JOURNAL OF FORENSIC SCIENCES

J Forensic Sci, September 2012, Vol. 57, No. 5
doi: 10.1111/j.1556-4029.2012.02225.x
Available online at: onlinelibrary.wiley.com

CASE REPORT

GENERAL; ODONTOLOGY

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Identification of a Tooth-Like Foreign Body in Swine Sausage*

ABSTRACT: A tooth-like foreign body (FB) was found inside a sausage bread. Analysis aimed to investigate whether the FB was a tooth and its origin. The FB was measured, weighed, photographed, and radiographed. Macroscopic findings were suggestive of an anterior tooth. Histological slides of undecalcified cross-sections of the FB and samples of human and swine teeth were prepared. Histological features of the FB (in light microscopy, 125× magnification) were discrepant from human tissues. Compared histological analysis displayed majority of features consistent with a hypsodont swine tooth, probably a canine. Cellularized cementum in crown region, adjacent to the enamel, and shape of the cementocytes were the main criteria excluding the possibility of human origin of the FB. Scanning electronic microscopy and energy-dispersive spectroscopy were not performed because of fewer features to be analyzed and FB size. It was concluded that the FB may have been incorporated during meat grinding of the sausage.

KEYWORDS: forensic science, forensic dentistry, food analysis, histology, compared, microscopy, food security

Considering the legislation and expectations of customers for good-quality products, the manufacturing of industrialized foods must meet sanitary standards for food security. The industry is responsible for providing foods that do not pose risks to customers' health. It should avoid allowing food containing foreign bodies (FBs) to be sold, or, subsequently, FBs must be detected and the food removed from the market. FBs can be defined as "any material not belonging to the product, related to inadequate conditions or practices of production, storage or distribution" (1).

Despite technological advances, some contamination always occurs, and controlling it is the subject of multidisciplinary research sponsored by the industry (2). Visual inspections made by humans can be affected by factors such as the age of the observer, motivation and concentration, fatigue, visual acuity, and local conditions such as lighting, temperature, ventilation, and noise (2). There are many automated methods for the detection of FBs in food during the production phase, such as thermal imaging (2), metal detection by coils, magnetic fields, automated optical techniques (analysis of wavelengths), radiographic inspections (3), electrostatic techniques, microwaves, semi-infrared, ultraviolet images, ultrasound, and magnetic resonance imaging and fluorescence (4).

Sometimes, these technologies are not sufficient to prevent foods containing FBs from being consumed. For the industry, such failures can lead to unwanted situations such as downtime on production lines to investigate the origin of FBs, consumer complaints that may tarnish the reputation of the company, or product recalls, with high costs and lawsuits (5). For consumers, foods containing FBs represent risks to health, such as infections, asphyxia (6), and damage to the digestive system (injuries and perforations of the walls of the gastrointestinal tract) and the stomatognathic system (damage to the oropharyngeal and oral soft tissues, tooth fractures, fractures of dental prostheses, and their consequences).

The purpose of FB analysis is to rapidly identify the object and its probable origin: the production process, packaging, raw materials, storage, and whether it was already in the food or was introduced into the food by the consumer during consumption (inadvertently or purposely) (7).

FBs that can be found by customers include material from the packaging of food (e.g., pieces of glass and plastic), material formed after storage for prolonged periods (e.g., flocculation in flour), material related to food that should not be part of the final product (e.g., seeds, leaves, and twigs in juice), parts of machinery used in industrial processes (e.g., screws and other parts), synthetic fibers (e.g., nylon, pieces of rope), human or animal hair, animals, whole or in parts (e.g., mites, insects, and rodents), animal excrement (e.g., rodent urine and feces), and materials of unknown origin with no apparent relationship with the product. Analysis and identification of FBs usually is performed with light microscopy and/or stereomicroscope, scanning electron microscopy (SEM), and energy-dispersive spectroscopy (EDS) (5).

The study investigated a tooth-like FB (Fig. 1), found by a customer inside a ground sausage *croissant*. The bread maker collected the food and the FB. After communication with the sausage maker, it was hypothesized that a failure in the manufacturing of this ingredient (which is made with several pieces of ground pork, including head cuts) could be the cause of the

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*Presented at the 10th Brasil Forense Congress, October 27–29, 2010, in Cuiabá, MT, Brazil.

Received 5 April 2011; and in revised form 20 June 2011; accepted 25 June 2011.

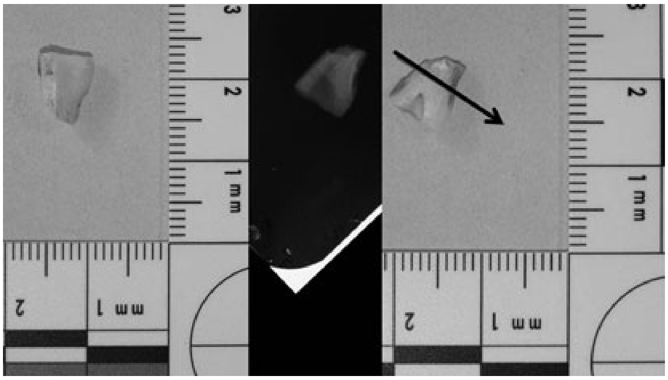

FIG. 1—*Macroscopic view of both sides of the foreign body (FB). Radiograph of the FB. Arrow indicates the direction of the cross-section of the resulting slide.*

FB. The manufacturer of the *croissants* requested a technical analysis of the FB from the Forensic Anthropology and Odontology Laboratory at the University of São Paulo (OFLAB-FOUSP). Along with the FB, a preliminary report from a laboratory specialized in food analysis was sent. In this document, the biologist in charge stated that the FB was a human tooth (determined through a "microscopic analysis methodology," without specifying histotechnical or observational methods). The objective of the analysis was to determine whether the FB was tooth tissue and, if so, to identify its possible origin, whether human or animal. Concerning tooth-like FBs found in sausages, there are few systematic studies in the literature. A case has been reported (8), but the larger size of the FB allowed identification through comparative anatomy (possibly a swine molar root) confirmed by SEM. In this case, this type of analysis would be impracticable owing to the FB's smaller dimensions.

Methods

The FB weighed approximately 0.19 g and measured 8.4 × 6.5 × 3.3 mm. The fragment was photographed and radiographed. Despite the preliminary report, no type of histotechnical preparation was found in the FB (as it was sound), suggesting previous analysis by stereomicroscopy. The FB was embedded in colorless acrylic resin, and a precision cutter LabCut 1010 (Enfield, CT) was used to obtain cross-sections (Fig. 1) of about 120 μm. Then, some sections were ground manually according to the methodology proposed by Maat et al. (9). Additionally, some sections were cleaned in distilled water, 17% EDTA solution, and 0.5% sodium hypochlorite (Dakin's) solution (to prevent the smear layer of the grinding process from hampering microscopy observations), progressively dehydrated in 70% and absolute alcohol, and then mounted on glass slides. For the purposes of control and comparative histomorphologic analysis, the same procedure was performed on human extracted teeth (for elective treatment) and swine teeth. Human teeth were obtained from the OFLAB tooth bank and swine teeth from a local butcher. The FB was compared to pork samples because of the manufacturing methods of the sausage (described above) and human samples because of the result of the preliminary report. The slides were analyzed using light microscopy and photomicrographed.

Results and Discussion

Macroscopically, the FB analysis showed format and color features consistent with a tooth crown. A triangular shape was noticed in the longitudinal direction, from base to vertex, suggestive of an anterior tooth crown (shape discrepant from posterior, rectangular/trapezium-shaped teeth). The surface of the FB was smooth with sharp edges, suggestive of an anterior tooth and incompatible with a cusp or posterior tooth occlusal table. There was a fractured portion of the FB, exposing its hollow core, suggesting the presence of a pulp chamber (still following the previously reported triangular shape, from base to vertex). Radiographic examination (Fig. 1) showed the presence of structures with different radiotransparencies, suggesting enamel (outer and more radiopaque layer) and dentin (the underlying layer, more radiolucent), with a radiolucent structure compatible with a pulp chamber (center). A histological section (Fig. 2) showed the presence of three hard dental tissues: enamel (outer periphery, broader layer, yellowish), dentin (dark central portion) with the pulp chamber and remnants of pulp, and cementum (outer portion of the periphery, smaller than the enamel and dentin in area and lighter in color), confirming that it was tooth tissue. The shape of the cross-section and the pulp chamber is also triangular. Samples of the enamel, dentin, and cementum of the FB, swine, and human can be seen in detail at 125× magnification (Figs 3–5).

Microscopic analysis of the FB was based on direct comparative features between the specimen and samples of known origin. References indicating the histological differences between human and swine dental mineralized tissues were also consulted for guidance (10–14).

Histological Results

Enamel—There were enamel rods oblique to the underlying dentin, as in the swine and human samples (Fig. 3). There were neither Hunter-Schreger bands nor Retzius *striae* in any sample, probably due to the transverse direction of the cuts. The path of the rods of the FB is similar to the pork crown sample (slightly oblique) and less sinuous than the human crown sample. There were few intersections of rods in both the FB and pork crown samples, unlike the larger number of intersections in the human sample, suggesting that the FB enamel was most likely swine (13).

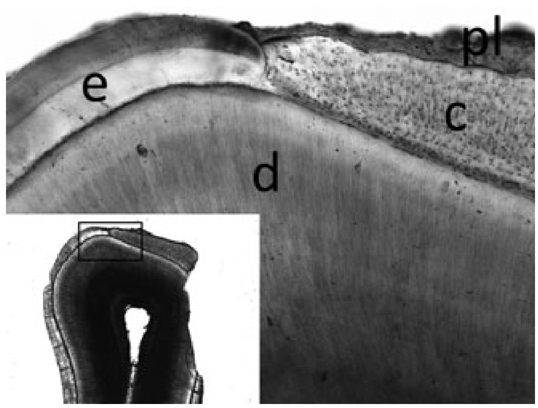

FIG. 2—*Histological cross-section slide of the foreign body (FB), showing a fracture and the presence of a pulp chamber with remnants of pulp tissue (lower left) and enamel (e), dentin (d), cementum (c), and periodontal ligament (pl) (in 125× magnification. Rectangular area on the lower left shows FB at 63× magnification).*

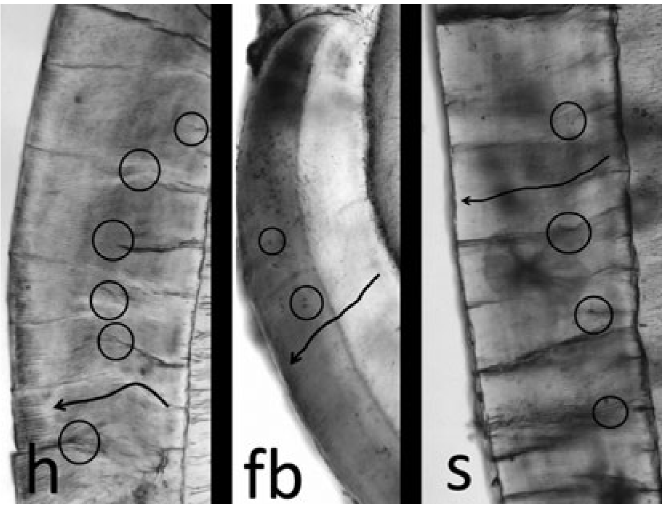

FIG. 3—*Human (h), foreign body (fb), and swine (s) samples of enamel. Circles indicate rod intersections and arrows indicate the sinuosity of the rod arrangement (detail of 125× photomicrographs).*

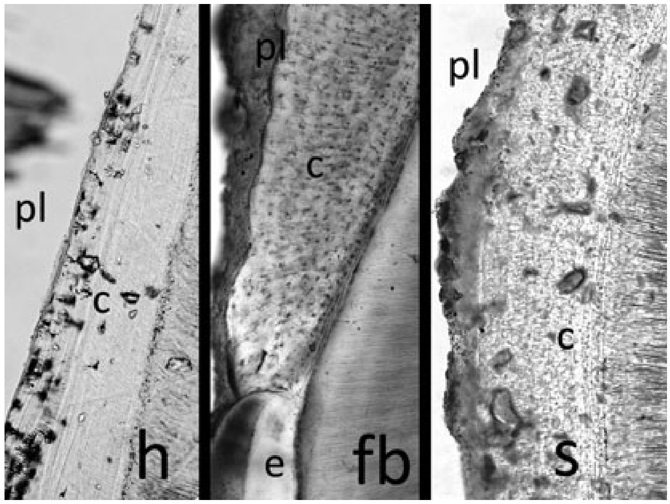

FIG. 5—*Human (h), foreign body (fb), and swine (s) cementum samples. Note the likeness between the shapes of the cementocytes (c) as well as the periodontal ligament remnants (pl) in "s" and "fb" and the discrepancy with "h." Enamel (e) adjacent to the cementum suggests a hypsodont tooth (detail of 125× photomicrographs).*

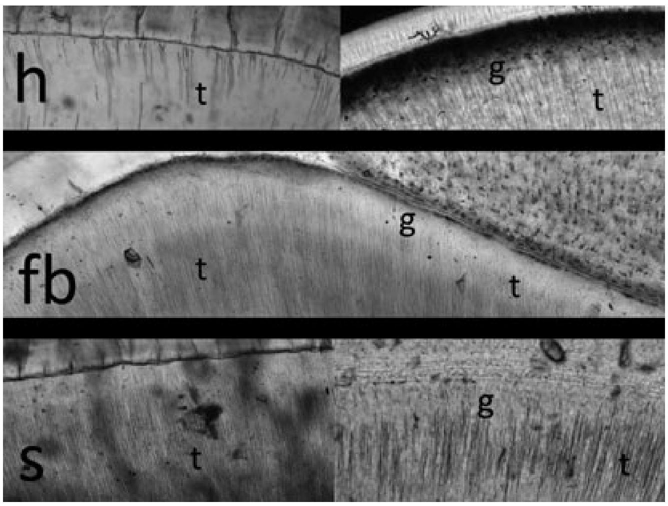

FIG. 4—*Human (h), foreign body (fb), and swine (s) samples of dentin. "H" and "s" crown samples are on the left, root samples on the right. Note the similarity between the "fb" and "s" tubules (t) and the discrepancy between the "h" and "fb" Tomes' granular layer (g) (detail of 125× photomicrographs).*

Dentin—The samples of known origin and the FB displayed homogeneously distributed dentinal tubules with few ripples (Fig. 4). The similarities between the quantity, pattern, and distribution of the canaliculi between the swine sample and the FB is higher than in the human sample. In all the samples, interglobular Czermak spaces could not be viewed in the region adjacent to the dentin–enamel junction.

In the cementum–dentin junction area, Tomes' granular layer of the FB and the swine sample was viewed in a discrete manner, with a few small dark spots, scattered and nonconcentrated. This pattern is different from that seen in the human sample, with black spots of larger size that were more focused and more frequent. The FB's dentin featured swine characteristics.

Cementum—The presence of cellularized cementum was noticed in the coronal portion (Fig. 5) adjacent to the enamel, characteristic of swine hypsodont teeth (specifically the canines) (10,11,14). By observing the morphology of the cementoblasts of the FB, similarities with the swine root sample were found, namely clear oval-elongated cells with short extensions. As for the human cementocytes, a discrepancy was noted, as the sample had darkened cells of more extensive and numerous extensions. There were similarities between the remnants of the periodontal ligament present in the cementum of the FB and the pig's (greater and more irregular thickness than the human sample).

The FB showed a majority of the histological characteristics of swine tooth, and this hypothesis was confirmed in the observations. Histological characteristics are similar to swine tooth and/or human discrepant in all analyzed tissues.

The presence of cellularized cementum in the coronary region adjacent to the enamel and the morphology of cementocytes were the main elements excluding the possibility of human origin of the FB. The presence of enamel and cementum together in the crown was decisive characteristics for the differential diagnosis of hypsodont tooth. In humans, the cervical third of the roots presents acellularized cementum only, with the visualization of cementocytes not being expected. Cellularized cementum is viewed from the middle to the apical third of the root. In pigs, the same would be expected, except for the canines. In these animals, the canine teeth are hypsodont, that is, they have no defined crown or neck but an elongated body that is continuously mineralized through the production of three mineralized dental tissues, erupting throughout the life of the animal and being ground during the cutting, laceration, and apprehension of food (10,11). This provides an explanation for the finding of cellularized cementum adjacent to the enamel. The presence of enamel only on one side (compatible with the buccal face) and cementum on another (compatible with the lingual face) allows us to exclude it as the cusp of a molar or premolar tooth and characterize it as a canine pig tooth. Knowledge of veterinary dental anatomy and histology, in addition to human characteristics, was essential to the analysis of the FB.

Owing to the small size of the FB, it was preferable to analyze it in a series of histological sections rather than metalizing the entire sample in comparison with human and swine teeth in

SEM. This would limit the number of characteristics analyzed as well as make the investigation process more expensive and critical, as biological materials are more difficult to prepare for SEM. Furthermore, the literature pointed to the differential characteristics of pigs observed in light microscopy, which was also decisive in choosing the method of analysis. The methodology of EDS would have had limited utility as all three of the samples had very similar chemical compositions. In addition, the application of simpler, faster, and cheaper means to identify the FB is preferred, proceeding to more complex methods only in case of inconclusive results for the initial techniques.

When investigating FBs, knowing the process of making food can be essential. Owing to the crushing of parts of pigs' heads during sausage preparation, it is possible that a tooth fragment was incorporated into it accidentally. Despite making the food unfit for human consumption, the presence of swine dental fragments can be interpreted as a less serious flaw than others, pointing to an error in the separation process of the ground meat. Usually, this problem can be solved with corrections of a technical nature. The finding of a human tooth, as mistakenly indicated in the preliminary report sent with the FB, would imply more serious consequences, indicating nonobservation of best practices for food production and sanitation. Solving this problem would require broader and more expensive actions to correct technical operational failures (often interrupting the production line) and train staff appropriately, aimed to establish adequate levels of food security.

The most recent available report of the National Sanitary Quality Monitoring of Food Program (2004–2005) on the website of the National Agency for Sanitary Surveillance (ANVISA-Brazil, http://www.anvisa.gov.br/alimentos/programa/etapa%204/categorias/linguica/padrao_sanitario_regiao.pdf, last accessed November 9, 2010) points out that, in regions where the sausage producer has factories (southern and central-western Brazil), up to 18.4% of analyzed sausage samples did not comply with the required sanitary standards. This finding strengthens the hypothesis that, during the manufacture of food, among the nonconformities pointed out in the report, situations in which the accidental incorporation of FBs (such as swine teeth) may occur, as reported in another study (8).

To illustrate the relative frequency of FBs found in sausages, a search performed on a Brazilian website specializing in consumer complaints against companies (www.reclameaqui.com.br, last accessed March 22, 2011) using the term "linguiça" (sausage, in Portuguese) returned at least four results indicating complaints of finding FBs in this food (needle, wire, tooth-like material, plastic, and metal).

On the basis of the histomorphological characteristics of the FB, human, and swine control samples, a predominance of swine tooth tissue characteristics was detected, with cellularized cementum adjacent to the enamel. It was concluded that the fragment analyzed was a hypsodont tooth of swine origin, probably a canine, presumably introduced into the food during its manufacture. A report was written and sent to the manufacturer of the *croissants*.

The investigation and identification of tooth-like FBs can be very useful to food companies. It can be performed by forensic dental laboratories, which conduct technical studies and analysis of dental tissues. This case illustrates an increasing area of activity in Brazilian forensic odontology.

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