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INTRODUCTION

Esthetics has become a high-value item for dental patients. Studies showed that patients’ satisfaction with dental esthetics was most influenced by tooth color than by the form and function. Therefore, it’s not surprising to see dental bleaching, and especially home bleaching products for whitening stained teeth have grown in popularity.

Original Article

EFFECT OF HOME BLEACHING AGENTS ON THE SURFACE CORROSION OF STAINLESS STEEL ORTHODONTIC BRACKETS

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Introduction: This in vitro study evaluates the home bleaching treatment effect on the surface corrosion of stainless steel orthodontic brackets.

Materials and Methods: Three types of brackets, 3M Unitek (U), Dentaurum (D) and Tomy (T), were immersed in either one of six bleaching treatments at 37 °C for 28 days. After immersion, the amounts of iron, chromium, and nickel ions released from the brackets were detected using inductively coupled plasma mass spectrometry (ICP-MS). A scanning electron microscope and an atomic force microscope were used to analyze the surface morphology and roughness, respectively. Two-way ANOVA and Tukey’s post-hoc, \( \alpha = 0.05 \), were used to analyze the test data for different brackets and bleaching treatments.

Results: The bleaching treatment and bracket brand had a statistically significant influence on metal ion release (p<0.01). Among the tested brackets treated with 10% H\textsubscript{2}O\textsubscript{2}, the Tomy bracket had the highest iron and nickel ion released while the 3M Unitek bracket had the highest chromium ion released.

Conclusion: These findings suggest that using home bleaching agents on stainless steel brackets could result in metal ions release, especially Nickel ions. However, the amount of released nickel ions was still below the critical value for inducing a negative biological effect. (Taiwanese Journal of Orthodontics. 30(3): 132-141, 2018)

Keywords: corrosion; home bleaching; metal ion release; stainless steel orthodontic brackets.
Currently there are two types of bleaching, in-office and at-home bleaching. Vital bleaching was first introduced in dentistry by the early 1800s. However, it was not until March 1989 that the first commercially available home bleaching product, White and Brite (Omni International), was marketed. Bleaching agents containing 25-35% hydrogen peroxide (H₂O₂) are commonly used for in-office bleaching. An overnight (8 h) bleaching agent with 10-20% carbamide peroxide (CH₆N₂O₃) is common for at-home bleaching. To achieve a satisfactory outcome, it is recommended that overnight bleaching treatment be repeated for two consecutive weeks. The average treatment time of 6 weeks will usually produce a tooth lightening of 2 Vita shades.

As a result of bleaching product use, some adverse effects (i.e. soft tissue irritation, sore throat, nausea) have been noted. The most common side effect to dental hard tissue is a transient and dose-related sensitivity of the teeth to thermal changes.

Several studies were carried out to investigate the effects of bleaching agents on the enamel and dentine structures. Lewinstein et al showed that 30% H₂O₂ bleaching gels did reduce the microhardness of enamel (25%) and dentine (22%) in 35 minutes. It was also found that home bleaching agents (10% carbamide peroxide and 6% H₂O₂) caused no alteration in wear resistance of enamel.

The effects of bleaching agents on dental restorative materials have been widely discussed, including composite resin, glass ionomer cement, porcelain, amalgam and gold. Canay et al investigated the effect of 10% carbamide peroxide on the electro-chemical corrosion of various dental casting alloys. The potential dynamic changes showed that corrosion may occur on Ni-Cr alloys and non-polished amalgam restorations because of their higher value of corrosion current density. Rostein et al studied the in vitro effect of 10% carbamide peroxide or 10% H₂O₂ on amalgam fillings tested with scanning electron microscopy and energy dispersive spectrometric microanalysis. They found that prolonged treatment may cause micro-structural changes in amalgam surfaces, possibly increasing patient exposure to toxic byproducts of mercury, silver, tin and copper ions. Al-Salehi et al. found that with the exception of gold, the differences in metal ion concentration after treatment with 0% (control) and each of 3%, 10% and 30% H₂O₂ were statistically significant (P < 0.05). Al-Salehi et al. also found that significant increases in mercury release from dental amalgam between control and all other H₂O₂ concentrations at all exposure times. Other researches showed that home bleaching products can affect the bonding strength of composite resin to etched enamel or orthodontic brackets.

The Fe-Cr-Ni-based stainless steel (SS) remains one of the most popular materials used for orthodontic brackets because of its favorable mechanical properties and corrosion resistance. Studies have shown that metal ions, such as Fe, Cr and Ni, may be released from orthodontic brackets in the acidic oral environment and in artificial saliva due to corrosion. Although SS alloys form corrosion-resistant passivation layers, Oshida et al. found that the bleaching agents made the passivation layer on the metallic materials unstable and leading to corrosion susceptibility.

The potential hazard associated with the release of Ni and Cr ions has come from their biological and cytotoxic side effects. Specifically, Nickel sulfate is the most frequently detected cause of allergic contact dermatitis (Nickel hypersensitivity) in the world. The prevalence is between 8 and 11% in female population and 1 to 2% in males.

By the late 1990s, “over the counter” (OTC) at home bleaching agents were introduced to the public which can easily be obtained without prescription. Recently it even became very easy to purchase from the internet or TV shopping channels in Taiwan. So, patients with brackets may apply bleaching agents at home during the active treatment period, although it is not recommended.
by orthodontists. However, the corrosive effect of these home bleaching agents on SS brackets has not been well documented to date. Therefore, clinically it is important to evaluate the effect of home bleaching treatments on Ni/Cr-containing SS orthodontic brackets.

MATERIALS AND METHODS

I. Materials

In this study, three different SS orthodontic brackets (as-received condition) were chosen. The type of brackets investigated were “Roth” prescription twin SS brackets (slot size: 0.022 inch) designated as follows: U (3M Unitek, Puchheim, Germany); D (Dentaurum, Pforzheim, Germany); and T (Tomy, Tokyo, Japan).

Three different brands of OTC home bleaching agents were purchased. Pola product (16% carbamide peroxide, SDI, Victoria, Australia), Colgate product (5.9% hydrogen peroxide, Colgate, New York, USA), and Crest product (19% sodium carbonate peroxide, Procter & Gamble, USA). Furthermore, 6% and 10% H₂O₂ solution were prepared for this study. The six groups were designated as follows.

(1) C: Control (No bleaching)
(2) CP: Pola product
(3) HP: Colgate product
(4) SCP: Crest product
(5) 6HO: 6% H₂O₂
(6) 10HO: 10% H₂O₂

II. Immersion test

The brackets were brushed with abundant deionized, distilled water to eliminate contamination for 5 seconds and air-dried. After different bleaching treatments, the brackets were placed into Eppendorf test tubes containing deionized water. The tubes were then placed into a 37°C incubator and kept vibrating for 8 hours at 50 rpm. The test brackets were taken out, brushed again for 5 seconds, transferred into new test tubes with a fresh solution and stored until the next day. This procedure was repeated for 28 days.

III. Metal ion concentration measurements

After the immersion test on the first and 28th day, the amounts of iron, chromium, and nickel ions released from the brackets were detected using inductively coupled plasma mass spectrometry (ICP-MS). The critical value for iron, chromium, and nickel ions detection was 1.52 (ppb), 0.14 (ppb), and 1.00 (ppb) respectively.

IV. Surface characterization analysis

Before and after the immersion test, all the brackets were inspected with scanning electron microscope (SEM) and with an atomic force microscopy (AFM), to analyze the alteration of surface morphology and roughness, respectively (20μm~20μm).

The amount of ion concentration was statistically analyzed using two-way analysis of variance (ANOVA) and Tukey’s post-hoc (α=.05) to analyze the test data between different brackets and bleaching treatments. The number of SS bracket specimens for each corrosion test group was 10.

RESULTS

I. Metal ion concentration measurements

Table 1 showed the average metal ion concentration from different bleaching treatment on different brackets at Day 1 and Day 28. There was significant difference between day 1 and day 28 (P < 0.01) for all three kind of released metal ions (Fe, Cr & Ni).

Figure 1 shows the average Iron ion concentration from different bleaching treatments on different brackets at Day 1 (1a) and Day 28 (1b). Figure 2 is for Chromium ion concentration at Day 1 (2a) and Day 28 (2b). Figure 3 shows the average Nickel ion concentration at Day 1 (3a) and Day 28 (3b).

The average Nickel ion released from all three brands of brackets increased significantly after 6%
and 10% H$_2$O$_2$ bleaching treatment at Day 1 and Day 28. Two-way ANOVA results showed that different bleaching treatments and bracket brands had a statistically significant influence on the nickel ion concentration at Day 1 and Day 28 (p<0.01). Furthermore, Tukey’s post-hoc test for the bracket brand factor revealed significant differences between two groups of brackets, namely (A) 3M Unitek and Dentaurum and (B) 3M Unitek and Tomy; but not between the Dentaurum and Tomy brand. As for the bleaching treatment factor, there was a significant difference between two groups of bleaching agents, i.e. H$_2$O$_2$ group (6% and 10% H$_2$O$_2$), and other bleaching agents (C, CP, HP and SCP groups). However, the C, CP, HP and SCP groups appeared to have no significant difference between each other.

II. Surface characterization analysis

Figure 4 shows the SEM result of three brands of brackets after different bleaching treatment. It shows no significant difference on 3M Unitek brackets morphology after bleaching treatments, the same results also found on Dentaurum® and Tomy® brackets.

Figure 5 showed one AFM result (Tomy® brackets) and Figure 6 was the comparative plot of surface roughness alteration. The alterations of the roughness are not significant and not relative to the different brands of bleaching agents.

### Table 1. Average metal ion concentration from different bleaching treatment on different brackets at Day 1 and Day 28 immersion test.

<table>
<thead>
<tr>
<th></th>
<th>3M Unitek</th>
<th>Dentaurum</th>
<th>Tomy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 1</td>
<td>Day 28</td>
<td>P value</td>
</tr>
<tr>
<td><strong>Release ion-Iron</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>C</td>
<td>ND</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>CP</td>
<td>156.2</td>
<td>ND</td>
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<tr>
<td>HP</td>
<td>162.3</td>
<td>2.8</td>
<td>***</td>
</tr>
<tr>
<td>SCP</td>
<td>12.5</td>
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<td></td>
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<tr>
<td>6HO</td>
<td>312.6</td>
<td>72.7</td>
<td>***</td>
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<tr>
<td>10HO</td>
<td>396.4</td>
<td>90.2</td>
<td>***</td>
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<tr>
<td><strong>Release ion-Chromium</strong></td>
<td></td>
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<tr>
<td>C</td>
<td>2.8</td>
<td>0.2</td>
<td>***</td>
</tr>
<tr>
<td>CP</td>
<td>45.1</td>
<td>9.1</td>
<td>***</td>
</tr>
<tr>
<td>HP</td>
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<td>1.8</td>
<td>***</td>
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<tr>
<td>SCP</td>
<td>42.5</td>
<td>0.7</td>
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<tr>
<td>6HO</td>
<td>240.3</td>
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<tr>
<td>10HO</td>
<td>272.4</td>
<td>18.9</td>
<td>***</td>
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<tr>
<td><strong>Release ion-Nickel</strong></td>
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<tr>
<td>C</td>
<td>16.2</td>
<td>ND</td>
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</tr>
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<td>CP</td>
<td>5.4</td>
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<td>HP</td>
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<tr>
<td>6HO</td>
<td>35.1</td>
<td>0.7</td>
<td>***</td>
</tr>
<tr>
<td>10HO</td>
<td>37.8</td>
<td>2.4</td>
<td>***</td>
</tr>
</tbody>
</table>

Note: ND = non-detectable, *** indicates P<.001
Figure 1. Average iron ion concentration from different bleaching treatment on different brackets at Day 1 (1a) and Day 28 (1b) after 8 hours of vibration in immersion test. (*: below ICP-MS detection limit)

Figure 2. Average Chromium ion concentration from different bleaching treatment on different brackets at Day 1 (2a) and Day 28 (2b) after 8 hours of vibration in immersion test. (*: below ICP-MS detection limit)

Figure 3. Average Nickel ion concentration from different bleaching treatment on different brackets at Day 1 (3a) and Day 28 (3b) after 8 hours of vibration in immersion test. (*: below ICP-MS detection limit)
Figure 4. Scanning electron microscope (SEM) observations of the as-received SS brackets (3M Unitek, Dentaurum and Tomy) from different bleaching treatment. (1000 X).
Figure 5. The atomic force microscope (AFM) observation of as-received SS brackets from different bleaching treatment – result of Tomy® brackets.

- N, Ra: 30.7 nm
- C, Ra: 39.6 nm
- CP, Ra: 21.7 nm
- HP, Ra: 28.8 nm
- SCP, Ra: 34.3 nm
- 6HO, Ra: 26.0 nm
- 10HO, Ra: 44.8 nm
Society (ACDS) because of its significant public health importance.\textsuperscript{26} Researches showed that Nickel sulfate is the most frequently blamed cause of allergic contact dermatitis, followed by Chromium.\textsuperscript{27,28} In this experiment, brand T showed the highest Nickel concentration (102.96 ng/cm\textsuperscript{2}) after bleaching with 10\% H\textsubscript{2}O\textsubscript{2} at Day 1, and 3M Unitek brackets showed a maximum Chromium ion release in 10\% H\textsubscript{2}O\textsubscript{2} group (272.4 ng/cm\textsuperscript{2}). The above values are the average amounts in one single bracket. Since orthodontic patients ordinarily have about 24 brackets in both arches, the total maximal Nickel ion release per day for one orthodontic patient would be 2.47 μg and 6.53μg for Chromium. Once applied to a clinical situation, the 2.47 μg Ni concentration is much lower than the concentration (600-2500 μg) that causes allergic reactions as mentioned by Kaaber,\textsuperscript{29} and this is also lower than the amount (300-500 μg) the human body absorbs from daily intake described by Schröder.\textsuperscript{30} The estimated 6.53 μg Chromium ion released also appears to...

**DISCUSSION**

The main chemical compositions (in wt\%) of commercial SS brackets were 68.5–70.9\% Fe, 17.9–19.6\% Cr, and 7.4–9.3\% Ni. Iron (Fe) is the largest component, followed by chromium, then Nickel.\textsuperscript{17,18} As observed from figures 1, 2, 3, and table 1, the order of the amount of ion released was Fe> Cr >Ni, which positively correlated with the bracket composition ratio.

Under all observations, maximum ion (Fe, Cr and Ni) release always occurred after 1 day, then diminished progressively. It is well known that the Cr element in the SS alloy can form a thin and adherent Cr\textsubscript{2}O\textsubscript{3}-based passive film which provides corrosion resistance in a substrate alloy.\textsuperscript{23} It can be inferred that the diminished ion release at Day 28 was due to the formation of Cr\textsubscript{2}O\textsubscript{3}-based passive film on the metal surface (Table 1).

Nickel was named the “contact allergen of the year” in 2008 by the American Contact Dermatitis Society (ACDS) because of its significant public health importance.\textsuperscript{26} Researches showed that Nickel sulfate is the most frequently blamed cause of allergic contact dermatitis, followed by Chromium.\textsuperscript{27,28} In this experiment, brand T showed the highest Nickel concentration (102.96 ng/cm\textsuperscript{2}) after bleaching with 10\% H\textsubscript{2}O\textsubscript{2} at Day 1, and 3M Unitek brackets showed a maximum Chromium ion release in 10\% H\textsubscript{2}O\textsubscript{2} group (272.4 ng/cm\textsuperscript{2}).

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be much lower than the amount of chromium ions (280 μg) that human body absorbs from daily meals determined by the International Agency for Research on Cancer (IARC).

Different surface topography was present among the test brackets after bleaching treatments (Figures 4, 5). However, the difference in surface topography with different bleaching agents did not correspond with metal ion released.

**CONCLUSION**

In this study, the bleaching treatment and the bracket brand had a statistically significant influence on metal ions released (p<0.01). Specifically, the Tomy bracket treated with 10% H2O2 had the highest Iron and Nickel ion release. These findings suggest that using home bleaching agents with stainless steel brackets could result in the release of metal ions, especially Nickel ions. However, the amount of the released nickel ions was still below the critical value to induce a negative biological effect.

It appears that the quantities of metals released in our experiments were too low to be a cause for concern in utilizing home bleaching products.

**REFERENCES**