The effective parameters on the corrosion behavior of dental amalgam

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ABSTRACT

Purpose: The aim of this research was to evaluate the effect of surface treatment, clinical performance and the condition and position of the dental restoration on the corrosion behavior of dental amalgam.

Materials & Methods: Commercial amalgam namely Oralloy was selected to prepare 21 flat amalgam samples. After triturating and condensation, the samples were divided into three groups and each group was finished by using one of the three clinical procedures; carving, carving-burnishing, carving-burnishing-polishing. A special cylindrical mold was used in order to simulate the inter-proximal areas and proximal surfaces of the dental restorations. Stainless steel matrix band was placed on the internal mold surfaces and amalgam paste was compacted in the mold and 14 cylindrical samples were prepared. Electrochemical tests were performed at a temperature of 37±1°C in normal saline in order to determine the corrosion behavior of dental amalgam samples. Tafel extrapolation and linear polarization methods determined corrosion potential and corrosion current densities. The mean value and standard deviations of the results were calculated. The mean values were statistically compared by ANOVA and Duncan methods at 95% level of confidence.

Results: The results showed statistically significant differences between the mean corrosion current density values of three different groups of dental amalgam (P<0.05). The carved group showed more corrosion resistance in comparison with the sample near the matrix band (P<0.05) as an index of the proximal surfaces of the dental restorations.

Conclusion: Even a simple clinical performance could effect on the corrosion resistance of dental amalgam. The proximal surfaces of the class II restorations are not only susceptible to concentration cell corrosion but also possess less corrosion resistance.

Keywords: Dental amalgam, Amalgam corrosion, Surface treatment, Amalgam restoration, Carving, Burnishing, Polishing.

INTRODUCTION

Dental amalgam has been widely used as a direct filling material due to its favorable mechanical properties as well as low cost and ease of use and placement. (1-4) An amalgam is an alloy of mercury with one or more other metals. (2,5) Dental amalgam is produced by mixing liquid mercury with solid particles of an alloy of silver, tin, copper, and sometimes zinc, palladium, indium, and selenium. (2,4-7) That combination of solid metals is known as the amalgam alloy. (5,6) The freshly mixed mass of the amalgam alloy and liquid mercury developed by dentist has a plasticity that permits it to be conveniently packed or condensed into a prepared tooth cavity (4,5,8) and consequently, carved to the desired shape. (4)

Although in use for many years, dental amalgam has been questioned more or less vigorously as a dental restoration material due to its alleged health hazard, corrosion products, biological toxicity and
environmental hazards. (3,9) Concerns have been expressed regarding toxicity of dental amalgam, in particular with respect to marginal fracture, surface degradation, corrosion, and release of corrosion products and biocompatibility. (10) The studies and researches about the corrosion and tarnish of dental amalgam have been continued during recent decades. (5,6,11)

It has been reported that the presence of amalgam fillings does not appear to effect the general health of patients and it can be stated that epidemiologic studies of amalgam bearers have not detected increased incidence; cancer, cardiovascular disease, diabetes, early death and subjectively reported ailments. (12) On the other hand, some researchers have even suggested that the use of amalgams should be discontinued (13) but the others concluded that amalgam restorations remain safe and effective (14) and amalgam restorations will continue to be used until esthetic techniques match amalgam’s longevity, ease of placement, and versatility. (4)

Dental amalgam restorations often tarnish and corrode in the oral environment. The degree of tarnish and the resulting discoloration appear to be dependent on the individual’s oral environment and, to a certain extent, on the particular alloy employed. (6) Excessive corrosion can lead to increased porosity, reduced marginal integrity, loss of strength, and the release of metallic products into the oral environment. (5) Both tarnish and corrosion occurs more on amalgam with rough surface than on smooth one. Thus a well-polished amalgam will limit these problems because dental restorative materials with surface characteristics from the tooth might affect pellicle formation and the ability of bacteria to colonize the oral cavity. (15)

Clinical studies have shown that a well-finished and polished amalgam is easier to keep clean and undergoes less corrosion. (4) Finishing and polishing amalgam restoration have been regarded as necessary steps in restorative dentistry. Finishing involves the removal of material and polishing is surface treatment. These procedures enable adjustment of contour and occlusion, and it has been claimed that they provide a better marginal adaptation by removing amalgam excess to at the margins that could otherwise fracture and leave a ditch between the tooth and filling. Finishing and polishing may also lead to increased resistance to tarnish and corrosion and thus to better esthetics. (16) For the success of dental amalgam restorations, a smooth surface is required. The smoothness of the surface of dental amalgam is not only a function of polishing technique; it also depends on structural characteristics of the material. (17) The benefits of polishing include: removal of flash and refinement of the amalgam margins, improved restoration marginal adaptation, and smoothing of the amalgam surface, thereby reducing its susceptibility to plaque retention, corrosion, and tarnish. (18-22) The importance of finishing cannot be overemphasized. The restoration is not completed until its margins have been fully adjusted and its surfaces have been finely polished. (8)

The corrosion behavior is an indicator of biocompatibility of dental materials and especially dental amalgam. (10,23) The aim of this research was to evaluate the effect of surface treatment, clinical performance and the condition and position of the dental restoration on the corrosion behavior of dental amalgam.

**MATERIALS & METHODS**

Commercial amalgam alloy namely Oralloy with spheroid particle shapes was selected. The chemical composition (Wt%) was; Ag 59, Sn 28, and Cu 13.

A special cylindrical mold was used in order to simulation of the interproximal areas and proximal surfaces of the dental restorations. Stainless steel matrix band was inserted on the internal mold surfaces. Commercial amalgam alloy was triturated according to the manufacturer’s instructions [Coltene (USA)] in a mechanical triturator (Deomat 3, Degussa, Germany) and hand-condensed into the special cylindrical mold by condenser (Φ3 mm, Aesculap, Germany)
Fourteen cylindrical samples were prepared. All of the fourteen cylindrical samples were kept at 37±1°C by using a water bath (Eyela Thermistor Temppt T-80) for one week. Half of the samples were used for the invitro tests in normal saline (0.9 Wt% NaCl) and the other half were utilized for the invitro tests in the artificial saliva solution.

In order to obtain flat samples, commercial amalgam alloy was triturated according to the manufacturer’s instructions in a mechanical triturator (Deomat 3, Degussa, Germany) and hand-condensed into special mold by condenser (Φ3mm, Aesculap, Germany) by one investigator, too.

Twenty-one flat samples (10×20mm) of commercial amalgam were prepared at room temperature and after condensation were divided into three groups. Each group was finished and polished by using one of three procedures; carving, carving-burnished, carving-burnished-polishing. Mold cavity was overfilled and excess amalgam was removed (carved) with a new Ward’s carver (Aesculap, Germany), by repeated carving for ten times and in the same direction for all of the specimens. Burnishing was accomplished on the surface of fourteen carved samples of amalgam with a football burnisher (Aesculap, Germany), for twelve times in the same manner and direction.

The Carved-burnished flat specimens were stored at 37±1°C for 24 hours. After that, polishing process was performed on the surface of seven carved-burnished specimens of commercial amalgam with pear shape polishing bur (Ash, England), a brown rubber point (Shofu Dental Crop, Menlo Park, CA 94025), pumice on a brush at 8000rpm. Each stage of polishing procedures was applied for 30 seconds for all of the specimens. Burnishing was accomplished on the surface of fourteen carved samples of amalgam with a football burnisher (Aesculap, Germany), for twelve times in the same manner and direction.

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An electrochemical corrosion polarization test cell was used for invitro potentiodynamic corrosion tests in normal saline (0.9 wt% NaCl). Graphite was used as the counter electrode and saturated calomel electrode (SCE) as a reference electrode.

All of the amalgam samples were washed and immersed in normal saline at 37±1°C for 24 hours. The potentiodynamic corrosion tests were performed at 37±1°C. Dynamic polarization curves were recorded at a potential scanning rate of 0.5mVS⁻¹ initiated at −250 mV blow the open circuit potential and the atmosphere was open to air. Seven replicate tests of each group of specimens were performed.

Specimens were dynamically polarized in normal saline. Potentiodynamic polarization curves were determined at 37±1°C using an EG&G model 263A potentiostat/galvanostat interfaced with a computer and a recorder.

The anodic and cathodic polarization curves were obtained for each specimen. Tafel extrapolation and linear polarization methods determined corrosion potential and corrosion current densities. The mean value and standard deviations of the results were calculated. The mean values were statistically compared by ANOVA and Duncan methods at 95% level of confidence.

RESULTS

The potentiodynamic polarization curves of the carved, carved-burnished, and carved-burnished-polished groups of the Oralloy amalgam in the normal saline solution are shown in Figure 1. These curves were selected because their extracted data were the most nearest to the mean values of the corrosion current densities of each group of specimens.

The results showed statistically significant differences between the mean corrosion current densities values of three different groups of the amalgam (P<0.05).

The carved-burnished-polished group of the Oralloy amalgam possesses the lowest corrosion current density [E_{cor}=-374(27)mV, i_{cor}=778(39)nA/cm²] and the carved group shows the highest corrosion current density [E_{cor}=-325(16)mV, i_{cor}=4295(489) nA/cm²] or the lowest corrosion resistance.

The potentiodynamic polarization curves of the amalgam samples near the matrix band (as an indication of the proximal surfaces of
the dental restorations) in the normal saline solution are shown in Figure 2. The similar curves of the amalgam samples near the matrix band in artificial saliva are plotted in Figure 2, too.

The amalgam samples near the matrix band possessed more corrosion current density \[E_{\text{corr}}=-313(15)\text{mV}, \ i_{\text{corr}}=6132(137)\text{nA/cm}^2\] (Fig2) in comparison with carved group of the Oralloy amalgam \[E_{\text{corr}}=-325(16)\text{mV}, \ i_{\text{corr}}=4295(489)\text{nA/cm}^2\], which means that carved amalgam possessed more corrosion resistance in comparison with the proximal surfaces of the dental restorations and indicates that even a simple clinical operation such as carving could increase the amalgam corrosion resistance in oral cavity.

**DISCUSSION**

The carved-burnished-polished Oralloy dental amalgam possessed the highest corrosion resistance and thus lowest corrosion current density \[E_{\text{corr}}=-374(27)\text{mV}, \ i_{\text{corr}}=778(39)\text{nA/cm}^2\] in comparison with the other groups (carved and carved-burnished groups) in normal saline solution, according to Figure 1. Vice versa, the carved Oralloy dental amalgam possessed lowest corrosion resistance and thus highest corrosion current density \[E_{\text{corr}}=-325(16)\text{mV}, \ i_{\text{corr}}=4295(489)\text{nA/cm}^2\]. Previous work by the present authors showed that the finishing procedure could affect on final surface roughness of each types of dental amalgam.\(^{(24)}\) The carved group dental amalgam showed the most surface roughness and carved-burnished-polished group had the most surface smoothness.\(^{(24)}\) Those results are in agreement with the present results about corrosion behavior of commercial dental amalgam because more surface smoothness may increase corrosion resistance.

It has been reported that the carvability of an amalgam is a function of the size and shape of the alloy particles. In general, the spherical alloys produce a better initial surface finish than the lathe-cut alloy.\(^{(13)}\) The increasing of corrosion resistance due to surface treatment performance and polishing process is not a novel result. It has been emphasized yet that every effort should be made to produce a smooth, homogeneous surface on a dental amalgam restoration to minimize tarnish and corrosion, regardless of the alloy system used.\(^{(6,7,9)}\) However, it should be noticed that the surface-polishing performance is more important for the dental amalgam with less corrosion resistance in comparison with a dental amalgam with more corrosion resistance.

It is very important for dentists to know how much polishing is necessary and enough for every brand of dental amalgam. On the other hand, it has been mentioned that the surface roughness of high-copper amalgams may be more dependent on particle size, shape, and distribution and less dependent on the polishing technique.\(^{(21)}\) A well-polished
amalgam filling will retain less plaque than a rough amalgam surface and thereby reduce the cariogenic challenge. A rough surface represents, of course, an increased surface area with a correspondingly increased corrosion. Polishing of amalgam fillings should therefore lead to less corrosion both through decreased surface area and through reduced plaque retention. After introduction of high-copper amalgams to dentistry, the researcher showed that the polishing after 24 hours produced a smoother surface than any of the immediate finishing procedures tested.

Because the gamma-2 phase is the most anodic of those present in set amalgam alloys, the high-copper amalgams, which virtually eliminate this phase, show improved laboratory corrosion behavior compared with traditional amalgams. The elimination of gamma-2 phase in high-copper amalgams will be perform after 24 hours or at the most during one week after amalgam restoration and as the result, the most corrosion reaction occurs during one week after amalgam triturating and restoration. Therefore, the occasion of amalgam polishing is very important. The polishing dental amalgam restoration should be delayed for 24 hours to allow the amalgam to set and should not be too much time after restoration. The goal of finishing and polishing procedures will be obtained if they perform on time, adequate level and appropriate manner.

The amalgam sample near the matrix band possesses more corrosion current density \([E_{corr}=-313(15) \text{mV}, i_{corr}=6132(137) \text{nA/cm}^2, \text{(Figure 2)}]\) and thus less corrosion resistance in compare with carved group of the Oralloy commercially amalgam \([E_{corr}=-325(16) \text{mV}, i_{corr}=4295(489) \text{nA/cm}^2] \). It means that carved amalgam possesses more corrosion resistance in comparison with the proximal surfaces of the dental restorations and indicates that even a simple clinical operation such as carving could increase the amalgam corrosion resistance of dental restoration in oral cavity.

The mean corrosion current density value of the Oralloy carved amalgam was only 30% of the mean corrosion current density value of the samples near the matrix band (as an indication of the proximal surfaces of the dental restorations). This means that even a simple clinical operation such as carving after amalgam condensation could affect on the amalgam corrosion resistance and could reduce corrosion current density at least 70%. The surfaces of a class I dental restoration could be surface treated by the dentist (Fig3). On the other hand, the dentist is not able to perform any clinical operation such as carving on the proximal surfaces of the class II restorations (Fig4). Thus, it could be expected that less amalgam corrosion resistance would be obtained and more ion releasing could be arisen from the proximal surfaces of the class II restorations into the oral cavity.

Fig 3. A class I dental restoration on mandibular right second molar. All of the surfaces of the restoration are accessible for clinical surface treatment.

Fig 4. A class II dental restoration on mandibular first molar. The surfaces adjacent to approximate teeth (the proximal surfaces) could not be carved and polished by dentist and more corrosion is expected.
The dental amalgam is susceptible to concentration cell corrosion or crevice corrosion. This situation exists whenever there are variations in the electrolytes or in the composition of the given electrolyte within the system. For example, there are often accumulations of food debris in the interproximal areas of the mouth, particularly if oral hygiene is poor. This debris then produces one type of electrolyte in that area, and the normal saliva provides another electrolyte at the occlusal surface. Therefore, electrolytic corrosion occurs with preferential attack of the metal surface occurring underneath the layer of food debris.\(^{(6)}\)

Therefore, the proximal surface of the class II restoration is not only susceptible to concentration cell corrosion due to variation in the electrolytes but also the surfaces possess less corrosion resistance because no clinical surface treatment could be performed by dentist.

Further research specially, in vivo evaluation should be performed in order to determine and evaluate the real corrosion behavior and ion release of the proximal surfaces of the dental restorations.

**CONCLUSION**

Even a simple clinical operation such as carving could increase the amalgam corrosion resistance of dental restoration in oral cavity. The proximal surfaces of the class II dental amalgam restorations are not only susceptible to concentration cell corrosion due to variation in the electrolytes but also possess less corrosion resistance because dentist could perform no clinical surface treatment.

**REFERENCES**


