Silver solder “tattoo,” a novel form of oral pigmentation identified with the use of field emission scanning electron microscopy and electron dispersive spectrography

H. M. Hussaini, BDS(Malaya), MDentSci(Leeds), FDSRCSEd, a
J. N. Waddell, MDipTech(DentTech)(TN), PGDipDCTech(Otago), HDE(UN), a L. Girvan, b
L. M. West, BDS(Otago), FDSRCS(Edin), FFDRCS(Irel), FRACDS, FRACDS(OMS), c
T. B. Kardos, MDS, PhD(Otago), FFOP(RCPA), a
A. M. Rich, BDS, MDSc, PhD(Melb), FRACDS, FFOP(RCPA), a and
G. J. Seymour, AM, BDS, MdSc(Syd), PhD(Lond), FRCPath, FFOP(RCPA), FRACDS FRSNZ, a
Dunedin and Auckland, New Zealand
UNIVERSITY OF OTAGO

Objective. The aim of this study was to investigate the use of field emission scanning electron microscopy and electron dispersive spectroscopy (SEM-EDS) to identify silver solder “tattoo.”

Study design. SEM-EDS was used to analyze material present in the connective tissue of a patient who presented with bilateral pigmentation of the mandibular lingual gingiva adjacent to the first molars. No dental restorations were present.

Results. SEM-EDS analysis identified silver, with no evidence of tin, copper, or mercury. The patient was wearing an orthodontic appliance where brackets had been soldered to the archwire with silver solder. It is hypothesized that the solder underwent electrolytic corrosion with subsequent regrouping of silver ions in the submucosa leading to blue-gray discoloration.

Conclusion. Spectrography proved to be a powerful diagnostic tool in identifying the metal within the oral mucosa. Attention is drawn to this newly described lesion, which should be included as a differential diagnosis for pigmented oral mucosal lesions. (Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;112:e6-e10)

The most common cause of exogenous oral mucosal pigmentation results from deposition of dental amalgam within the tissues and is known as an amalgam tattoo.1 Dental amalgam comprises alloys of mercury with other metallic elements, such as silver (Ag) copper (Cu), tin (Sn), and/or indium.2 Amalgam can be incorporated into the oral mucosa during the placement of dental restorations or at the time of tooth extraction.3 Clinically, an amalgam tattoo appears as a blue-black asymptomatic macule, and if found beside a large amalgam restoration it is readily recognized. A radiograph taken at low exposure may show the presence of amalgam particles in the soft tissues, but this is not always reliable if the metal is widely dispersed and present in small particles. A biopsy is usually recommended to exclude melanocytic lesions and to make a diagnosis of an amalgam tattoo. The routine histologic diagnosis is made by identifying the dark brown/gray particles, usually aligned along collagen fibers and not often associated with a foreign body–type immune reaction. Embedded graphite from pencil “lead” may mimic an amalgam tattoo,4 and systemic ingestion of metals, such as lead and bismuth, can also cause oral mucosal pigmentation.

Because oral mucosal pigmentation may have a number of causes, it is becoming more important to be able to identify the nature of the foreign material to have an accurate diagnosis. The aim of the present study was to investigate the use of field emission scanning electron microscopy (SEM) and electron dispersive spectrography (EDS) to identify silver solder “tattoo,” a novel form of oral pigmentation.

MATERIALS AND METHODS

Tissue was obtained from a 17-year-old girl who had been referred to a maxillofacial surgeon by her orthodontist for removal of her premolars. She had recently completed orthodontic treatment, which had involved wearing an orthodontic appliance where brackets had been attached to the archwire by silver solder.
She was otherwise fit and taking no medication. The tissue consisted of 2 almost identical symmetric gray-black pigmented macules from the lingual interdental papillae between the mandibular second premolar and the first molar on both the left and the right sides (Fig. 1). The patient had no related symptoms and was unaware of the lesions. Periapical radiographs showed no radiopaque material (Fig. 2). The tissue was fixed in 10% neutral-buffered formalin and sent to the Medlab Dental Oral Pathology Laboratory with a clinical diagnosis of oral melanotic macule. The specimens were prepared for routine histologic examination and subsequent SEM-EDS.

For SEM-EDS, histologic slides from both blocks were taken to the Otago Centre for Electron Microscopy, University of Otago, where coverslips were removed and analysis was conducted using a JSM-6700F field emission SEM (Jeol, Tokyo, Japan) and EDS analysis with the Jeol 2300F EDS system. EDS analysis was performed at an accelerating voltage of 25 kV. Deadtime was kept to <20% and counts per second between 1,500 and 3,000. Spot analysis for 100 seconds per area was used to identify the material embedded within the tissue. Standardless ZAF quantification was applied to the results to give an indication of relative weight percentages of the material present. Images were acquired using a backscattered electron detector.

Tissue was obtained and stored according to the International Accreditation New Zealand guidelines, and signed informed consent to use the tissue for research was obtained from the patient.

RESULTS

Histologic examination of both specimens showed cellular fibrous connective tissue with overlying stratified squamous epithelium. Deposits of dark granular foreign material were scattered throughout the connective tissue, along collagen fibers, and around small blood vessels and nerves. Some particles were ~1 mm in diameter, others smaller and dust-like. There was no evidence of melanin pigmentation nor an obvious increase in the number of melanocytes, and there were no nevus cells. In some regions the granular foreign material was associated with a lymphohistiocytic foreign body reaction (Fig. 3).

The SEM images indicated granules of foreign material of various sizes scattered throughout the fibrous connective tissue (Fig. 4). Visualization of the relationship of the granules with the surrounding connective tissue was enhanced with the use of 3-dimensional analysis. Some of the granules were large and surrounded by chronic inflammatory cells and red blood cells (Fig. 4), allowing comparison of their sizes.

The EDS analysis showed the presence of silver sulfide only, which was present in a large amount (Fig. 5).

DISCUSSION

Oral mucosa is usually not pigmented despite the fact that it has the same density of melanocytes as skin. In physiologic oral pigmentation, such as racial pigmentation or pigmentation associated with pregnancy, there is increased melanin production by melanocytes, without an increase in the number of melanocytes. A similar histologic picture is seen in the oral pigmentation...
known as oral melanotic macule or focal melanosis, and this is associated with a range of conditions, from drug effects to Addison disease. Other melanocytic lesions, which uncommonly involve the oral mucosa, are nevi and malignant melanoma.

The most common exogenous form of oral pigmentation is an amalgam tattoo, but there is no definite way of identifying the foreign material in an amalgam tattoo with the use of histology alone. The histologic findings in the presented case were consistent with implantation of foreign material, which was initially presumed to be dental amalgam. However, the radiographs provided by the clinician showed no evidence of dental restorations

Fig. 2. Bilateral periapical radiographs with no radiopaque material present.

Fig. 3. Photomicrograph showing numerous fragments of dark foreign material scattered within the connective tissue and around small blood vessels. There was a mild chronic inflammatory cell infiltrate associated with the foreign material in some regions.

Fig. 4. Low-power scanning electron microscopy (A) imaging showing scattered granular material within the connective tissue, and a higher magnification with 3D enhancement (B) showing a large particle of foreign material with red blood cells and inflammatory cells. This was the largest particle detected and was used for spot analysis for element analysis.
in the posterior mandibular teeth. Further communication with the clinician led to the advice that the patient had never had any dental restorations in her deciduous or permanent teeth and that there was no history of accidental implantation of graphite or lead materials. This led to further investigation in an attempt to identify the embedded material. EDS analysis showed the presence of silver sulfide only. In amalgam tattoos there is degradation of amalgam with time and Sn and Hg are progressively liberated.\(^5,6\) This process is thought to be due to electrolytic corrosion and bacterial and cellular enzyme activity.\(^5,7\) The degradation process is variable, and EDS analysis may not detect all 4 elements, Ag, Sn, Cu, and Hg.\(^6,7\) What is usually found is a combination of Ag, Sn, and traces of either Cu or Hg, as shown by Zhang et al. (2007).\(^6\)

Orthodontic brackets and archwires are composed of alloys of various proportions of nickel, cobalt, and chromium.\(^8\) It has been shown that Ni and Co ions can be released from these appliances that later can be identified within cells of the oral mucosa.\(^8,9\) In the current study, only Ag and S were present in the tissue. We therefore proposed that the silver deposits observed were derived from silver solder joining the bracket to the archwire of the orthodontic appliance. It is unlikely that the silver was “tattooed” or implanted in a similar fashion to an amalgam tattoo. We hypothesize that the silver solder underwent electrolytic corrosion in the presence of salivary enzymes and intraoral bacteria in plaque in the gingival crevice, as has been demonstrated by Joska et al. (2009)\(^10\) in relation to Ag in cast post and core restorations. The soluble silver ions within the gingival crevice of the molar tooth enclosed by a bracket then penetrated the gingival epithelium and subsequently formed insoluble precipitates in the submucosa with S derived from cellular sulfur-containing enzymes, as explained by Zhang et al. (2007)\(^6\) and Magos et al. (1987).\(^11\) This situation is analogous to that proposed to occur in systemic argyrosis, where ingested silver is absorbed in the small intestine and transferred through the blood as soluble colloids or salts and later deposited in various tissues where it is reduced to the metallic form.\(^12\) There it forms insoluble silver sulfide in conjunction with S from cellular enzymes\(^6\) and produces blue-gray skin discolouration. EDS analysis in systemic argyrosis shows peaks for Ag and S,\(^13\) as was seen in the present case.

**CONCLUSIONS**

We report local argyrosis or silver solder “tattoo” of the oral mucosa, a condition that is not recognized in the literature and occurs as a result of wearing a silver-soldered orthodontic appliance. SEM-EDS analysis allowed identification of the etiologic agent. Diagnostic oral pathologists and clinicians managing oral mucosal diseases should be aware of this form of oral pigmentation to reassure the patient and to ensure that a prompt accurate diagnosis is obtained.

**REFERENCES**


Reprint requests:
Associate Professor Alison Rich
Faculty of Dentistry
University of Otago
P.O. Box 647
Dunedin, 9054
New Zealand
alison.rich@otago.ac.nz