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Foreign body gingival lesions: distribution, morphology, identification by X-ray energy dispersive analysis and possible origin of foreign material

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BACKGROUND: Foreign material may cause and aggravate gingival lesions. This is rarely considered clinically. The lesions are resistant to frequently protracted conventional therapy. The foreign material is often inconspicuous and easily overlooked by the pathologist.
METHODS: 85 cases of gingival lesions containing foreign material were investigated by conventional and polarization light microscopy, focusing on the morphology and optical characteristics of the foreign substance. Supplemented with the results of X-ray energy dispersive analysis the foreign material was compared with commonly used dental materials.
RESULTS: The foreign material was most frequently compatible with amalgam. Inconspicuous crystals, often revealed only by polarization microscopy, were most commonly compatible with abrasives, particularly corundum and silicates, and mostly occurred together with amalgam dust.
CONCLUSIONS: Iatrogenic introduction of dental materials during dental procedures explains most foreign body gingival lesions which could be reduced or avoided by prophylactic measures. Pathologists should meticulously scrutinize gingival biopsies routinely applying polarization microscopy.
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Keywords: foreign body gingival lesions; iatrogenic gingival lesions; therapy-resistant gingival lesions

Introduction

Foreign material is rather frequently observed in oral biopsies. We have previously identified such material in post-endodontic granulomas and cysts, were it may perpetuate and even initiate the inflammatory reaction (1, 2). In our experience foreign material is also a common finding in gingival biopsies, particularly in cases of localized therapy-resistant gingivitis and marginal periodontitis. Non-microbial gingivitis associated with inorganic foreign particles other than amalgam, which is frequently the offender, was first reported by Daley and Wysocki (3), and based on energy dispersive X-ray analysis (EDXA) and clinical history a possible iatrogenic source of the foreign material was suggested. In a more comprehensive study of 61 cases the term foreign body gingivitis (FBG) was coined for these lesions, and frequently elements compatible with abrasives and restorative materials were identified (4, 5). However, foreign elements may cause practically non-inflammatory gingival changes manifested clinically as swellings and/or discolouration, and we suggest the term foreign body gingival lesion for both inflammatory and non-inflammatory gingival changes of which foreign material is a feature.

Apart from in cases with obvious discolouration clinically diagnosed as amalgam tattoos, clinicians rarely consider foreign material as an aetiological factor in gingival lesions, and patients may be submitted to protracted, expensive, non-curative periodontal therapy before eventual biopsy. Further, the foreign material is often minute and easily overlooked on microscopy unless particularly searched for by the pathologist.

The purpose of the present investigation was to draw attention to foreign body gingival lesions by investigating a comprehensive biopsy material, including epidemiological data and tissue reactions, and focusing on morphological characteristics of the foreign material as seen by conventional and polarized light microscopy. Further, the results of EDXA would be compared with analysis of relevant dental materials suspected to be offenders. Moreover, comparisons were made with element constituents of products and materials given in textbooks of dental materials science.

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Materials and methods

One hundred and twenty gingival biopsies containing foreign material submitted to the Department of Pathology and Forensic Odontology, Faculty of Dentistry, University of Oslo from 1990 to 1997, and to Laboratory for Pathology A/S, Oslo, Norway, from 1998 to 2000, were retrieved from the respective files. Thirty-five cases were excluded from the investigation due to poor specimen quality, too minute amounts or no traceable foreign material in sections prepared for scanning electron microscopic (SEM) with EDXA, leaving 85 cases for further investigation.

Patient age and sex were recorded from the biopsy requisition forms submitted by the clinicians, as was the localization of the gingival lesion in jaw segments as follows.

Maxilla, anterior segment: Gingiva tooth 3-3, including the distal papilla.
Maxilla, posterior segment: Gingiva tooth 4-8.
Mandible, anterior segment: Gingiva tooth 3-3, including the distal papilla.
Mandible, posterior segment: Gingiva tooth 4-8.

Histological and polarization microscopical methods

The biopsies had been fixed in 4% aqueous formaldehyde, processed according to standard procedures, paraffin-embedded, sectioned at 3–4 μm and stained with H&E or H&erythrosin & safranin.

The criterium for the diagnosis of foreign body lesion was the presence of foreign material with adjacent inflammation or fibrosis, in at least two serial sections. Likewise, lesions in which foreign material evidently had been displaced during microtomy, and had left empty spaces, possibly with an adjacent inflammatory reaction or fibrosis/sclerosis and evidence of displacement track in the tissue, were included.

The foreign bodies were investigated morphologically by conventional and polarized light microscopy and their largest dimension measured with a micrometer scale.

In concurrence with Gordon and Daley (4), the foreign particle size was assessed as small/minute (≤ 1 μm in diameter), medium (1–5 μm in diameter) or large (> 5 μm in diameter). The inflammatory reaction was subjectively assessed by an experienced pathologist (HSK) as mild, moderate or severe chronic or subacute, or in a group comprising foreign body reactions with epithelioid cells, with or without giant cells and granulomatous lesions.

Scanning electron microscopical and energy dispersive X-ray analytical method

Subsequent to diagnosis, 3–4-μm-thick parafinized, unstained sections mounted on carbon discs were coated with carbon for visualization in the SEM and investigated in either a Philips SEM (Fei Company, Eindhoven, The Netherlands) equipped with an EDAX® 9900 analyzer (EDAX, Paoli, PA, USA) with a windowless ECON detector or in a Philips XL 30 ESEM (Fei Company) with a Phoenix X-ray analyzer (EDAX), the detector and analyzer being capable of detecting elements with atomic number 11 (Na) and above. The foreign bodies were identified by high contrast backscatter detection, enabling the distinction between surface particles that could be contaminants, from particles located in the tissue. Semiquantitative analysis was performed on several randomly chosen particles localized with SEM in each section and recorded on diagrams.

EDXA of dental materials and equipment

For comparison with foreign material found in the biopsies, samples of dental materials suspected to be introduced into the gingiva during dental procedures, were subjected to EDXA investigation (Tables 1 and 2).

Samples of the powder component of three temporary cements and two periodontal dressings, of pumice, carborundum, aluminium oxide (corundum), chalk and talc were included. Further, samples of two prophylaxis pastes were dissolved in ethyl alcohol and acetone four times to remove the organic component. Each time the inorganic material was allowed to precipitate, and the organic supernatant pipetted off. The precipitate was dried in an oven at 100°C.

The samples were fixed to carbon discs with colloidal carbon (Leit – C, Conductive Carbon Cement, Neubauer Chemikalien, Münster, Germany). The carborundum sample was coated with Au –Pd. Also included is the manufacturer's product declaration for a third prophylaxis paste (Table 1).

Further, dental metal strips, sand paper, carborundum discs, various dental stones, dental diamonds, steel and tungsten carbide burs, rubber cup, rubber grinder, orthodontic bracket band and orthodontic string were fixed on carbon-coated discs with dental wax and earthed with colloidal silver (Silver Print, Provac AG, Balzer, Lichtenstein). All samples were investigated in the SEM with EDXA (Table 2).

Comparisons were made with elemental constituents of dental products and materials given in textbooks of dental materials science (6). The comparisons were performed by an experienced chemist with special competence in dental materials science (RK).

Results

Biopsy material: patient age and sex and anatomical distribution of foreign body gingival lesions

The mean age of the patients was 50.3 years (range: 18–80; Figs 1 and 2). The lesions most frequently occurred in the age groups of 41–50 (19 cases, 22.4%) and 51–60 years (20 cases, 23.5%; Fig. 1). Fifty-eight (68%) patients were female and 27 (32%) male; ratio 2.1:1; the mean age and age range were approximately the same in both genders (Fig. 1).

The lesions were localized in the mandibular and maxillary posterior segments in 29 cases (34%) and 25 (29%) of the cases, respectively, followed by the maxillary anterior region with 22 cases (26%). The mandibular anterior segments were affected in nine cases (11%).

Table 1 Elements identified by EDXA[a] in/given in manufacturer's product declaration of materials commonly used in dental procedures

Material	*Elements identified by EDXA[ab]*
Temp Bond NE™, Kerr Italia, S.p.A. Salerno, Italia	Zn
Temp Bond Modifier, Kerr Italia, S.p.A. Salerno, Italia	Zn
Opotrow Trial Cement, Teledyne Water Pik, Ft Collins, Co, USA	Si, Ca, Zn
GC Temporary Pack, G.C. America Inc., Alsip, IL, USA	Zn
Coe-Pack catalyst periodontal dressing, G.C. America Inc., Alsip, IL, USA[b]	Zn, Mg large particles: Mg, Zn (traces); small particles: Zn, Mg (traces)
Profylan® putspasta, Dental Pharma, Stockholm, Sweden[b]	Ba, S, Si, Al, traces of K
CCS Prophy Paste, RDA 250, CCS AB, Borlänge, Sweden	From manufacturer: pumice, aluminium hydroxide, disodium phosphate, titanium dioxide, sodium fluoride
Hawe Cleanic® Prophylaxis Paste, Hawe Neos Dental, Bioggio, Switzerland[b]	Si, Ti, Al, K, Fe
Pumice Powder	Si, little Al, K, traces of Ca, Fe, Cl
Carborundum powder	Si
Aluminium oxide p.a., Woelm, Eschwege, Germany[c]	From manufacturer: Al_2O_3
Chalk powder	Ca
Talc	Si, Mg

[a]X-ray energy dispersive analysis.
[b]Materials obtained as pastes were washed with ethanol and acetone to remove organic materials.
[c]Aluminium oxide occurs in nature as the mineral corundum and is used in dental abrasive discs/wheels and for points mounted on mandrels.

Table 2 Elements identified by EDXA[a] in or given in manufacturer's product declaration of dental equipment from the shelves of the Faculty of Dentistry, University of Oslo, Norway

Material	*Elements identified by EDXA*
Dental metal strips	Ni, Al
Sand paper disk, white	Al, traces of Si, Cl, Ti
Sand paper disc	Si, Al
Grinding disc, brown, soft	Al, traces of Si, Cl, Ti
Carborundum grinding disc, black, hard	Si
White stone	Al, Si, K
Arkansas stone	Al, Si, K, traces of Cl, Fe
Green stone	Si, Al, K, traces of S, Cl, Ti, Fe, Cu, Zn
Grey stone wheel	Si, Mg, Cl, traces of S, K, Ca
Grey-blue stone	Si, traces of Al, K, Fe
Pink stone	Al, Si, traces of K, Ca, Ti, Cr, Fe
Viking green stone (H. Foss & Co. A/S, Fetsund, Norway)	Given from manufacturer: Silicium carbide bonded in ceram (clay)
Viking white stone (H. Foss & Co. A/S, Fetsund, Norway)	Given from manufacturer: Aluminium oxide bonded in ceram (clay)
Viking diamonds (H. Foss & Co. A/S, Fetsund, Norway)	Given from manufacturer: Diamonds are bonded with Ni and with Cu to stainless steel bur
Rubber cup	Si
Green rubber, flame formed	Si, Cl, Ti, traces of S, Cr, Fe
Tungsten carbide bur	W, Co
Steel bur	Fe, traces of Si, Cr, Mn
Orthodontic bracket band	18-8 steel (Fe, Cr, Mn, Ni)
Orthodontic string	18-8 steel (Fe, Cr, Mn, Ni)

[a]X-ray energy dispersive analysis.

In females, lesions were most frequently localized in the mandibular posterior segment (23 cases, 39.7%) and most rarely in the mandibular anterior region (seven cases, 12%); in males most lesions occurred in the maxillary anterior and posterior segments (10 cases, 37% and nine cases, 33.3% cases, respectively), while the mandibular anterior region was most rarely affected (two cases, 7.4%) also in this gender (Fig. 2).

Type and degree of inflammation

The inflammatory reaction was graded as mild chronic in 14 cases (16.5%), moderate chronic in 33 cases (38.8%), severe chronic in 17 cases (20.0%), moderate subacute in one case (1.2%), severe subacute in two cases (2.4%) and foreign body or granulomatous in 18 cases (21.2%; Table 3). Five cases (5.9% of the entire material) in the chronic inflammation group and one case (1.2%), in the granulomatous group revealed additional fibrosis or sclerosis. The inflammatory infiltrate was dominated by lymphocytes, plasma cells and macrophages, with the addition of polymorphonuclear granulocytes (PMNs) in subacute cases. Foreign body reactions and granulomatous lesions were characterized by macrophages and frequently foreign body giant cells, both sometimes with phagocytized foreign bodies, and rarely with the contribution of lymphocytes.

Conventional and polarization light characteristics of foreign material

Various types of foreign material were observed by conventional and polarization light microscopy (Fig. 3).

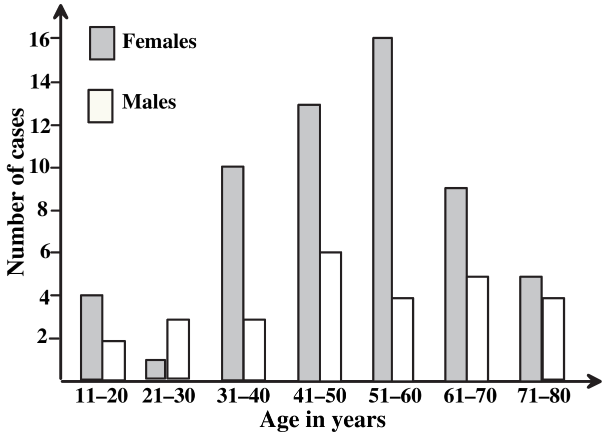

Figure 1 Age distribution of 85 cases of foreign body gingival lesions in females and males.

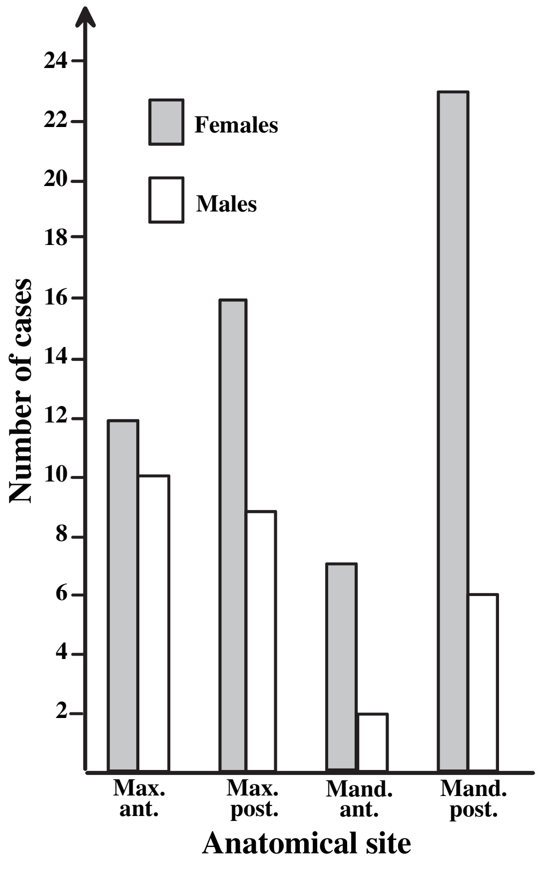

Figure 2 Anatomical distribution of 85 cases of foreign body gingival lesions in females and males. Max. ant., maxillary anterior region; max. post., maxillary posterior region; mand. ant., mandibular anterior region; mand. post., mandibular posterior region.

Table 3 Type and degree of inflammation in 85 cases of foreign body gingival lesions

	Cases	
Type and degree of inflammation[a]	*Number*	*%*
Mild chronic	14	16.5
Moderate chronic	33	38.8
Severe chronic	17	20.0
Moderate subacute	1	1.2
Severe subacute	2	2.4
Granulomatous/foreign body	18	21.1
Total	85	100.0

[a]Assessed by an experienced oral pathologist (HSK).

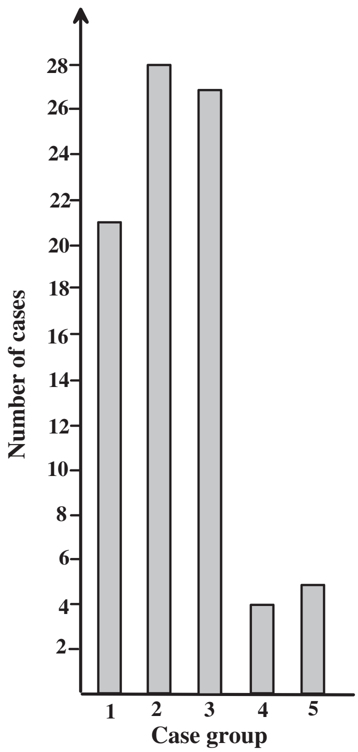

Figure 3 Grouping of 85 cases of foreign body gingival lesions according to conventional and polarization light microscopical characteristics of the foreign material. 1: cases with foreign material compatible with metal only; 2: cases with foreign material compatible with metal and additional crystals; 3: cases with crystalline foreign material associated with minute black granules; 4: cases with crystals only; 5: cases with various foreign/dissolved material, different form that in groups 1–4.

In 21 cases (24%) the foreign material appeared as large black, isotropic fragments measuring 0.02–0.35 mm in largest dimension, and often with additional medium-sized or minute black/brownish granules with a diameter of 1–4 μm, barely visible with the 40× objective. The granules might be present in the basement membrane zone and also incorporated in reticular and collagenous fibres, which also revealed diffuse brownish to yellow discolouration (Fig. 4). Twenty-eight cases (32.9%) additionally revealed colourless, translucent anistropic (crystalline) structures, occurring as fragments and needles, measuring 2–80 μm in largest dimension (Fig. 5) and frequently aggregated in rounded clusters (Fig. 6). The crystals were easily overlooked by conventional light microscopy and might be revealed only when polarized light was applied. The crystals were frequently associated with minute black granules (≈1 μm in diameter), superimposed upon the crystals or haphazardly

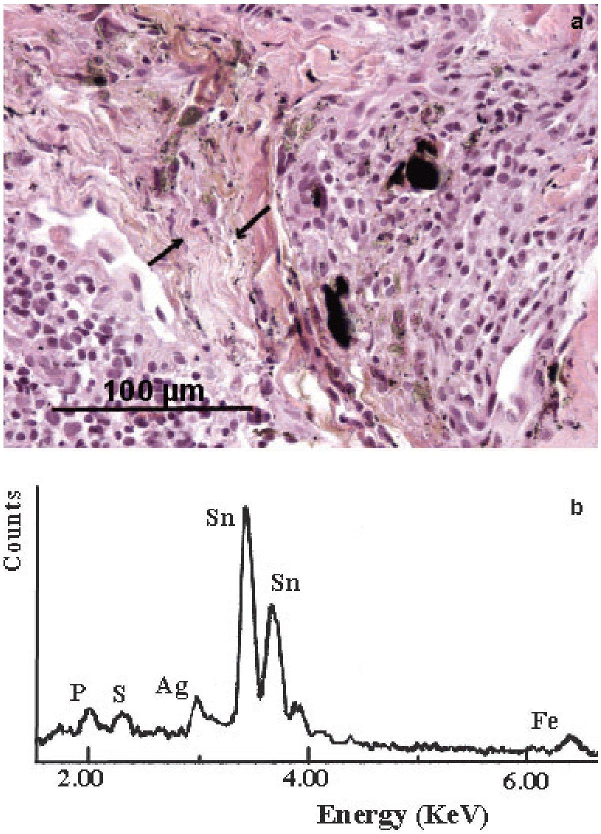

Figure 4 Foreign body gingival lesion. (a) Microphotograph shows black fragments and minute black to brown granules in an infiltrate of lymphocytes and macrophages in and adjacent to reticular and collagenous fibres (arrows). H&E (bar = 100 μm). (b) Energy dispersive X-ray analysis spectrum shows mainly Sn and Ag, compatible with amalgam components.

distributed on their vicinity, sometimes incorporated in macrophages but not in reticular fibres (Fig. 7). In 27 cases (31.8%) only crystals and such minute black granules were observed, while four cases (4.7%) revealed crystals only.

Five cases (5.9%) presented heterogeneous foreign material not fitting into the above categories and will be described separately at the end of the following section.

The results of EDXA of the biopsies will be described below. To avoid unnecessary repetition and for the sake of convenience, we will concomitantly elucidate the possible origin of the foreign material by comparison with the EDXA results and known composition of suspected offenders, notably dental materials and equipment, EDXA results of examples of which are presented in Tables 1 and 2.

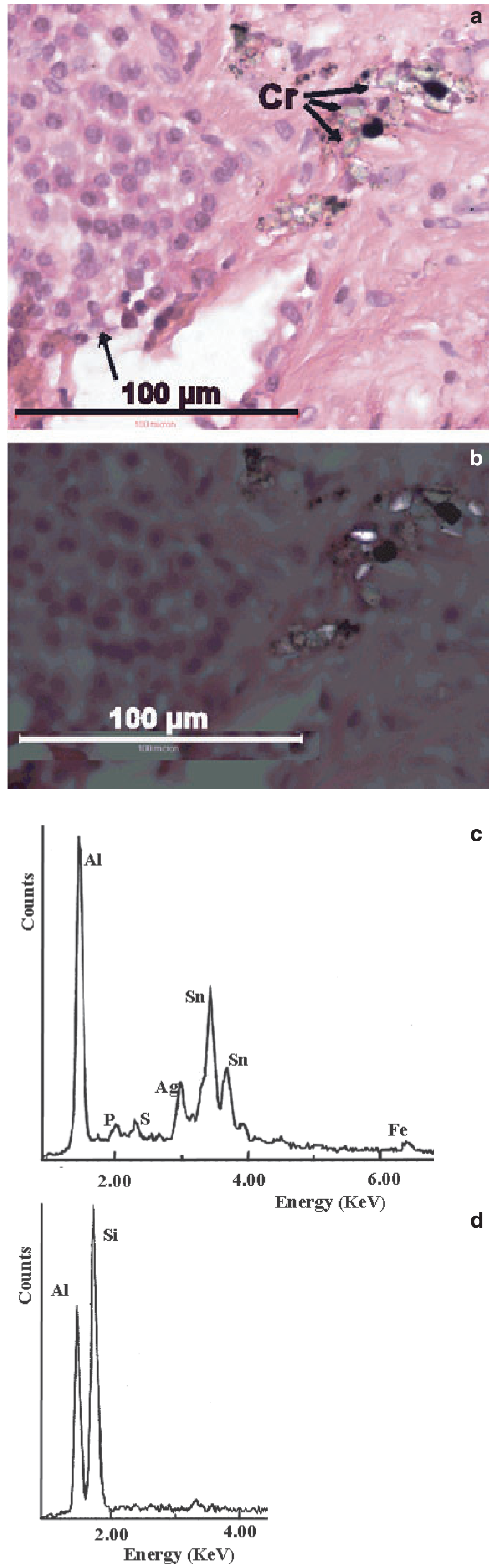

Figure 5 Foreign body gingival lesion. (a) Inconspicuous, colourless, translucent fragments (Cr), black fragments and minute black granules adjacent to infiltrate of macrophages (arrow). (b) Same area in polarized light reveals anisotropic fragments and needles. H&E (bar = 100 μm). (c) EDAX spectrum of black fragments and granules shows Ag and Sn, compatible with amalgam components, and also Al from adjacent crystals, possibly corundum. (d) EDAX spectrum of anisotropic structures also shows Si and Al, compatible with sand from fine sand paper disc.

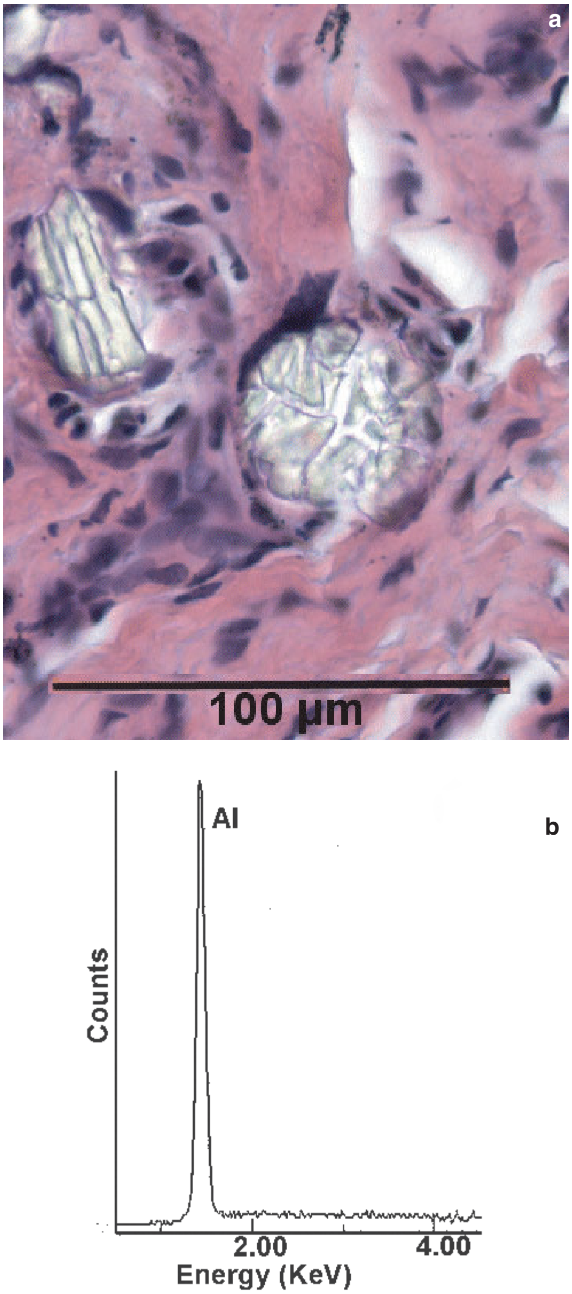

Figure 6 Foreign body gingival lesion. (a) Rounded and elongated cluster of translucent fragments. H&E (bar = 100 µm). (b) Energy dispersive X-ray analysis (EDXA) spectrum shows Al, compatible with corundum.

EDXA of biopsies and possible origin of foreign material

Elements identified by EDXA are presented in descending order of frequency in Table 4 and their compatibility with dental materials in Table 5. Taken together, the elements most frequently identified were Ag in 67%, Al in 66%, Si in 61%, Sn in 58%, S in 55%, Cu in 47%, Ca in 41%, P in 36% and Fe in 35% of the cases. Ti was found in 19% of the cases (Table 4). In the 49 cases with black fragments and brown black granules, mostly Ag, Cu, Sn, Zn and Hg, in various combinations and sometimes co-localized with Au, were generally identified, and compatible with amalgam. Au and Pd, sometimes together with Ag and Cu, could also originate from cast alloy.

The 28 cases with additional crystals, the 27 cases with crystals and minute black granules, the four cases with crystals only, and a few cases where no crystals were observed by conventional light and polarization microscopy, generally revealed Al, compatible with corundum (Al_2O_3), Al combined with Si, and occasionally Fe, Cr, Ca, P and S, compatible with silicate, probably from sand paper disc, polishing paste, tooth paste or less possibly restorative filling material.

One case additionally revealed Ba, raising the possibility of prophylaxis paste (type Prophylan®) being the offender.

Ba also occurred together with S, most likely representing $BaSO_4$ from polishing agent. In some cases Mg was identified together with Si, the components of talc, as was Si alone, compatible with carborundum (SiO). Further identified were combinations of Si, Al and Ca, compatible with pumice.

In some cases with crystals and minute (≈1 µm in diameter) black granules, also Ag, Sn, Cu, Zn and Hg, compatible with amalgam, were found, and in two cases with crystals only in H&E sections, Cu was traced. These elements are taken to explain the granules as amalgam dust (carbon is not identified by our EDXA equipment). In one case, identification of Fe, Cr and Ni was indicative of 8–18 steel alloy, probably dust from bracket band. In one case W was identified, probably from tungsten carbide bur, and also Al, compatible with corundum. Five cases (≈5.9%) displayed morphologically heterogeneous foreign material different from that described above.

Thus, one case revealed crystals, equidimensional minute black granules and irregular amphophilic structures which could not be further determined morphologically, and a surrounding foreign body inflammation. EDXA identified Zn and Cu, which could originate from amalgam, and appreciable amounts of Fe, possibly compatible with Fe_2O_3, which may be a component of polishing agents. Small amounts of Si may be interpreted as carborundum, probably constituting the crystal component. In another case a lumen rimmed by foreign body giant cells contained scanty amorphous basophilic material with minute anisotropic acicular and granular structures, possibly a composite material, as mainly Si and small amounts of Al, S, Cl, K and Fe were identified by EDXA. Further, black granules incorporated in reticular fibres were compatible with amalgam components, as supported by the finding of Ag, Sn and Cu. One case showed anistropic rounded foreign bodies up to 0.1 mm in diameter and irregular sheet-like structures, with centrally densely packed and peripherically disperse black granules, and having evoked a foreign body reaction. Morphologically, these structures resembled endodontic sealer components, as seen in surplus in post-endodontic granulomas and cysts, an assumption corroborated by the identification of Ba, S and Ti compatible with barium sulphate and titanium oxide. In addition, minute black isotropic granules in

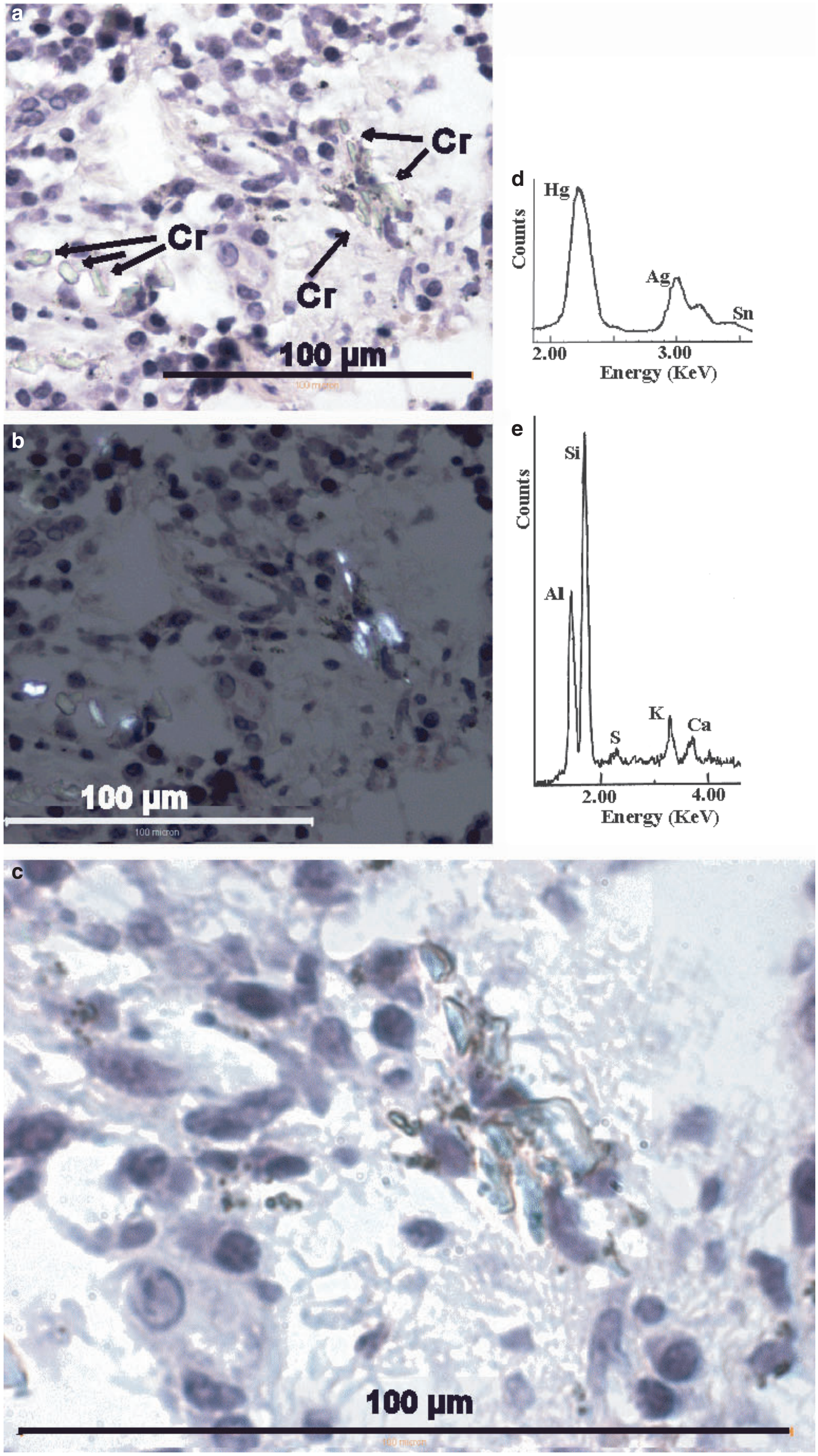

Figure 7 Foreign body gingival lesion. (a) Minute, translucent fragments and needles (Cr) are easily overlooked and may be identified only in polarized light as seen in (b). H&E (bar = 100 µm). (c) High magnification better reveals the fragments and adjacent minute black granules. H&E, oil immersion (bar = 100 µm). (d) Energy dispersive X-ray analysis (EDXA) of black granules reveals Hg, Ag and Sn, compatible with amalgam components. (e) EDXA spectrum of crystalline fragments identifies Si, Al and small amounts of K, Ca and S, compatible with silicate, probably from dental stone.

Table 4 Elements identified by EDXA[a] in 85 cases of foreign body gingival lesions

Element	*Number of cases*	*Percentage of cases*
Ag	57	67
Al	56	66
Si	52	61
Sn	49	58
S	47	55
Cu	40	47
Ca	35	41
P	31	37
Fe	30	35
Ti	16	19
Mg	15	18
Hg	13	15
Se	12	14
Zn	10	12
Ba	5	6
Pd	4	5
Ni	3	4
W	2	2
Co	1	1
Ga	1	1
Mo	1	1

[a]Energy dispersive X-ray analysis.

Table 5 Elements/element combinations most commonly identified by EDXA[a] in 85 cases of foreign body gingival lesions and the compatibility with dental materials

Elements/element combinations most frequently identified by EDXA[a]	*Compatibility with dental materials*
Ag, Cu, Sn, Hg, Se, S, Zn, Au[b]	Amalgam (restoration)
Al	Corundum (abrasive). Alminium hydroxide (in prophylaxis paste)
Si	Carborundum (abrasive). Silicon dioxide (in prophylaxis paste)
Si, Mg	Talc (polishing agent)
Si, Ca, Cr, P, S	Silicate
Al, Si, Ca	Pumice (abrasive and polishing agent)
Al, Si, Zn	Temporary cement
Si, Ca, P	Temporary cement
Ba, S	Polishing agent
Ti	Polishing agent

[a]Energy dispersive X-ray analysis.
[b]Identified in various combinations.

reticular fibres, were compatible with amalgam components, as Ag and Sn were also demonstrated.

In a fourth case, several large lumina surrounded by fibrotic connective tissue with mild chronic inflammation harboured weakly greyish, amorphous material with anisotropic colourless needles and granules. Si, compatible with carborundum, and Si, Ca and P, compatible with temporary cement (e.g. Opotow trial), were found by EDXA.

Finally, one case revealed a large (2.0 by 0.7 mm in largest dimensions), macroscopically white, microscopically cracked foreign body with densely packed black granules on pinkish, weakly anisotropic background, with scanty starch and minute anistropic granules. The foreign body was surrounded by a capsular structure with delicate connective tissue fibres and numerous macrophages. We interpret this foreign body as most probably a temporary cement, as Al, Si and Zn were found by EDXA. In addition, a small epitheloid cell granuloma with irregular, curved, amphophilic structures was present. Ca and P identified by EDXA indicate that these structures were mineralized.

Table 6 Elements most frequently identified by EDXA[a] in 18 gingival lesions with foreign body/granulomatous inflammation

Element	*Number of cases*
Ag	9
Sn	9
Al	9
Si	9
Cu	7

[a]X-ray energy dispersive analysis.

In the 18 cases **with foreign body reaction** with epithelioid cells, giant cells or frank foreign body granulomas, the elements most frequently identified (by EDAX) were amalgam components Ag and Sn, both in nine cases (50%), and Cu in seven cases (39%) and mostly co-existing.

Al and Si were both found in nine cases (50%), mostly together and then indicative of sand from grinding stone, paper disc or polishing agent (Table 6). In a few cases Si and Mg occurred together, indicating talc, and likewise the combination of Si and Ca, which might originate from temporary cement, was found.

Three cases showed **subacute inflammation**, assessed as severe in two cases where only Al, compatible with corundum, was identified. Moderate subacute inflammation was found in the third case, where Al, compatible with corundum was identified, as were Mg and Ca, which might originate from a temporary cement.

Fibrosis or encapsulation of the foreign material by sclerotic connective tissue and very mild, mild or moderate chronic inflammation was observed in five cases, thereof four with large black particles, 23–300 μm in largest dimension and with Ag and Sn as the common denominator.

Additionally, crystalline structures showing Al, compatible with corundum were seen in one of these cases, while another revealed Al and Si, compatible with Al-silicate (sand). The fifth case revealed anisotropic structures and minute black granules, but only Al was identified by EDXA.

Hg was identified by EDXA in 13 cases (15%), eight of which showed moderate chonic inflammation, while three were severely and one mildly chronically inflamed, and one showed granulomatous inflammation.

Discussion

Underdiagnostication of foreign body gingival lesions

Gordon and Daley (4) found FBG in 0.3% of a total of 19 534 biopsies to their Oral Pathology Diagnostic Service files and considered this a minimum estimate of the clinical incidence of this disorder, as it is not commonly recognized by clinicians, and most cases are not subjected to biopsy. We strongly concur with this view, as in our experience patients may have been subjected to protracted periodontal therapy before a biopsy is taken, and FBG only occasionally is entertained as a clinical diagnosis.

Criteria for the diagnosis of foreign body gingival lesions
The criteria for the diagnosis of FBG as defined by Gordon and Daley (4) were: (i) the presence of chronic inflammation in a gingival specimen; (ii) the presence of foreign bodies in an area of inflammation and (iii) the consistent localization of these foreign bodies in at least two serial sections. We have also included subacute inflammation, as we found in three cases.

A mixed chronic and acute inflammation was also described in a later case report by Gordon (7). It should be appreciated that neutrophils may be attracted to the area if the foreign material is chemotactic, but pre-existing or superimposed infection seems a more likely possibility for their presence.

Further, we have incorporated lesions where foreign material had obviously been displaced during microtomy, leaving a sectioning track in the tissue, or empty spaces the circumference of which correspond to that of the displaced material.

Applying these criteria, there is little possibility for including cases with contamination from laboratory equipment and materials, a possibility addressed by others (5). Finally, we feel it appropriate also to include cases with mainly fibrosis and encapsulation and negligible contribution of inflammatory cells. We therefore suggest the designation foreign body gingival lesion to replace the term FBG.

EDXA – limitations
EDXA is, except when performed with recently developed equipment, not absolutely quantitative but may give the relative proportions of the elements in the area analysed. It can detect elements with atomic number > 10, i.e. from Na, atomic number 11 (8) exclusive of O, because the X-ray energy of this element is below the cut-off energy of the thin beryllium window of the X-ray detector (9). Consequently, organic material, consisting of C, O and H only, cannot be identified by this method, unless the beryllium window is removed to allow for O detection.

Although the semiquantitative nature of EDXA is a limiting factor for identification of the source of foreign material, it allows for conclusions as to compatibility with known materials or compounds. In 80 (94%) of the present cases, the foreign material identified by EDXA was compatible with some type of dental material.

As many elements of dental materials and products, as Si, Al, Ca and P, that may be impacted into the gingiva, also are components of non-dental products, it is difficult to prove a dental material source based on EDXA alone, but such a source still is possible and even probable, considering the high frequency with which these elements are found in dental products, including porcelain, abrasives, polishes and toothpastes, and in particular when the frequency of dental and hygiene procedures, professional and self-administrated, in the gingiva, are taken into account (3, 5). Moreover, the predilection of these lesions in jaw segments most frequently exposed to dental procedures speaks in favour of dental materials as the offenders, and alternative sources appear unlikely (5). Based on these considerations, we find it justified using terms as compatible with, consistent with or indicative of certain dental materials in cases of foreign body gingival lesions.

It should be considered, though, that the composition of the foreign material may change over time. Thus, there is a rapid loss of Cu and Zn, and a gradual loss of Sn and Hg from implanted amalgam, leaving only Ag at the site (10, 11).

Further limiting the use of EDAX is that in cases with small amounts of foreign material, it may not be present in the sections prepared for EDXA.

The foreign material is easily overlooked
While black fragments and brownish-black granules incorporated in reticular fibres and basement membrane, and compatible with amalgam components, are comparatively readily observed, crystals may easily be overlooked as they appear colourless and translucent. We therefore find it important to apply polarization microscopy to all gingival biopsies. The minute black granules, interpreted as amalgam dust, and often occurring associated with the crystals, may have to be meticulously searched for. To the best of our knowledge, the co-existence of crystals and minute black granules has not been reported previously.

While Gordon and Daley (4, 5) did not include cases with amalgam components in their investigation, we feel they should be incorporated as they are present in a majority of cases of foreign body gingival lesions, and not the least in order to alert clinicians so as to take precautions to prevent amalgam introduction into the gingiva.

The frequent association of amalgam components with crystalline structures (Al, Si) indicates that they have been detached during trimming/polishing of fillings with abrasive tools.

Elements most frequently identified by EDXA and their most likely origin
The element most frequently identified by EDXA was Ag (67% of the cases), and also Sn and Cu were frequently found (in 58% and 47% of the cases, respectively), all compatible with amalgam components. The morphology and distribution of material identified as amalgam components concurred with previous reports (10, 12). Amalgam elements occurred less frequently in Gordon and Daley's (5) material which, however, did not include cases with the histological diagnosis of amalgam tattoo. The elements most frequently observed by these authors were Si (61% of cases) and Al (46% of the cases); in our material Al was found more frequently (Si, 61% of the cases; Al, 66% of the cases). Other elements were identified less frequently in both materials.

Al and Si are major components of various abrasives-like stones, discs and sand paper strips, prophylaxis pastes, porcelains, glass ionomers and composite filling materials, and also occur in most tooth pastes, all of which must be considered possible origins of foreign material in the gingiva.

Ca and P, also frequently identified (41% and 37% of the cases, respectively), are ubiquitously present in human tissue but are also components of tooth pastes. Fe, occurring in 35% of the cases, may originate from stainless steel burs with or without diamonds attached. Ni, a part of the metallic binder in diamond burs (6) and with cytotoxic properties (13), was found in only 4% of the cases.

The inflammatory reaction

Cases with components compatible with amalgam only, were dominated by mild chronic and foreign body inflammation, concurrent with findings in amalgam tattoos (10, 12). In cases with co-existing amalgam components and crystals, moderate and severe chronic inflammation supervened. When crystals and minute black granules occurred together, the inflammatory reaction was predominantly moderate chronic.

While the amalgam components mostly identified, viz. Ag and Sn, are allergenic, Al and Si, the major elements of the crystalline structures, are classified as cytotoxic (5) with a high phlogistic effect. The more severe reaction in cases where amalgam co-existed with crystals is probably due to a synergistic effect of the elements present.

A more severe inflammation with a higher tissue content of Hg has been reported in amalgam tattoos (11). The present material cannot confirm this finding, as most cases where Hg was identified, revealed moderate chronic inflammation. The low occurrence of Hg (17%) when compared with other amalgam components, particularly Ag (67%) and Sn (58%) in the present material, probably is due to dissolution of Hg from amalgam with time, as has been shown in amalgam tattoos (10).

It should be considered that metals and their degradation products may, by forming complexes with native proteins, mediate metal hypersensitivity (14).

Cytotoxic or allergenic materials are thought to be more likely to induce a granulomatous reaction than other materials (5). The present identification of Al, Si, Ag and Sn in cases with foreign body and granulomatous reactions supports this view. Gordon and Daley, however, found no association between any specific attribute of FBG and the presence of allergenic or cytotoxic elements and indicated that the mere physical presence of foreign elements in the gingival tissues might be a sufficient stimulus for the development of inflammation (5).

In this context, it should be considered that features as particle size, shape, position (5, 15), surface tension, surface charge, mechano-compatibility and electro-compatibility (13), porosity and degradation rate (16) of the foreign bodies, the exposure time (17), as well as the individual host response may influence the tissue reaction.

Subacute inflammation, as observed in three cases, may be due to secondary factors (e.g. plaque toxins, infections). However, all these cases revealed Al (alone, in two cases, co-existing with Ca and Mg in one case), which reportedly evokes mixed chronic and acute inflammation in peri-implant fibrous tissue (15).

Moreover, granulomatous reactions to Al compounds (Al_2O_3, AlOH) used as vaccine adjuvants are reported (18). Al_2O_3 particles, used for blasting of Ti implants have been shown to activate macrophages and have been incriminated for implant loosening (19).

Further, five of the present cases (5.9%) showed prominent fibrosis, sometimes encapsulating the foreign black material appearing as large fragments and fine granules.

Amalgam components were identified in four of these cases, one of which revealed additional Al and another Al and Si. The fifth case only showed minute black granules and crystals, but only Al was identified by EDXA.

A sequential process, starting with acute inflammation, giving way to a chronic condition and ending with fibrosis, occurs as a response to many foreign materials (17). Regarding amalgam, however, extensive investigations of experimental (20, 21) and biopsy (10) material showed that the size of the particles is a more important and decisive factor for the development of fibrosis than the time of exposure.

Thus, large pieces of amalgam induced encapsulation 4 weeks after implantation (20), while small amalgam particles elicited a granulomatous inflammation (10, 20, 21), persisting well beyond a year (20).

The present finding of fibrosis and encapsulation associated with large amalgam particles supports previous investigations (10, 20, 21), but the material is small, and a possible synergistic effect of crystalline foreign bodies in some of the cases, has to be considered.

Gordon and Daley (4) described prominently fibrous tissue in 5% of their cases of FBG, but did not mention the degree of associated inflammation, or relate fibrosis to particle size or elements identified by EDXA (4). Cases microscopically diagnosed as amalgam tattoo were not included in these investigations.

Age, sex and anatomical distribution

The age distribution in the present material covered a wide range (18–80 years) with a mean age of 50.3 years, in contrast to the prevalence of conventional gingivitis, which increases with age. This concurs with previous reports (3, 4; mean age 49.1 and 48 years, respectively). While Gordon and Daley (4) reported most cases in the age group of 41–50 years, our material showed approximately equal occurrence in the age groups of 41–50 years and 51–60 years, comprising 22.4% and 23.5% of the cases, respectively. The increase in foreign body lesions up to middle age can be attributed to increased exposure to dental materials. The subsequent decline may be due to a smaller old population, a reduced exposure to dental procedures due to increasing edentulism, or even a decreased susceptibility with age (4).

Concurrent with the only comprehensive previous report on foreign body gingival lesions of which 84% occurred in females (4), the present material showed a higher frequency of such lesions in females (68%) than in males (32%), with a ratio of 2.1:1.

This may be due to a higher tendency for females to seek dental and periodontal care and thus a greater exposure to dental materials (4). It has also been contemplated that females might be more prone and willing to consent to biopsy, and it has been reflected on the possible role of aggravating hormonal influences on gingival lesions in the female (4).

Similar age and sex distribution has been found for amalgam tattoos of the oral mucosa, including the gingiva (12).

While Gordon and Daley (4) did not find any predilection site for FBG, the present material showed the mandibular and maxillary posterior segments to be most frequently affected with foreign body gingival lesions (34% and 29%, respectively), followed by the maxillary anterior region (26%). This probably is attributable to the high frequency of dental procedures in these segments. Moreover, in a comprehensive investigation of amalgam tattoos, almost half were located on the gingiva with the mandibular region being more frequently affected than the maxillary region (12). The low occurrence (11%) of lesions in the mandibular anterior region can likewise be explained by the infrequency of dental procedures at this site.

The obligation of the pathologist

When presented with inflammation restricted to the gingiva refractive to conventional therapy, clinicians and pathologists should strongly consider a foreign body lesion. It has been pointed out that such lesions may mimic lichen planus both clinically and histologically (4). In atrophic and so-called erosive gingival lichen planus, lesions are susceptible to damage with disruption of the epithelium, and as in ulcerative forms, foreign material may easily get access to the tissue. Thus, a foreign body inflammation may be superimposed upon and a consequence of a pre-existing inflammation (4).

We have found support for this in a group of patients with both buccal and gingival lichen planus and lichenoid reactions, where the buccal lesions were microscopically well compatible with the clinical diagnosis, while in gingival lesions the presence of foreign material was taken to explain an aggravated and less characteristic inflammation (22).

While metal fragments may easily be observed by conventional light microscopy, metal granules and in particular crystals, which are optically clear, may be inconspicuous and easily missed. The pathologist should meticulously search for such elements when foreign body gingival lesions may be considered, and we strongly advocate the routine application of polarization microscopy in gingival lesions. Moreover, as the foreign material may be quite localized, the necessity of scrutinizing sections at various levels is emphasized.

The same applies for the differential diagnoses of foreign body granulomatous inflammation and granulomatous diseases such as Crohn's disease, sarcoidosis, tuberculosis and certain mycoses (4). In this context, attention should be drawn to the possibility of sarcoidosis developing in silica-containing scars (23, 24).

Some hold that EDXA, while desirable, is not required in the majority of cases of FBG, as the composition of the foreign material apparently does not influence the clinical appearance or prognosis (7). In our opinion, however, it is the obligation of the pathologist to render as complete and accurate a report as possible within practical limits, as also advocated by others (25).

Pursuing this aim and attempting to trace the origin of the foreign material, the clinician and through him also the patients may be alerted to prevent the introduction of foreign material into the gingival tissues.

Prophylaxis

Thus, care should be taken to minimize such introduction to tissues denuded during dental procedures (26) or weakened or ulcerated due to conditions such as lichen planus (4) or pemphigoid.

The clinician should aim at avoiding traumatization of gingivia when inserting, trimming and polishing restorations. Likewise, the application of abrasive tools and materials adjacent to the gingiva should be kept at a minimum and with great care. Prophylactic procedures performed professionally or self-administered should be performed with caution, and ample time interval allowed for healing after periodontal procedures before prophylactic polishing is carried out (5). In particular, the application of air flow with abrasive components (e.g. silica) must be considered potentially hazardous.

Therapy

The importance of biopsy to establish the diagnosis in cases of gingival lesions refractive to conventional therapy is emphasized. A cautious attitude as to stripping foreign body gingival lesions has been suggested, as the lesions may regress with time, much as may an amalgam tattoo (10, 12). Not surprisingly, topical steroid application has apparently not caused any lasting relief of symptoms (7). Surgical excision has been recommended by others (27). We concur with this view and advocate that at least localized foreign body gingival lesions should be excised if foreign material can be expected to remain, and this approach should also be considered for more extensive lesions.

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