) and IV) Ni-Cr-Mo-Be (Fit Cast-V, Talladium do Brasil).

After casting, the metal disks were polished with 180-grit sandpaper (Norton Abrasives, Saint-Gobain, France) in a polishing machine (Arotec, Cotia, Brazil). Metallic flasks were previously prepared with Teflon rectangular matrices (38 × 18 × 4 mm) and then invested with type IV dental stone (Durone Dentsply, Petrópolis, Brazil). The Teflon matrices were removed, and the cast disks were inserted in the flasks in the left side of each rectangular mold. Before packing the heat-polymerized acrylic resin (Lucitone 550, Dentsply), the mold was isolated with a separating medium (Cel-Lac, SS White, Rio de Janeiro, Brazil).

The resin was manipulated, packed, and pressed into the mold according to the manufacturer's instructions. The curing cycle was carried out in water at 73 °C for 90 min and at 94 °C for 30 minutes. The specimens were immersed in distilled water at 37 ± 1 °C for 50 ± 2 hours to eliminate any residual monomer. The excess resin was trimmed, and one of the surfaces was finished using 180, 220, 400, 600 and 1200-grit sandpapers (Norton, Saint-Gobain, Vinhedo, Brazil) in a polishing machine and then using polishing cloths and a 1-µm diamond suspension (Fortel Ind. e Com., São Paulo, Brazil). Thirty-five specimens of each metal were prepared.

The specimens (n = 5; power level = 0.94) were randomly distributed into groups and immersed in the following solutions for the indicated length of time: 1) 0.05% sodium hypochlorite (Q'Boa; Anhembi S/A, Osasco, Brazil) - 10 minutes; 2) 0.12% chlorhexidine digluconate (Periogard, Colgate-Palmolive Ind., Osasco, Brazil) - 10 minutes; 3) cetylpyridinium chloride, 0.500 mg (Cepacol, Sanofi-

Aventis Farmacêutica Ltda., Suzano, Brazil) - 10 minutes; 4) Corega Tabs (sodium perborate and enzyme, Stafford-Miller Ind., Rio de Janeiro, Brazil) - 5 minutes; 5) Medical Interporous (citric acid, MSI-Laboratories AG, Vaduz, Liechtenstein) - 15 minutes; and 6) Polident 3 Minute (sodium perborate and enzyme, GlaxoSmithKline, Philadelphia, USA) - 3 minutes. The control group was immersed in 200 mL of deionized water for 15 minutes. The 0.05% sodium hypochlorite solution was prepared by mixing 200 mL of deionized water ( $23 \pm 2$  °C) and 6 mL of Q'Boa (2% sodium hypochlorite). The samples used in the Periogard and Cepacol tests were immersed in 50 mL of the solution. The effervescent tablets were prepared by adding one tablet to 200 mL of warm deionized water ( $30 \pm 2$  °C). All of the experiments consisted of 180 consecutive hygiene immersion trials, so the immersion time was multiplied by 180. This corresponded to 9 hours for Polident, 15 hours for Corega, 30 hours for sodium hypochlorite, Cepacol and Periogard, and 45 hours for Medical Interporous and deionized water. The solutions were changed six times for all of the products.

The color measurements were determined by a colorimeter (Color-guide, BYK-Gardner, Geretsried, Germany) with a standardized lighting D65, an observation angle of 10°, and a light source within the visible spectrum (400 to 700 nm). A heavy silicone mold was used to standardize the position of the specimens for the color measurements. The measurement geometry was 45°, and the area was 11 mm in diameter. The CIELab color system was used, and the total color alteration ( $\Delta E$ ) was calculated using the following equation:  $\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ . To relate the  $\Delta E$  to the clinical environment, the data were quantified according to National Bureau of Standards units<sup>20</sup> using the following formula: NBS units =  $\Delta E \cdot 0.92$ ; they were then classified according to: 1) Insignificant, 0.0-0.5; 2) Slight, 0.5-1.5; 3) Noticeable, 1.5-3.0; 4) Considerable, 3.0-6.0; 5) Very, 6.0-12.0; 6) Excessive, > 12.0.

The metallic brightness was measured visually by a single calibrated examiner and classified by the presence or absence of tarnish on the metal sur-

face. One control specimen (without immersion) was employed for comparative analysis.

The  $\Delta E$  values were submitted to two-way analysis of variance (ANOVA) followed by a Tukey test for pair-wise comparisons ( $\alpha = 0.05$ ) using the SPSS 17.0 program (SPSS Inc., Chicago, USA).

## Results

The color changes were recorded as the difference between the average of three measurements in each period of time (T0 and T1). Figure 1 shows the mean  $\Delta E$  values. ANOVA showed that there was a difference among the groups ( $p < 0.001$ ), but not among the solutions ( $p = 0.273$ ) or among the interactions ( $p = 0.168$ ). Table 1 shows the results of the Tukey test.

The highest mean was obtained for group III (Fit Cast-SB Plus<sup>®</sup>), followed by group II (Vi-Star<sup>®</sup>). The lowest averages were obtained for groups I (Tritan<sup>®</sup>) and IV (Fit Cast-V<sup>®</sup>), which did not differ from each other. Table 2 shows the results in NBS units.

The changes in groups I, II and IV were classified as "slight" (< 1.5) and "noticeable" (< 3.0), except for Polident in group II. However, for group III, the changes were classified as "considerable" ( $3.0 < x < 6.0$ ). The visual analysis showed that the sodium hypochlorite caused metallic brightness changes, with dark tarnish on the metal surface in groups II and IV (Figures 2 and 3). Groups I and III did not show any tarnishing. The other solutions did not cause any surface changes on the alloys.

## Discussion

Daily hygiene for a removable prosthesis should include brushing and immersion in solutions for biofilm control<sup>21</sup> and the reduction of microorganisms, as well as to avoid the signs of denture stomatitis.<sup>22</sup> The materials involved in making removable partial

**Table 1.** Mean and standard deviation of color change ( $\Delta E$ ).

Groups	Mean (SD)
I	1.33 (1.11) <sup>A</sup>
II	2.14 (1.22) <sup>B</sup>
III	5.06 (1.96) <sup>C</sup>
IV	1.35 (1.07) <sup>A</sup>

Values followed by different letters are significantly different ( $p < 0.05$ ).

**Table 2.** Mean and standard deviation of color change in NBS units.

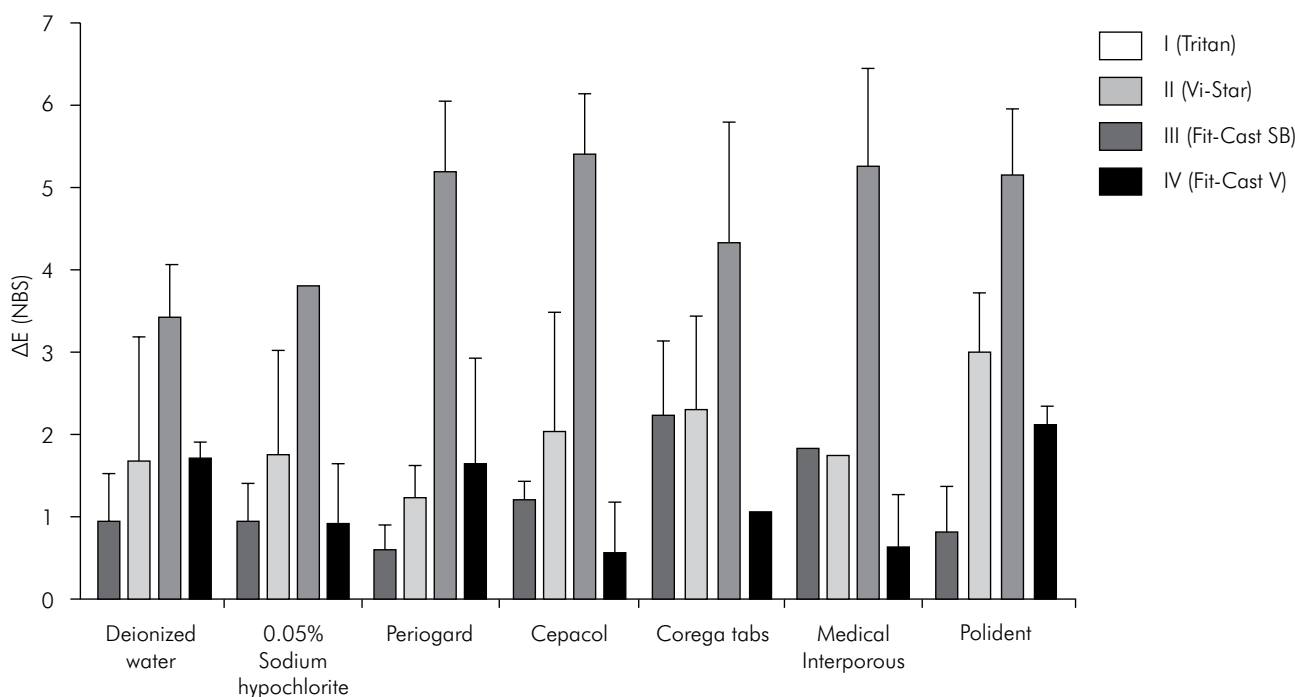
	I	II	III	IV
Water	0.95 (0.19)	1.69 (0.65)	3.44 (1.50)	1.72 (0.60)
Sodium hypochlorite	0.95 (0.72)	1.78 (0.77)	3.82 (1.25)	0.93 (0.47)
Periogard®	0.60 (0.26)	1.24 (0.89)	5.20 (2.78)	1.66 (0.61)
Cepacol®	1.22 (0.65)	2.02 (1.21)	5.41 (0.76)	0.55 (0.25)
Corega Tabs®	2.23 (1.29)	2.31 (0.85)	4.33 (0.40)	1.04 (0.31)
Medical Interporous®	1.85 (0.65)	1.74 (0.75)	5.26 (1.47)	0.64 (0.23)
Polident®	0.82 (0.28)	3.00 (1.48)	5.15 (1.14)	2.13 (0.92)

dentures are acrylic resins and metallic alloys, which makes it difficult to institute a safe hygiene protocol. The effects of cleansers have not been widely evaluated on RPD metallic components.<sup>1</sup>

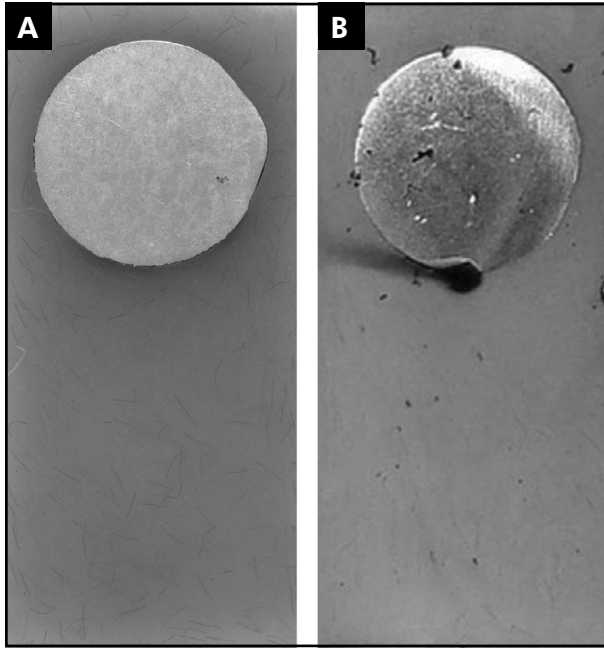
Commercial bleaches are often indicated as cleansers because they are inexpensive and easy to use.<sup>4,23</sup> Hence, 0.05% sodium hypochlorite was employed due to its antimicrobial properties.<sup>22</sup> The tablets and mouthwashes were included for the comparison of the methods usually employed and studied<sup>5</sup> and due to their antimicrobial effects.<sup>6,24</sup> Water was used as a control because it is indicated for overnight immersion,<sup>5</sup> and it prevents the release of ions.<sup>25,26</sup>

Among the properties of the acrylic resin, color stability is considered to be the most decisive in both the longevity of the prosthesis and in patient satisfaction.<sup>16</sup> The measurements were performed with a colorimeter using an objective, and quantitative readings were analyzed and correlated to NBS units for comparing the color and quality control functions. The  $\Delta E$  values were considered equal to a visually detectable difference in 50% of cases, and a  $\Delta E$  greater than 2 was detected 100% of the time.<sup>20</sup>

The study results suggest that the null hypothesis should be rejected because the disinfection solutions influenced the color stability of the acrylic resin



**Figure 1.** Mean  $\Delta E$  values after immersion in the solutions.



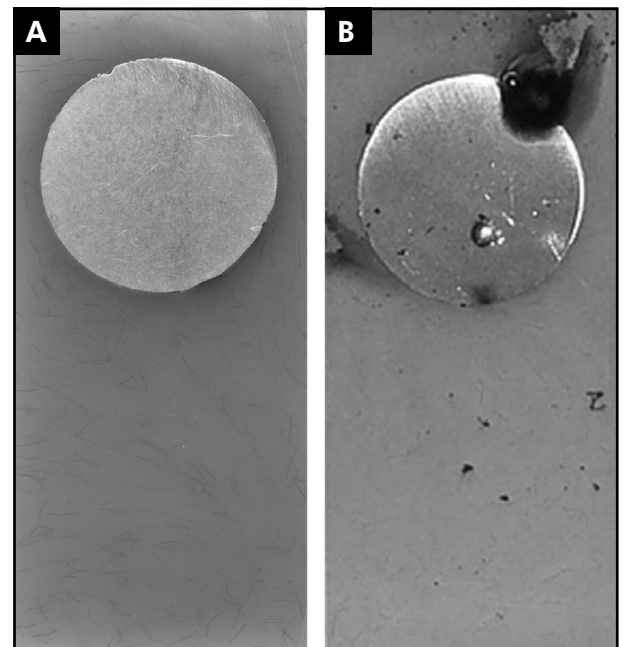
**Figure 2.** Images of the Vi-Star group (A) before and (B) after immersion in a 0.05% sodium hypochlorite solution.

and the surface brightness of the dental alloys. However, there were no differences among the solutions. Paranhos *et al.*<sup>14</sup> performed 20-minute immersions in sodium hypochlorite (0.5% and 1%) for 180 days and found no color changes for resins; however, in the same period with immersions of 8 hours, a 1% solution caused “slight” changes in NBS units.<sup>26</sup> Similarly, Hong *et al.*<sup>16</sup> found changes with 8-hour immersions in a 0.5% solution, indicating a trend of increasing  $\Delta E$  values with time. Therefore, the use of sodium hypochlorite as an everyday cleanser would require a study using lower concentrations over longer periods.<sup>7</sup> No studies have evaluated the color alterations with a 0.05% concentration.

The results revealed that the effects were the same as those of the other solutions. There is controversy about tablets, specifically regarding whether they cause damage to the resin and the metallic components of the prosthetic device. The water temperature,<sup>27</sup> immersion time<sup>26</sup> and the composition of the product<sup>8</sup> are critical factors. Studies have found that for acrylic resins, Corega Tabs have a greater whitening effect than Polident,<sup>17</sup> Bony Plus<sup>18</sup> and a 0.5% hypochlorite solution.<sup>7</sup> Corega contains agents that

release oxygen with enzymes, supporting the hypothesis that oxidation in combination with a strong alkaline solution can be deleterious.<sup>7,17</sup> In relation to the metallic components, weight loss and ion release,<sup>19</sup> as well as tarnishing and spot corrosion,<sup>25</sup> were observed in Co-Cr alloys after immersion in a citric acid product (Medical Interporous). With regard to titanium, Davi *et al.*<sup>26</sup> did not find alterations in surface roughness, but the color was not evaluated. Although mouthwashes can have adverse effects on resins (that is, stains on denture bases and teeth),<sup>2</sup> the results are not different from those of the other solutions.

Despite the use of the same resin and despite having followed the manufacturers’ instructions, there were differences among the groups. The Fit Cast-SB Plus specimens showed changes classified as “considerable”. The resin associated with titanium (Tritan) and Ni-Cr-Mo-Be (Fit Cast-V) showed the least color change. The manipulation difficulties, storage time, water temperature and the limitations of in vitro studies may explain these differences. The manipulation followed the manufacturer’s instructions, and the polymerizing cycle was standardized. However, the inclusion of oils



**Figure 3.** Images of the Fit-Cast V group (A) before and (B) after immersion in a 0.05% sodium hypochlorite solution.

or moisture could be considered because oil from the operator's hands might cause local deterioration within the mass of resin, resulting in a whitening effect.<sup>27</sup> In addition, the use of short or low-temperature heat-polymerizing cycles could result in an elevated level of residual monomer that could react with the solvents and external reagents,<sup>17,27</sup> promoting resin color change. The high temperature of the water used with the tablets could cause bleaching of the resin because the boiling water may disorganize the resin matrix and allow higher water adsorption, which acts as a plasticizer on the acrylic and promotes the bleaching effect.<sup>28</sup> The immersions were performed for the same amount of time and with the same water temperature, eliminating the possibility of color change due to high temperatures. Thus, the results should be due to the different chemical compositions of the tested alloys.

The visual analysis showed that the hypochlorite caused metallic brightness changes, with dark tarnish on the metal surface in groups II and IV. Corrosion is an electrochemical process of ion release and is dependent on the alloy composition, surface conditions, pH and environmental mechanical factors. Chemical compounds known as 'corrosion products' are produced when the metal comes in contact with non-metal elements.<sup>29</sup> By means of passivation, that is, by the formation of a protective pellicle on the metal surface, there is an inhibition of the corrosion process, which is very common on titanium surfaces. This also occurs in nickel-chromium alloys without beryllium, whose passivating pellicle is composed of chromium oxide, which is transparent and strongly adheres to the surface. In this study, commercially pure titanium did not show any metallic brightness change. However, although Vi-Star alloy containing titanium was used, it was not sufficient to prevent tarnish on the metallic surface.

When using sodium hypochlorite, there is a dissociation of chloride ions, which are extremely reactive.

Surface changes and staining were also observed in previous studies,<sup>12,30</sup> which reported severe oxidation of metals immersed in sodium hypochlorite solution. Keyf and Güngör<sup>23</sup> reported that not only hypochlorite but also peroxide solutions caused both discoloration (loss of gloss) and staining on the surface of a Co-Cr alloy. These findings are not in accord with our results because the tablets and mouthwashes did not cause any surface changes on the alloys. This finding may be explained by differences in the evaluation methods employed, *i.e.*, visual vs. spectrophotometric. Felipucci *et al.*<sup>25</sup> reported that the use of 0.05% sodium hypochlorite and citric acid-based tablets caused harmful effects to the metallic components of a Co-Cr alloy, including tarnishing and spot corrosion.

With regard to the methodological limitations of this study, only one property of the acrylic resin was evaluated, with one immersion time (short immersion) and a 6-month simulated period. The lack of objective and SEM analyses of the metallic brightness must also be considered.

Future studies should address the use of different immersion times and longer periods of use and focus on other properties that are also relevant to removable partial denture components, such as flexural strength and surface roughness. Moreover, the use of optical microscopy and SEM as well as EDS can detect small color changes and the chemical elements present on metallic surfaces.

## Conclusion

It can be concluded that all the cleansing agents had the same effect on the color of the acrylic resin and that the greatest color change occurred for the Fit Cast-SB® group. The alloys were resistant to the action of the cleansing agents except for the 0.05% sodium hypochlorite, which caused alteration of the metal surface, especially of the Ni-Cr alloys.

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