Galvanic interaction between gold and amalgam

Effect of zinc, time and surface treatments

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ABSTRACT

Background. Previous studies have investigated the electrolytic action of oral electrogalvanism. However, the reasons why certain treatments or materials are successful in reducing galvanic current have not been addressed fully. This study assessed galvanic current with several materials, surface conditions and treatments.

Methods. The authors measured galvanic currents between a type 3 cast gold alloy and Dispersalloy Dispersed Phase Alloy (zinc) (Dentsply Caulk, Milford, Del.) under different surface conditions using a zero-resistance-ammeter technique in a synthetic saliva solution for 10 hours. In addition, the galvanic currents between the same gold and Tytin alloy (non-zinc) (Kerr, Orange, Calif.), experimental zinc alloy (same makeup as that of Tytin, with the addition of zinc) and non-zinc dispersed-phase experimental alloy (essentially the same physical and chemical makeup as that of Dispersalloy, with the exclusion of zinc) were measured. Triplicate tests were performed for each condition.

Results. The statistical analysis indicated that electrogalvanic activity is reduced significantly when the amalgam surface is treated with tin oxide or silver nitrate. Both zinc-containing amalgams in their as-carved condition exhibited higher anodic charge densities than did their zinc-free counterparts. Galvanic current measured in Dispersalloy was reduced with the passage of time after carving.

Conclusion. Galvanic interaction between cast gold and amalgam is reduced with time and surface treatments, but is increased considerably when the amalgam contains zinc.

Clinical Implications. Amalgam restorations containing zinc that are in contact with gold restorations occasionally elicit galvanic pain. Selection of a non–zinc-containing amalgam will reduce the level of galvanic interaction. Galvanic pain from occlusal contact is reduced or eliminated when the restoration is brushed with tin oxide immediately after carving or is treated with 2 percent silver nitrate. Some patients may benefit from having their teeth separated with nonconducting rubber dam material.

Contact between gold and dental amalgam restorations in the oral environment may elicit sensitivity from galvanic current flow between the two restorations. Snyder[1] reported the incidence of painful oral electrogalvanism from a variety of dissimilar metals to be 0.4 percent, or 68 of the 16,929 amalgam restorations placed by senior dental students in a two-year period. The frequency may vary with the level of anesthesia at the conclusion of the appointment,[1] the physiological condition of the tooth,[2] electromotive force between the two metals,[3] patient's pain threshold,[4] salivary electrolyte concentration, type of dental amalgam (spherical versus lathe-cut) and relative size of the restorations.[5]

Galvanic interaction between cast gold and amalgam is increased considerably when the amalgam contains zinc.

ORAL ELECTROGALVANIC PAIN

Typically, dental galvanic current arises from the difference in electrode potentials of gold and amalgam; amalgam gives up electrons and acts as an anode, while gold accepts electrons and acts as a cathode. When the dissimilar metals contact, the electrical charge flow is concentrated in the well-innervated tooth before it spreads to the surrounding tissues.[3] Current density (that is, current divided by electrode area) within the range of dental galvanic current has been shown to elicit tooth pain.[4]

During amalgam's first 24 hours of setting, the pain from galvanic current can be severe; however, clinical experience indicates that the pain may subside with time.[2,3] The reduction in pain may be due to a decrease in the electromotive force of amalgam as it fully sets,[4] as well as the deposition of corrosion products on the surface of the amalgam that have a passivating effect.[5]

The phenomenon of painful oral electrogalvanism has occurred in our dental school clinic with Dispersalloy Dispersed Phase Alloy (zinc) (Dentsply Caulk, Milford, Del.), an admixed alloy, and gold restorations of unknown composition. Dispersalloy amalgam alloy is gamma-2–free, and in its alloy powder form contains approximately 1.0 percent zinc.[6] Our dental school clinic has experienced fewer episodes of galvanic pain with Tytin (Kerr, Orange, Calif.), an all-spherical gamma-2–free amalgam that contains no zinc.

Explanations for Tytin's decreased oral electrogalvanism may relate to the absence of zinc in the formulation; the fact that the particles all are spherical rather than a combination of lathe-cut and spherical, therefore leading to faster structural stabilization of the alloy; or the homogeneous unicompositional nature of the alloy, rather than a heterogeneous mixture of both high- and low-copper components. However, the microstructural complexity of both of these alloys makes it difficult to determine the sources of differences in electrogalvanic activity.

A slurry of tin oxide and water applied with a rotary brush is effective in reducing painful oral electrogalvanism.

Once a patient's pain is diagnosed as being galvanic in origin (from contact between gold and amalgam), a variety of treatment options are available. If the two teeth involved are opposing each other, the clinician may use a cotton swab to apply silver nitrate solution[7] to the occlusal surface of the amalgam or brush the surface with tin oxide. We have found in our dental school clinic that a slurry of tin oxide and water applied with a rotary brush is effective in reducing painful oral electrogalvanism.

Another course of treatment is to replace the amalgam restoration with a nonmetallic or gold restoration. If the two teeth involved have interproximal contact, the dentist can replace the newly placed amalgam with a nonmetallic or gold restoration; alternatively, the contact area of the amalgam can be replaced with resin-based composite.[8] However, patients with mild oral electrogalvanic pain may benefit from having the two teeth separated with nonconducting rubber dam material.[9] This will stop the pain and allow the setting amalgam to stabilize. Our experience with mild galvanic pain has been that within four to 24 hours, the rubber dam material may be removed with no recurrence of pain.

The objective of this study was to assess the influence of zinc content and time after placement on the galvanic current of an amalgam-gold material couple. A secondary objective was to determine the effect on measured galvanic current of treating the amalgam with tin oxide or silver nitrate immediately after carving.

MATERIALS AND METHODS

One of the authors (A.G.W.) measured the galvanic currents between a type 3 cast gold alloy (JRVT, Jensen Industries, North Haven, Conn.) and four types of amalgam alloys placed in a synthetic saliva solution for 10 hours at 20 C. The four types of alloys were Dispersalloy (zinc), non-zinc dispersed-phase experimental alloy (essentially the same physical and chemical makeup as that of Dispersalloy, with the exclusion of zinc), Tytin (non-zinc) and experimental zinc alloy (same makeup as that of Tytin, with the addition of 1.0 percent by weight zinc). The composition of the synthetic saliva solution (pH = 7.4) was as follows: sodium chloride, 137 millimolar; potassium chloride, 2.7 mmol/L; and phosphate^{-3}, 10 mmol/L.

Using a potentiostat,[5] the researcher measured the galvanic current via the zero-resistance-ammeter technique (Figure). In this technique, the potential difference between various amalgams (that is, working electrode) with different surface treatments and gold (that is, reference electrode) was maintained at zero. No auxiliary electrode was used. The researcher measured the anodic current generated to maintain the potential difference over a 10-hour period, recording data every five seconds using a computer-controlled device. The current/time curve (y-axis/x-axis, respectively) for 10 hours was integrated to yield anodic charge density in coulomb/square centimeter, or C/cm^2. Coulomb has been used as a measure of electrogalvanism. The researcher measured galvanic current for the Dispersalloy (zinc) anode under the following conditions:

- as carved;
- as carved, with a 24-hour delay;

- as carved, followed immediately by polishing with tin oxide;
- as carved, followed immediately by treatment with 2 percent by weight silver nitrate.

In addition, the galvanic current between the same gold alloy and Tytin (non-zinc), experimental zinc alloy and non-zinc dispersed-phase experimental alloy was measured in their as-carved condition. The exposed area of all amalgam electrodes was 0.125 cm^2, and the gold-amalgam area ratio was 2:1. We performed triplicate tests for each condition. Analysis of variance and Tukey test were used for statistical analysis ($P < .05$).

RESULTS

The table lists the mean values of the integrated anodic charge densities of all galvanic couples studied. The means with the same letter designation are statistically significantly similar ($P < .05$). It is apparent from the table that both of the zinc-containing amalgams in their as-carved condition exhibited higher anodic charge densities than did their zinc-free counterparts (Dispersalloy [zinc] alloy versus non-zinc dispersed-phase experimental alloy; experimental zinc alloy versus Tytin [non-zinc] alloy). With regard to the effect of time after carving, delaying exposure of the Dispersalloy amalgam to synthetic saliva reduced its electrogalvanic activity. Similarly, electrogalvanic activity was reduced significantly when the amalgam surface was treated with tin oxide or silver nitrate.

Figure. Electrochemical setup for measurement of galvanic corrosion.

DISCUSSION

Regarding the observed effect of zinc, we should note that zinc is a highly corrosion-prone metal in its elemental form, and it maintains its electrochemical activity in dental amalgams.[6,10] This electroactivity of zinc is reflected in the release of significant amounts of soluble zinc during the early stages of corrosion of dental amalgam.[11-13] Our observation that both of the zinc-containing amalgams exhibited higher anodic charge densities than did their zinc-free counterparts is consistent with the previous observation[6,10] that the presence of zinc makes an amalgam more prone to corrosion.

It seems that the zinc-containing dental amalgams have a higher potential to induce galvanic pain, at least after initial placement. Unfortunately, there are too many clinical variables (for example, salivary electrolyte concentrations, surface area of alloys, depth of cavity preparation and patient's pain perception) to determine the minimum level of galvanic current that will elicit pain in every patient.

Silver nitrate treatment. The surface treatments of brushing with tin oxide and applying silver nitrate to Dispersalloy (zinc) immediately after carving reduced the electroactivity level to nearly that of Tytin (non-zinc) with no surface treatment. Both surface treatments proved to be effective methods of reducing galvanic current. Silver nitrate has been reported to be an effective method of allaying dental electrogalvanic pain.[1,14] The silver nitrate solution turns the amalgam surface black because of the precipitation of silver mercury compounds. This precipitate may reduce the zinc activity on the surface. The black color

TABLE

INTEGRATED ANODIC CHARGE DENSITIES.

GALVANIC COUPLE (WITH TYPE 3 GOLD CATHODE)	MEAN ± SD* ANODIC CHARGE DENSITY (COULOMB/cm²†)	SIGNIFICANCE‡ ($P < .05$)
Dispersalloy Dispersed Phase Alloy§ (Zinc), as Carved	24.88 ± 3.04	E
Experimental Zinc Alloy, as Carved	20.32 ± 1.36	D
Dispersalloy (Zinc), Tin Oxide Polish	13.52 ± 2.48	C
Dispersalloy (Zinc), Silver Nitrate Treatment	12.88 ± 2.56	C
Tytin¶ (Non-zinc), as Carved	12.40 ± 1.20	C
Non-zinc Dispersed-Phase Experimental Alloy, as Carved	6.88 ± 1.04	B
Dispersalloy (Zinc), 24-Hour Delay	2.32 ± 0.48	A

* SD: Standard deviation.
† cm²: Square centimeter.
‡ Means with the same letter designation are statistically significantly similar.
§ Dispersalloy amalgam alloy is manufactured by Dentsply Caulk, Milford, Del.
¶ Tytin amalgam alloy is manufactured by Kerr, Orange, Calif.

will wear away with time or may be polished off at a subsequent appointment, with no recurrence of pain.[14]

Tin oxide treatment. The tin oxide treatment has the benefit of not turning the amalgam black and may mask surface zinc by covering the surface with a film of tin oxide. We have not examined in this study the mechanisms by which silver nitrate and tin oxide reduce galvanic current. Other surface treatments to reduce electrogalvanic pain in patients with newly placed amalgams include applying copal varnish[2] or a resin-bonding agent[15] to create a barrier between dissimilar metals. One of us (R.W.) has found that these methods are not always effective because the patient may wear through the resin in minutes or the materials may not form a complete barrier.[15]

The effect of delaying measurement of galvanic current (for 24 hours after carving) and allowing Dispersalloy (zinc) to set also reduced the galvanic current. With time, the amalgam becomes more stable, thus decreasing the electroactivity.[3] For patients with mild electrogalvanic pain, removing the contact between dissimilar metals for 24 hours or less will allow the amalgam-setting reaction to run to stabilization. On occasion, removing any metal occlusal contact will eliminate the source of the pain permanently.[9] However, the pain may recur if the teeth return to occlusal contact.[16]

Electrogalvanism between adjacent teeth is interrupted with the placement of nonconducting materials, such as a rubber dam. This technique is invaluable for the diagnosis of painful electrogalvanism. If dissimilar metals in interproximal contact produce only mild pain, one of us (R.W.) has found that separating the teeth with rubber dam material and allowing the setting amalgam to stabilize may be the only treatment required. (We should note, however, that interproximal galvanic pain is rare and Dr. Walker has treated only a few patients with it within the last 25 years.)

We recommend removal of the rubber dam material after 24 hours because of the lowered galvanic current after 24 hours of setting time, and, if pain recurs, the patient can receive further dental treatment. However, the rubber dam material may become dislodged prematurely, which is why we report a range of retention times. We should note that Senia and Bales[16] reported recurring pain following removal of the separating material after four days, and Williamson[15] reported it after one week.

In patients with persistent electrogalvanic pain resulting from the interproximal contact between gold and amalgam restorations, one of the restorations must be replaced with a nonmetallic material, the contact area may be restored with a resin-based composite material[8] or both restorations must be made of electrochemically similar materials.

CONCLUSION

Dental galvanic current, and therefore the anodic charge density associated with gold and amalgam contact, increases when the amalgam contains zinc. The results of our study show that the current is decreased when the amalgam is brushed with tin oxide or treated with silver nitrate immediately after carving, or when measurements are delayed for 24 hours after carving. ■

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