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Analysis of two Different Types of Orthodontic Mini-Implants Immersed in Fluoridated Mouthwashes Using Scanning Electron Microscopy (SEM)

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ABSTRACT

Objective: *The current in vitro study was performed to evaluate the effect of fluoridated mouthwashes and immersion time on the corrosion behavior and microscopical surface of two different types of orthodontic mini-implants (titanium (Ti) and stainless steel (SS)).* ***Methods:*** *Total 30 orthodontic mini-implants (15 titanium and 15 stainless steel) were collected. Each group was subdivided equally into 3 subgroups which were immersed separately in (Artificial saliva, Lacalut-white and Kin B5 mouthwashes) for 28 days at following immersion intervals: 1-7 days, 8-14 days and 15-28 days. All mini-implants were assessed for metal ions release, however, only 6 MIs: 3 Ti and 3 SS were selected from the studied groups (one from each group), and subjected to SEM analysis before and after immersion in the storage media. The mini-implants were used in as received condition without any additional treatment.* ***Results:*** *The results of (SEM) showed that the pitting and crevice corrosion was obvious in different regions of examined samples, being greater in titanium than stainless steel mini-implants, and more evident in both fluoridated mouthwashes than artificial saliva.* ***Conclusion:*** *The results of the microscopical examination revealed that the signs of corrosion in the form of crevice and pitting were detected in all groups of MIs, being most evident in those immersed in fluoridated Kin-B5 MW followed by fluoridated Lacalut-White MW and finally the artificial saliva group.*

Keywords: Fluoridated mouthwashes, Orthodontic mini-implants, Anchorage, Dental alloys

INTRODUCTION

Anchorage can be defined as the resistance to the undesirable tooth movement. The success of orthodontic treatment has been frequently determined by the proper anchorage control in all three planes of the space and most practitioners realize it as a challenging factor in establishing the orthodontic treatment planning [1]. The introduction of orthodontic mini-implants (MIs) via kanomi in 1997, has demonstrated a revolution in the anchorage discipline through serving as an absolute source of stability [2]. In opposition to prosthodontics implants, MIs are metal devices which are temporarily fixed to the bone and have been utilized to achieve a variety of orthodontic tooth movements [3,4].

Although there is a huge number of metals and alloys in the industry of materials, only a considerable number of metals and alloys could be suitable for the use as a bio-implant. The widespread utilization of metallic biomaterials includes 316L austenitic stainless steel (ASS), Cobalt-chromium (Co-Cr) alloys and titanium (Ti) and its alloys [5].

Despite the effective role of MIs in orthodontic anchorage, they are considered to be a potential source of human exposure to metallic ions due to the different elements used in the manufacturing of these devices and because of the corrosion of titanium and stainless steel alloys in different body fluids [6,7].

Corrosion is defined as the process of interaction between a solid material and the chemical environment, which results in the loss of the structural integrity, change of the structural features, and loss of the substance from the material. Corrosion can also be defined as the degradation of material into its composing atoms due to the chemical reactions existed between the materials and its surrounding environments [8-10].

In the oral cavity, the corrosion is induced by metal ions released, the subject that has been broadly estimated with regards to orthodontic brackets, fixed appliances, and other devices were employed in the oral cavity during the course of orthodontic treatment [11,12].

In 2010, Manivasagam, et al., reported that the metallic dental alloys used in the oral cavity are subjected to the impact of chemical, mechanical, biological, thermal and electrical forces which could have a negative effect on the major dental practice or may affect the adjacent tissue. Electrochemical corrosion is considered as the most destructing factor affecting the dental works [13].

Mostly, the metal corrosion occurs via the interaction with electrochemical cells resulting in various forms of corrosion reactions which were represented mainly in the biomedical implants by general (uniform corrosion), pitting and electrochemical corrosion [14]. General corrosion occurs when the entire metal surface is subjected to the cathodic reactants during the localized corrosion [15]. Pitting corrosion is considered as a form of localized corrosion on the surface of the metal that points to pitting attacks in the form of pits or spots over the surface [16]. However, electrochemical corrosion includes the following processes (fretting, fatigue, stress corrosion cracking and interaction of corrosion and shielding forces that enhances the stress accumulation), these conditions can lead to premature degeneration, structural alteration and changes of mechanical aspects, which might result in the acceleration of the whole metal elements and ions deficiencies [17,18].

Variety of electrochemical approaches had been utilized to evaluate the influence of fluorine ion on the corrosion potential of Ti and Ti6-Al-4V implant alloys, in artificial saliva when being combined with either metal/ceramic or all the ceramic frameworks. Actually, it can be concluded that with increased fluoride concentration, the corrosion resistance of Ti and its Ti6-A1-4V alloy has become reduced [19].

On the other hand, the passivation of stainless steel results from the superior corrosion resistance exhibited by the Cr (III) oxide–hydroxides existed in passivation layers. Fluorine ion is an aggressive ion which can damage the passive protective oxide film formed on the surface of SS. The oxide layer consequently gets weakened because of the complex formation of the fluorine ion molecules on the alloy surface [20,21].

The aim of the current study is to evaluate the microscopical surface changes of orthodontic MIs before and after immersion in different storage media.

PATIENTS AND METHODS

SEM examination was performed to obtain a descriptive analysis of the implant design and qualitative evaluation of MIs surface characteristics as to the presence of any contaminants due to various important factors such as (milling procedure, manufacturing defects, imperfection, and corrosion behavior).

The surface microstructure analysis was accompanied using the TESCAN Vega-III high-resolution SEM, equipped with an energy dispersive spectrometer, operated in a high vacuum (HV) mode (Figure 1).

Figure 1 SEM (Model number: TESCAN, Vega III/Czech Republic)

Total 6 orthodontic MIs: 3 Ti and 3 SS were selected from the study groups (one from each group), and were subjected to surface microstructure analysis with SEM two times. The first time was before immersion in storage media (artificial saliva, Kin-B5, and Lacalut-white MWs) and the second time was at the end of immersion period where the samples were thoroughly dried and resubmitted for the SEM analysis (Figure 2,3).

Figure 2 Ti (MI) (Morelli, BRAZIL)

Figure 3 SS (MI) (Leone, Italy)

The samples were examined at the end of the 3rd interval (28 days) because the manifestation of pits, crevices, and inter-granular corrosion need several days or weeks to be identified.

In this study, MIs were taken from each group (one orthodontic MI was taken from each subgroup) to represent the different studied groups, and their surface was examined and photographs were taken at 50X, 100X, 200X, 500X, 1000X, to facilitate the comparison between MIs before and after immersion procedure. However, some regions required magnification of more than 1000X to better clarify the after immersion texture of MIs. The examined sites included the head, body, threaded region, body-thread junctions and screw tip of MIs.

RESULT

Various regions in the components of orthodontic MIs have undergone two examinations, before the immersion procedure for the determination of manufacture defects and to permit the comparison after the total immersion period (at 28 days) in the three testing solutions (Artificial saliva, Kin-B5, and Lacalut-White MWs) with different PH values. By inspecting the results of the SEM analysis, it can be detected that, even before immersion procedure, there were some microscopical surface imperfections and manufacturing defects in the form of scratches and indentations in all MIs groups. The Ti type exhibited more surface defects and irregularities than SS group, characteristically noted by SEM images of large magnification powers (500X and 1000X). These findings were most evident in Group 1, 2 and 3. The results of SEM images obtained from immersion showed loss of gloss and surface finish with a consequentially dull appearance in all tested groups. The exhibited signs of corrosion were mostly in the form of crevices or pitting scattered over the surface of MIs in different sites, mainly at the threaded regions, body-thread junctions, the tip region and the sites of machining defects. All the groups had integuments that were identified in Figure 4-6.

Titanium (MIs)

The surface topographies of all the examined Ti (MIs) groups exhibited a rough fibrous surface structure with greater imperfections in comparison with the SS groups.

Group 1-A (MIs): It was immersed in the artificial saliva of pH 6.75. Figure 4 showed relatively less surface roughness and corrosion when compared to that immersed in Kin-B5 and Lacalut white MWs (Group 2 and Group 3), with pH 6.5 and 5.5 respectively. The threads of MI showed surface roughness and the body-thread junctions exhibited crevice corrosion, in addition, there were pits and indentations clearly seen in large magnification images (Figure 4).

Group 2-A (MIs): It was immersed in Kin-B5 MW of pH 6.5. It exhibited more roughness and a larger number of pitting corrosion when compared to those of (Group 1 and Group 3). The head region has lost its glossy surface and there was increased crevice and pitting corrosion with more apparent surface indentations (Figure 5).

Group 3-A (MIs): It was immersed in Lacalut-White MW of pH 5.5, which revealed less pitting and crevices than Kin-B5 MW group (Figure 6).

Stainless Steel (MIs)

The examination of MIs before immersion revealed that stainless steel groups have the smoothest surface as compared with Ti groups of MIs. In Figure 4-6, SEM images clearly showed that smooth texture of SS groups, especially with a magnification power of (200X, 500X and 1000X).

The most common types of corrosion were pitting, and crevice corrosion. The pits appeared as circular or semicircular area (single or in groups), while the crevice regions were presented with a finger-like projection which comprised of the microscopic pits sometimes.

Group 1-B (MIs): It was immersed in artificial saliva, Figure 4 showed less crevice and surface pitting in comparison with the other two SS groups.

Group 2-B (MIs): It was immersed in Kin-B5 MW. Figure 5 presented the greatest surface defects and corrosion that were revealed by SS (MIs) after immersion procedure. Corrosion was represented by pitting in the head, body and tip regions of MI and crevices along the body-thread junctions.

Group 3-B (MIs): It was immersed in Lacalut-white MW. Figure 6 similarly, appeared with signs of corrosion following immersion. The pits were scattered in less number at the tip region, as well as there was less crevice corrosion involving the body and body-thread junctions.

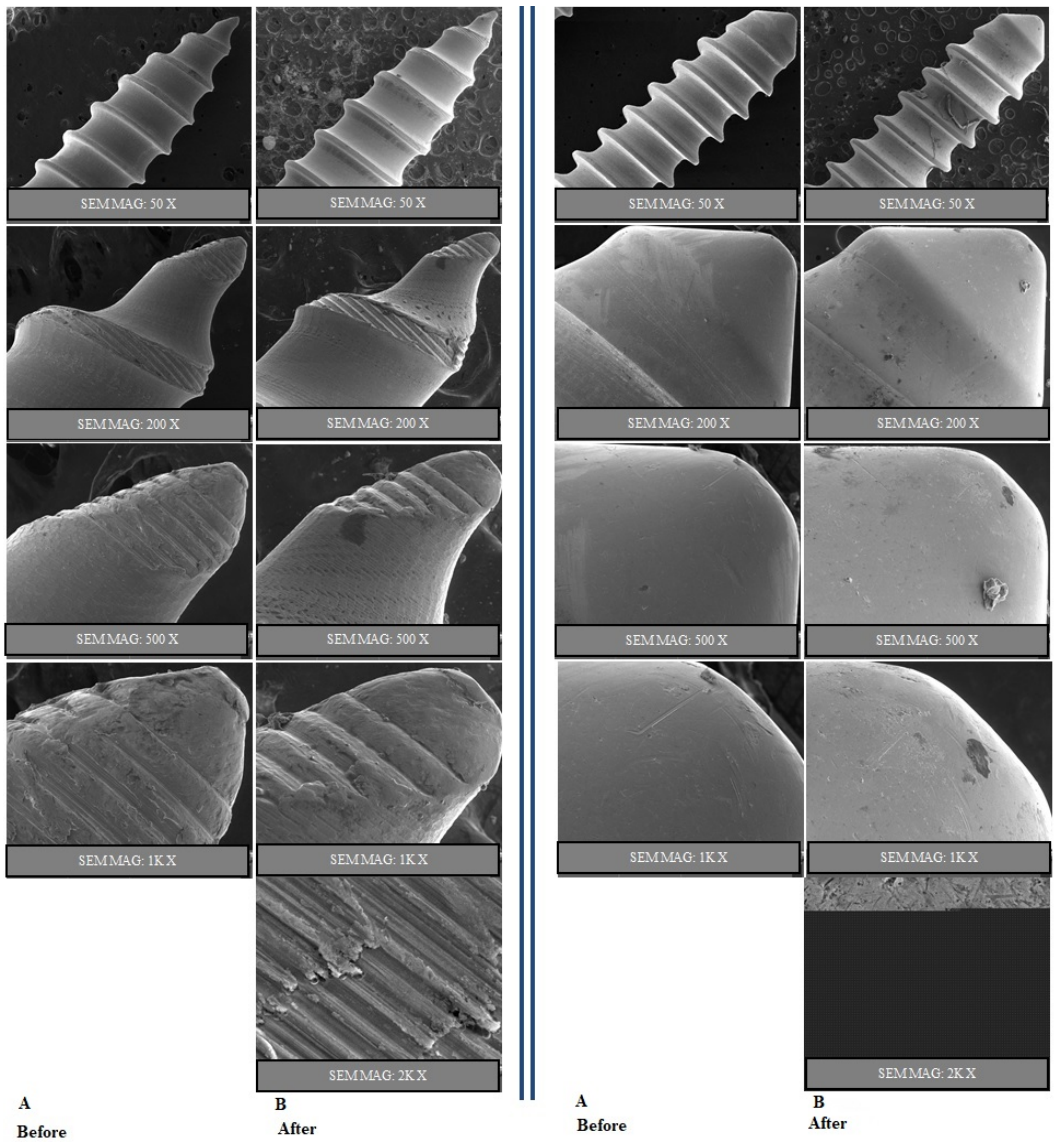

Figure 4 Group 1 (A,B) before and after the immersion in artificial saliva, A) SEM images of Ti (MIs), B) SEM images of SS (MIs)

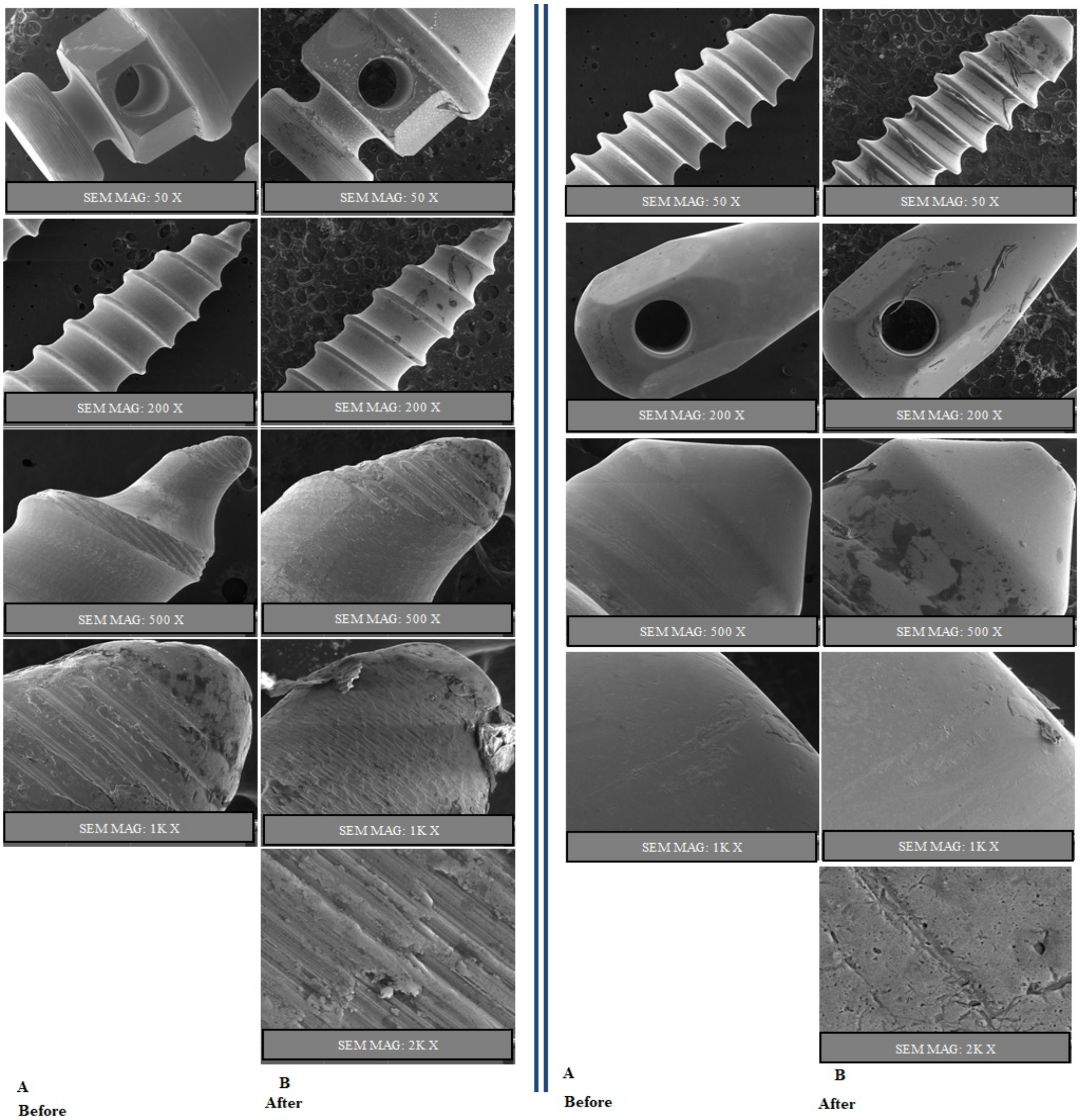

Figure 5 Group 2 (A,B) before and after the immersion in (Kin-B5) MW, A) SEM images of Ti (MIs), B) SEM images of SS (MIs)

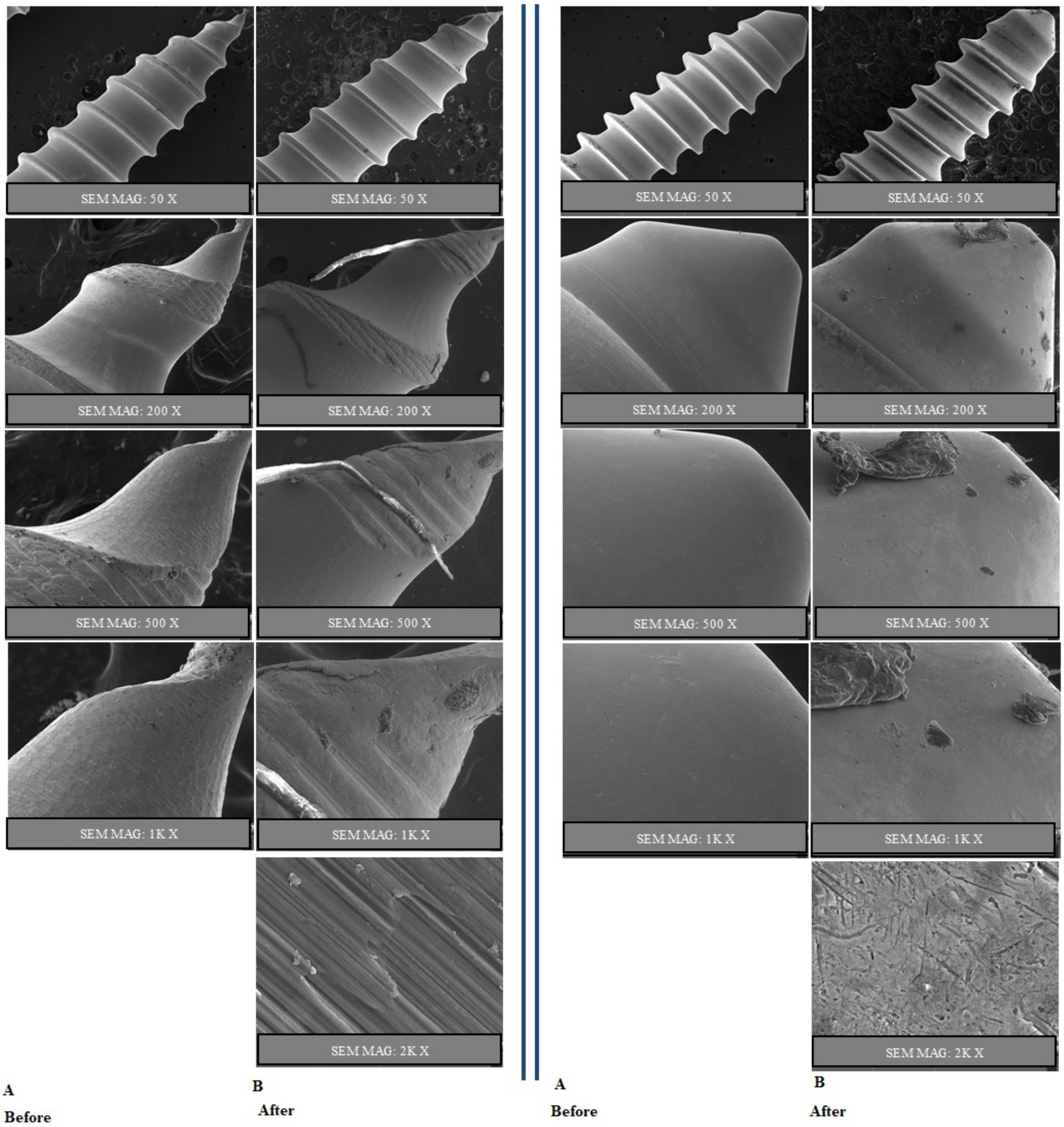

Figure 6 Group 3 (A,B) before and after immersion in (Lacalut-White) MW, A) SEM images of Ti (MIs), B) SEM images of SS (MIs)

DISCUSSION

In the present study, the topographic surface characteristics of received orthodontic MIs and after immersion in artificial saliva and fluoridated MWs of different pH values were assessed by means of SEM. The results of the microscopic examination confirmed the results of ions released which is determined by the atomic absorption spectrophotometer.

The microscopical examination showed the presence of some microscopic surface roughness, irregularities and machining defects in the form of scratches and indentations in all MIs groups as received from the manufacturer, such defects could be mostly noted in the form of blunt edges at certain regions in the head and threads of MIs [22].

The most common types of corrosion in the various parts of orthodontic appliances and devices were pitting and crevices [23,24].

The SEM images achieved after the immersion procedure in this study demonstrated a loss of gloss and surface smoothness with a resulting dull appearance in all tested MIs groups. The corrosion was represented by signs of crevices or pitting. This was seen principally at the sites of machining defects. The surface pits were also observed at the screw tips of MIs from Group 5. All the groups had some impurities scattered over the surface of MIs. All of these findings were also revealed by other *in vitro* corrosion studies [22].

The crevice corrosion that was mainly obvious in the regions of manufacturing defects and body-thread junctions of MIs was tested in the existing study, the sites of crevice represent a port of solution stagnation, where the oxygen exhaustion occurred under the deposit site. After the exhaustion of oxygen, further oxygen reduction does not occur, despite the continuous dissolution of the metal, this could create an additional amount of positive charges within the solution which is balanced by chloride ions immigration to the area of the crevice. This leads to an increased amount of metal-chloride in the crevice site. This leads to an increased amount of metal-chloride in the crevice site [26].

The findings of the current study showed that the corrosion attack was locally confined to the shielded sites whereas the residual surface area undergoes little or no corrosion, because the level of oxygen reduction on the neighboring surface increases with the increase in the corrosion in the crevice regions, which can cathodically shield the outer surface area [27,28].

The analysis of SEM images after contact with the artificial saliva for one month, revealed similar results to the *in-vivo* study achieved by Sebbar, et al., who compared the surface microstructure of new, as-received MIs with retrieved MIs using the optical microscopy [29].

The widespread areas of pits and crevices could be observed in the regions of MIs that were immersed in mouthwashes of more acidic pH (Kin-B5 and Lacalut-White mouthwashes). However, in the artificial saliva of (pH=6.75), there were less obvious pits and crevices. This occurred because the acidic state creates a reducing media resulting in the diminished stability of the protective oxide film of SS alloy, which is needed for the corrosion resistance [30]. In addition, the greater surface defects were observed in MIs immersed in Kin-B5 mouthwash as compared with MIs immersed in Lacalut-white mouthwash. In the present study, it could be due to the higher fluoride concentration contained in Kin-B5 than that existed in Lacalut-white fluoridated mouthwashes, because the fluoride is an aggressive destructing ion that can damage the surface of titanium and stainless steel dental alloys, and the amount of surface defects is likely to be directly proportional to the level of fluoride presented in the storage medium [21].

CONCLUSION

The factors of exposure time, alloy type, and type of the storage medium have influenced the corrosion behavior of orthodontic MIs.

The findings of the microscopical examination revealed that the signs of corrosion in the form of crevice and pitting were detected in all groups of MIs, which was highest in those immersed in Kin-B5 MW followed by Lacalut-white MW and finally the artificial saliva group. In addition, the presence of machining defects and imperfections in as-received (before immersion) MIs that appeared in SEM examination. Corrosion sites were mainly represented by the tip, threads and body-thread junctions of MIs.

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