Corrosion Behavior Of Ni-Cr Dental Alloys In Artificial Saliva With Different Concentrations Of Khat Extracts  

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Abstract: Corrosion behavior of Ni-Cr dental alloy used for crown and bridge treatment was evaluated in artificial saliva in the absence and presence of different concentrations of khat extracts using potentiodynamic polarization, electrochemical impedance spectroscopy and surface analysis. Khat is an evergreen plant that grows at high altitudes in East Africa and Arabian Peninsula. Khat leaves contain alkaloids, tannins, flavonoids, amino acids, vitamins Fluoride, and minerals. Our results have shown that, Kera N® and 4 all® alloys contained a high Cr and Mo content, shows the best corrosion resistance in Fusayama-Meyer artificial saliva compare with that of Commend® alloy which contained a low Cr and Mo content. The presence of khat extract (Catha edulis) in artificial saliva lead to accelerate the corrosion of Ni-Cr alloys may be due to presence of fluoride, amino acids, tannic acid and ascorbic acid in khat. The corrosion resistance of three Ni-Cr alloys decreases by increasing the concentration of khat extract. Our advise would be to recommend to avoid khat chewing to patients treated with Ni-Cr alloy when the crown and bridge treatment because during the corrosion processes the metals ions can be released from Ni-Cr alloy as the results of corrosion and may be the reason for allergic and some other diseases.

Key words: Ni-Cr dental alloys; Corrosion behavior; Khat extract; Artificial saliva.

INTRODUCTION

Nickel-chromium casting alloys used in dental crown, bridge applications and were introduced into dentistry as a possible replacement for precious alloys due to the increasing cost of gold throughout the 1980s (Hsin-Yi, L., et al., 2008). Corrosion is one parameter to determine the biocompatibility of dental alloys.

Doubts remain as to the biocompatibility of Ni-based alloys and when used in restorative procedures, the crowns are placed in close proximity to the gingival and often extend subgingivally, where metal release through corrosion processes may cause adverse reactions (Schmalz, G. and Garhammer, P, 2002; Mjor, I.A. and Christensen, G.J, 1993). Whilst nickel sensitivity is thought to be a clinical manifestation towards dental cast alloys (Schmalz, G. and Garhammer, P, 2002), the use of nickel is of particular concern since it is the most allergenic of all metallic elements (Hildebrand, H.F., et al., 1989).

Khat (Catha edulis) is an evergreen plant that grows at high altitudes in East Africa and Arabian Peninsula. Chewing its fresh leaves is a widespread habit in the local populations, with several million people consuming khat regularly in social sessions that often last for hours (Kassie, F., et al., 2001).

The main ingredients of khat leaves include alkaloids, tannins and flavonoids. It also contains amino acids, tannic acid, vitamins (Ascorbic acid, Niacin, Riboflavin, B-carotin, Thamine) and minerals (Hattab, F. N. and Angmar-Manssor, B, 2000; Sporkert, F., et al., 2003).

When chewing, khat leaves are contacted with Ni-Cr alloy during crown, bridge treatment and the Ni-Cr alloy used. To our knowledge, no studies have yet been carried out to assess the influence of Khat (Catha edulis) on corrosion behavior of Ni-Cr dental alloys. The purpose of this study was to evaluate the effects of Khat extract on corrosion behavior of Ni-Cr dental alloy used for crown and bridge treatment in relation to a reference solution, namely Fusayama Meyer artificial saliva, using potentiodynamic polarization, electrochemical impedance spectroscopy and surface analysis.
MATERIALS AND METHODS

Materials And Sample Preparation:
The origin and composition of Ni-Cr dental alloys studied are shown in table 1. Kera N®, 4 all® and Commend® alloys were used as test materials in this study. The three materials were selected from metal used for crown and bridge treatment. Three specimens of each type of material were used for this study (so nine specimens). The samples were already prepared in a cylindrically form (7 mm in diameter and 15 mm length), the samples were embedded with epoxy resin. The exposed surface of the metal constituted the working electrode (the area concerned was 0.38 cm² for each specimen). The working electrode were mechanically polished with emery papers of different grades (230-320-600-1200), washed in distilled water and then dried with ethanol before corrosion test.

Collection And Drying Of Khat Leaves:
Al-Awdi Catha edulis (khat) from Karbit Al-subari Village, Al-nadrh City, Yemen was used in this study. Fresh khat leaves were collected in summer, weighed, washed with distilled water three times and left to dry for three days in a clean dry room (20±5°C) protected from sunlight. After drying, the plant was weighed, packed in a closed foil packet and stored at 20°C until use.

Extraction Of Dried Khat Leaves:
Khat was extracted from leaves as described by previous studies (Aziz, HA., et al., 2009; Craig, M., et al., 2011). Briefly, dried khat leaves (100 g) were chopped into small pieces, homogenized in 100 ml of 95% ethanol, centrifuged at 5000 rpm for 5 min and the supernatant then filtered with Whatman filter paper (no.1). Ethanol (100 ml) was added to the remaining leaves and the procedure repeated. The ethanol khat extract was concentrated using a rotary evaporator (BUCHI 461 Water Bath, Switzerland) at 30°C with a rotation speed of 70 rpm until 70% of the ethanol solvent had evaporated. The resulting viscous solution was diluted with 100 ml of distilled water and then stirred at 1000 rpm with for 1 h at ambient temperature. The filtrate was kept frozen at −70°C for 24 h and then dried by lyophilization (CHRIST, Alpha, 2-4 LD Plus). Typically, 100 g of dried leaves yielded 8 g of khat extract powder. An amount of 50 mg/kg body weight of khat extract powder equivalent to an average amount of khat extract consumed by human (Aziz, HA., et al., 2009). We have been selected the concentrations of khat used in this study according to amount of khat extract consumed by human.

Test solution:
The reference solution was Fusayama-Meyer artificial saliva (Schiff, N., et al., 2004; Rassam, A., et al., 2012). The composition of this solution, which closely resembles natural saliva is: KCl (0.4 g/l), NaCl (0.4 g/l), CaCl₂·2H₂O (0.906 g/l), NaH₂PO₄·2H₂O (0.690 g/l), Na₂S·9H₂O (0.005 g/l), Urea (1 g/l). The pH was measured with a glass electrode (pH meter HANNA Instrument, France). The pH of this reference saliva measured was 5.3. The second medium used had the same contents as the reference solution but enriched with khat extract with a concentration 1 g/l. The pH measured was 4.6. The third medium was identical to the reference solution but enriched with khat extract with a concentration 2 g/l. The pH measured was 4.5. The last medium used had the same contents as the reference solution but enriched with khat extract with a concentration 3 g/l. The pH measured was 4.5. The experiments were made at 25°C.

Electrochemical Measurements:
The electrochemical measurements were carried out using Voltalab (Radiometer PGZ 301) potentiostate and controlled by corrosion analysis software model (Voltamaster 4). The corrosion cell used had three electrodes. The reference electrode was a saturated calomel electrode (SCE). A platinum electrode was used as auxiliary electrode and Ni-Cr samples was used as working electrode. The measurements were performed after the establishment of a reasonable steady state condition, which was safely achieved after 30 min of immersion (Rassam A., et al., 2013; Ameer, M., et al., 2004). The polarization curves were obtained in the potential range from -1000 mV/SCE to +1000 mV/SCE at scanning rate of 0.2 mV/s. The Voltalab (Radiometer PGZ 301) equipment with its Voltamaster 4 program was used for adjusted the Tafel curves for calculation of values of the corrosion current densities (i corr) and polarization resistance (R p). Electrochemical impedance spectroscopy (EIS) was also used to evaluate the corrosion behavior of Ni-Cr dental alloys. The impedance spectra for Ni-Cr alloys were obtained at the open circuit potential, with a scan frequency range of 100 kHz to 0.01 Hz with amplitude of 10 mV (Mareci, D., et al., 2010; Ningshen, S., and Kamachi Mudali, U., 2009; Mareci, D., et al., 2009). The corrosion parameters are: corrosion potential (E cor), corrosion current density (i cor), polarization resistance (R p), charge transfer resistance (R ct), resistance of solution (R s) and double layer capacitance (C dl) (Ameer, M., et al., 2004). All experiments were performed in three replicates.
Surface Analysis:
Two specimens of each material were observed using scanning electron microscopy (SEM) (Philips, Quanta 200 X. TM-© Fei Company.). The specimens were subjected to immersion for 7 days in two different media: Fusayama-Meyer artificial saliva and artificial saliva containing khat extract at 25°C.

Statistical Analysis:
Results of the electrochemical measurements were tested for statistical significance by one-way ANOVA. A statistically significant difference was considered when \( P < 0.05 \).

Results:

Polarization Curves:
Figures 1, 2 and 3 shows the polarization curves of Kera N®, 4 all® and Commend® alloys in artificial saliva in the absence and presence of different concentrations of khat extracts. From the results reported in table 2, the polarization resistance values of Kera N® decrease from 11.67±0.4 kΩcm² at Fusayama-Meyer artificial saliva to 5.55±0.1 kΩcm² at artificial saliva containing khat extract with a concentration 3 g/l. On the other hand, corrosion current values of Kera N® increase from 5.25±0.2 μA cm⁻² at Fusayama-Meyer artificial saliva to 8.43±0.4 μA cm⁻² at artificial saliva containing khat extract with a concentration 3 g/l. The results from the polarization curves (figure 2 and table 3), the corrosion potential of 4 all® at Fusayama-Meyer artificial saliva was -460.4±18 mV/SCE while at artificial saliva containing khat extract with a concentration 3 g/l the corrosion potential of 4 all® was -340.45±3 mV/SCE. The polarization resistance values of 4 all® decrease from 11.74±0.5 kΩcm² at Fusayama-Meyer artificial saliva to 6.15±0.12 kΩcm² at artificial saliva containing khat extract with a concentration 3 g/l. The corrosion current values of Commend® increase from 6.66±0.3 μA cm⁻² at Fusayama-Meyer artificial saliva to 8.9±0.4 μA cm⁻² at artificial saliva containing khat extract with a concentration 3 g/l. Thus, the results from the polarization curves and values reported in table 2, 3 and 4 indicated that the Kera N®, 4 all® and Commend® alloys exhibited the least corrosion resistance in artificial saliva containing different concentrations of khat extracts compared with that of reference solution, the corrosion resistance of Kera N®, 4 all® and Commend® alloys were decreases by increasing of khat extract. Similar polarization curves were obtained for Kera N® and 4 all® in Fusayama-Meyer artificial saliva and the polarization resistance values obtained for Kera N® and 4 all® in Fusayama-Meyer artificial saliva were also of the same order (11.67±0.4 kΩcm² and 11.74±0.5 kΩcm² respectively). The results obtained for Commend® alloy (Figure 3 and table 4) were different from those obtained with Kera N® and 4 all® in Fusayama-Meyer artificial saliva. As summarized in table 4 the polarization resistance obtained for Commend® alloy in Fusayama-Meyer artificial saliva was low (7.96±0.35 kΩcm²) compared with that of Kera N® and 4 all® alloys.

Fig. 1: The polarization curves of Kera N® in artificial saliva in the absence and presence of different concentrations of khat extracts.
Fig. 2: The polarization curves of 4 all® in artificial saliva in the absence and presence of different concentrations of khat extracts.

Fig. 3: The polarization curves of Commend® in artificial saliva in the absence and presence of different concentrations of khat extracts.

Table 1: The origin and composition of materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Composition (wt%)</th>
<th>Supplier</th>
</tr>
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<tbody>
<tr>
<td>Kera N®</td>
<td>Ni: 63 %, Cr: 25.75 %, Mo: 11%, Al: &lt; 1.0%, Si: 1.5%, Mn, C: &lt; 1.0%</td>
<td>Eisenbacher Dentalwaren Ed GmbH, Germany</td>
</tr>
<tr>
<td>4 all</td>
<td>Ni: 61.4 %, Cr: 25.7 %, Mo: 11%, Si:1.5%, Al: 2%, C: 0.5 %</td>
<td>Ivoclar, Vivadent, Germany</td>
</tr>
<tr>
<td></td>
<td>Ni: 77 %, Cr: 14 %, Mo: 4.7%, Be: 1.8%</td>
<td>The argen corporation</td>
</tr>
</tbody>
</table>
Table 2: Corrosion parameters of Kera N® obtained from potentiodynamic polarization and impedance measurements in artificial saliva in the absence and presence of different concentrations of khat extracts.

<table>
<thead>
<tr>
<th>Solution</th>
<th>Ecorr (mV/SCE)</th>
<th>Icorr (μA cm⁻²)</th>
<th>Rp (kΩ cm²)</th>
<th>Rct (kΩ cm²)</th>
<th>Rint (kΩ cm²)</th>
<th>Cdl (μF cm⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artificial saliva</td>
<td>-422±10</td>
<td>5.25±0.2</td>
<td>11.67±0.4</td>
<td>79.5±1.9</td>
<td>91.4±0.7</td>
<td>15.6±0.6</td>
</tr>
<tr>
<td>A.S. with 1 g/l of khat extract</td>
<td>-458±12</td>
<td>6.52±0.3</td>
<td>7.91±0.3</td>
<td>71.5±2.9</td>
<td>43.2±2.0</td>
<td>24.71±1.01</td>
</tr>
<tr>
<td>A.S. with 2 g/l of khat extract</td>
<td>-307±14</td>
<td>8.01±0.2</td>
<td>6.80±0.2</td>
<td>67.5±0.6</td>
<td>30.8±1.3</td>
<td>35.13±1.07</td>
</tr>
</tbody>
</table>

Table 3: Corrosion parameters of 4 all® obtained from potentiodynamic polarization and impedance measurements in artificial saliva in the absence and presence of different concentrations of khat extracts.

<table>
<thead>
<tr>
<th>Solution</th>
<th>Ecorr (mV/SCE)</th>
<th>Icorr (μA cm⁻²)</th>
<th>Rp (kΩ cm²)</th>
<th>Rct (kΩ cm²)</th>
<th>Rint (kΩ cm²)</th>
<th>Cdl (μF cm⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artificial saliva</td>
<td>-460±18</td>
<td>5.48±0.17</td>
<td>12.14±0.5</td>
<td>80.9±0.3</td>
<td>93.96±0.35</td>
<td>16.45±0.4</td>
</tr>
<tr>
<td>A.S. with 1 g/l of khat extract</td>
<td>-448±10</td>
<td>6.45±0.3</td>
<td>9.40±0.2</td>
<td>74.55±1.6</td>
<td>49.95±1.5</td>
<td>28.45±1.2</td>
</tr>
<tr>
<td>A.S. with 2 g/l of khat extract</td>
<td>-389±11</td>
<td>7.07±0.25</td>
<td>7.9±0.3</td>
<td>67.95±0.8</td>
<td>31.95±1.2</td>
<td>34.45±1.01</td>
</tr>
<tr>
<td>A.S. with 3 g/l of khat extract</td>
<td>-340.45±3</td>
<td>8.55±0.4</td>
<td>6.15±0.12</td>
<td>64.95±1.7</td>
<td>20.97±0.7</td>
<td>55.45±0.9</td>
</tr>
</tbody>
</table>

Table 4: Corrosion parameters of Commend® obtained from potentiodynamic polarization and impedance measurements in artificial saliva in the absence and presence of different concentrations of khat extracts.

<table>
<thead>
<tr>
<th>Solution</th>
<th>Ecorr (mV/SCE)</th>
<th>Icorr (μA cm⁻²)</th>
<th>Rp (kΩ cm²)</th>
<th>Rct (kΩ cm²)</th>
<th>Rint (kΩ cm²)</th>
<th>Cdl (μF cm⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artificial saliva</td>
<td>-408±9.85</td>
<td>6.66±0.3</td>
<td>7.96±0.2</td>
<td>82.49±2.2</td>
<td>16.39±0.6</td>
<td></td>
</tr>
<tr>
<td>A.S. with 1 g/l of khat extract</td>
<td>-448±5.71</td>
<td>7.34±0.25</td>
<td>7.3±0.25</td>
<td>70.95±1.5</td>
<td>40.65±1.5</td>
<td>26.46±0.7</td>
</tr>
<tr>
<td>A.S. with 2 g/l of khat extract</td>
<td>-420±14</td>
<td>7.85±0.3</td>
<td>6.4±0.3</td>
<td>66.9±2.9</td>
<td>27.37±0.8</td>
<td>39±1.1</td>
</tr>
<tr>
<td>A.S. with 3 g/l of khat extract</td>
<td>-330±10</td>
<td>8.9±0.4</td>
<td>4.28±0.15</td>
<td>57.20±0.8</td>
<td>17.93±0.5</td>
<td>58.3±0.7</td>
</tr>
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</table>

**Electrochemical Impedance Spectroscopy:**

The Nyquist diagrams of Kera N®, 4 all® and Commend® alloys in artificial saliva in the absence and presence of different concentrations of khat extracts show in figures 4, 5 and 6 respectively. The plots of the three alloys exhibited an incomplete semicircle, indicating a capacitive behavior, a passive film, showing some distortions due to the irregularity of the protected oxide layer and their diameters decreases with increasing the concentration of khat extract in artificial saliva. The Nyquist diagrams of our study agree with previous studies (Prioteasa, P., et al., 2007; Kocijan, A., et al., 2011; Vasilescu, C., et al., 2012). The impedance parameters such as the double layer capacitance (Cdl), the charge-transfer resistance (Rct) and the solution resistance (Rs) of Kera N®, 4 all® and Commend® alloys derived from Nyquist diagrams are given in tables 2, 3 and 4 respectively. The EIS results were interpreted using a simple equivalent circuit circuit shown in Fig. 7. The simple circuit description consisting of solution resistance in series with a double layer capacitance and charge transfer resistance in parallel. The selection of this circuit was a compromise between a reasonable fitting of the experimental values and a minimum of components in the simple equivalent circuit.

From the results of Nyquist diagrams, the charge transfer resistance values of Kera N® decrease from 91.4±0.7 kΩ cm⁻² at Fusayama-Meyer artificial saliva to 19.2±0.8 kΩ cm⁻² at artificial saliva containing khat extract with a concentration 3 g/l, while the double layer capacitance values of Kera N® increase from 15.6±0.6 μF cm⁻² at Fusayama-Meyer artificial saliva to 55.9±0.53 μF cm⁻² at artificial saliva containing khat extract with a concentration 3 g/l. From the results reported in table 2 and 3 indicated that, the double layer capacitance (Cdl), the charge-transfer resistance (Rct) and the solution resistance (Rs) of 4 all® in artificial saliva and artificial saliva containing different concentrations of khat extracts were similar to Kera N®. It was noticed that, in Fusayama-Meyer artificial saliva the Commend® alloy which contain a low Cr content has low charge transfer resistance compared with that of Kera N® and 4 all® alloys, these results agree with previous studies (Ameer, M., et al., 2004; Prioteasa, P., et al., 2007). The charge transfer resistance values of Commend® were decreases by increasing of khat extract. The double layer capacitance values of Commend® increase from 16.4±0.6 μF cm⁻² at Fusayama-Meyer artificial saliva to 58.3±0.7 μF cm⁻² at artificial saliva containing khat extract with a concentration 3 g/l. The results from the Nyquist diagrams and values reported in table 2, 3 and 4 indicated that, the Kera N®, 4 all® and Commend® alloys showed low charge transfer resistance in artificial saliva containing different concentrations of khat extract compared with that of reference solution and the charge transfer resistance (Rct) decreases by increasing the concentration of khat extract. On the other hand, the double layer capacitance (Cdl) of the Kera N®, 4 all® and Commend® alloys have the high values in artificial saliva containing different concentrations of khat extract compared with that of reference solution. The results of Nyquist diagrams of Kera N®, 4 all® and Commend® alloys confirmed the results of the polarization curves.

**Surface Analysis:**

The Kera N®, 4 all® and Commend® alloys were observed after immersion in artificial saliva and artificial saliva containing khat extract for 7 day in order to study the corrosion attack on its surface by using The scanning electron microscopy. Figure 8 (a and b) show the SEM for the Kera N® after immersion in Fusayama-
Meyer artificial saliva and artificial saliva containing khat extract. It is seen from the figure 8b that Kera N® has pitting corrosion distributed at different areas on the surface of Kera N® alloy after immersion in artificial saliva containing khat extract, while after immersion in artificial saliva there is no corrosion but there is a general change in color on the surface of the alloys which may be due to immersion for long time. Figure 9 (a and b) show the SEM for the 4 all® after immersion in Fusayama-Meyer artificial saliva and artificial saliva containing khat extract. The micrographs show localized corrosion on the surface of 4 all® alloy after immersion in artificial saliva containing khat extract, while after immersion in artificial saliva there is no corrosion on the surface of 4 all® alloy. The micrograph of Commend® alloy after immersion in artificial saliva containing khat extract show a generalized corrosion on the surface (Figure 10b ), while after immersion in artificial saliva the micrograph reveal the presence of some defects which could be related to pitting corrosion (Figure 10a).

Fig. 4: Nyquist complex impedance plot for Kera N® in artificial saliva in the absence and presence of different concentrations of khat extracts.

Fig. 5: Nyquist complex impedance plot for 4 all® in artificial saliva in the absence and presence of different concentrations of khat extracts.
Fig. 6: Nyquist complex impedance plot for Commend™ in artificial saliva in the absence and presence of different concentrations of khat extracts.

![Nyquist plot diagram]

Fig. 7: Simple equivalent circuit for fitting of EIS data, where $R_s$ is the solution resistance, $R_{ct}$ the charge transfer resistance, and $C_{dl}$ the double layer capacitance.

![Equivalent circuit diagram]

Fig. 8: The scanning electron microscopy of Kera N® in artificial saliva (a) artificial saliva containing khat extract (b).

![SEM images]
Discussion:
Corrosion properties of nickel-chromium alloys depend on their bulk composition, microstructure, development of protective surface oxide and composition of surrounding electrolyte selected for the study (Kedici, SP., et al., 1998; Bumgardner, J.D. and Lucas, L.C, 1995). From the results obtained from potentiodynamic polarization and impedance measurements, in Fusayama-Meyer artificial saliva the Commend® alloy has low polarization resistance, low charge transfer resistance and high corrosion current density compared with that of Kera N® and 4 all® alloys. Thus, in Fusayama-Meyer artificial saliva, the corrosion results indicate that Commend® alloy which Be containing shows the least corrosion resistance compared with that of Kera N® and 4 all® alloys which non-Be containing. Bumgardner, J.D. and Lucas, L.C, 1994, showed that, Be containing alloys exhibit higher corrosion rates, smaller passivation ranges, and increased susceptibility to pitting/crevice corrosion as compared to non-Be containing alloys. In the present study the Kera N® and 4 all® alloys had a high Cr content (25.7 wt. %), and high percentage of molybdenum (11 wt. %) shows the best corrosion resistance compared with that of Commend® alloy which contain a low Cr and molybdenum content (Cr: 14 wt. %, Mo: 4.7%). Thus, chromium as chromium oxide (Cr2O3) and molybdenum as molybdenum oxide (MoO3) provide the initial stability to prevent dissolution of metal ions and thus provide resistance to corrosion (Rao, S.B. and
Chowdary, R., 2011). Also molybdenum is believed to have a role in the de-protonation of the hydroxide by acting as an electron acceptor, helping in the formation of a stable CrO$_3$/Cr$_2$O$_3$, protecting oxide (Olsson, C.A, 1995 ). Thus, in Fusayama-Meyer artificial saliva the corrosion resistance of the three Ni-Cr dental alloys are in the following order: Kera N$^8$ > 4 all$ @$ > Commend$^8$.

In the present study, from the corrosion parameters obtained from potentiodynamic polarization and impedance measurements, in artificial saliva containing khat extracts the Kera N$^8$, 4 all$ @$ and Commend$^8$ alloys have low polarization resistance, low charge transfer resistance and high corrosion current density compared with that of reference solution. The values of double layer capacitance ($C_{dl}$) of the Kera N$^8$, 4 all$ @$ and Commend$^8$ alloys increases by increasing concentration of khat extract due to the dissolution of alloy, which produces positive ions leaving the negative charges on the surface leading to increase the positive charges and increase the double layer capacitance.

Thus, the composition of Khat (Catha edulis) effects on the corrosion resistance of Ni-Cr alloy, the corrosion resistance of three Ni-Cr alloys decreased in artificial saliva containing khat extract compared with that of reference solution and the corrosion resistance of three Ni-Cr alloy decreases by increasing the concentration of khat extract. Khat has a complex group of alkaloids. It also contains amino acids, tannins, tannic acid, vitamins (Ascorbic acid, Niacin, Riboflavin, B-carotin, Thamine) and minerals (Calcium, Manganese, Iron, Zinc and Fluoride). All the ingredients found in khat contain chemicals that may become dissolved in saliva and affect the corrosion of metallic materials. From the polarisation curves of three Ni-Cr alloys are that the presence of khat extract in artificial saliva lead to accelerates the cathodic reaction, this may be result from the reduction of protons H$^+$ (acid medium pH =4.5) and certain constituents of khat such as amino acids, tannic acid and alkaloids on the electrode surface. Atlabachew et al., 2010, determined the concentration levels of metals in six different varieties of Ethiopian khat (Catha edulis). The results showed that the concentrations ranges were recorded in the following order: Ca (1,038-2,173 µg/g) > Mg (478.2-812.3 µg/g) > Fe (53.95-82.83 µg/g) > Zn (5.18-9.40 µg/g) > Mn (6.98-8.66 µg/g) > Cu(1.85-5.53 µg/g) > Cr (0.66-3.47 µg/g) > Co (0.41-0.80 µg/g). While the toxic metals (Pb and Cd) were not detected in all the samples analyzed.

Atlabachew et al., 2011, determined the Fluoride content of Ethiopian khat (Catha edulis) chewing leaves, they found that, the fluoride concentration in matured leaves (12 µg g$^{-1}$) was higher than that in young leaves (6.5 µg g$^{-1}$) dry weight. On the other hand, Ameer et al. 2004, showed that in artificial saliva containing different concentration of fluoride, the corrosion rate of Co-Cr and Ni-Cr dental alloys increases by increasing concentration of fluoride. The acidity of the solution effect on corrosion resistance of the Ni-Cr dental alloy. Bennani, A., et al. 2008, showed that, the corrosion current of Ni-Cr alloy was increased with reduced pH of artificial saliva from 7.70 to 2.26. Therefore, the corrosion resistance of Ni-Cr alloys decreased in artificial saliva containing khat extract may be due to presence of fluoride, amino acids, tannic acid and ascorbic acid in khat.

When chewing, khat leaves are placed in the oral mucobuccal fold and masticated for several hours, the khat prolonged close contact with Ni-Cr alloy when the crown and bridge treatment, the khat released amounts of fluoride and another chemicals compounds in saliva, these chemical compounds lead to accelerated corrosion of Ni-Cr alloy. During the corrosion processes the metals ions can be released from Ni-Cr alloy as the results of corrosion and may be the reason for allergic and some other diseases.

**Conclusion:**

To the best of our knowledge this is the first study to report the effects of khat extract on corrosion resistance of Ni-Cr dental alloys. Our results have shown that Kera N$^8$ and 4 all$ @$ alloys contained a high Cr and Mo content, shows the best corrosion resistance in artificial saliva compare with that of Commend$^8$ alloy. The presence of khat extract (Catha edulis) in artificial saliva lead to accelerate the corrosion of Ni-Cr alloys may be due to presence of fluoride, amino acids, tannic acid and ascorbic acid in khat. The corrosion resistance of three Ni-Cr alloys decreases by increasing the concentration of khat extract in artificial saliva. On the basis of the results obtained, our advise would be to recommend to avoid khat chewing to patients treated with Ni-Cr alloy when the crown, bridge treatment because during the corrosion processes the metals ions can be released from Ni-Cr alloy as the results of corrosion and may be the reason for allergic and some other diseases.

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