Radiodensity of enamel and dentin of human, bovine and swine teeth

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Summary Several studies have aimed to evaluate the characteristics of hard dental tissues from animal species in order to adequately substitute the usage of human teeth. The purpose of this study was to evaluate the radiodensity of enamel and dentin of human, bovine and swine teeth. Five specimens of 2 mm in thickness were obtained from human, bovine and swine teeth and the radiographic images were taken positioning it on a phosphor plaque digital system, Digora (Soredex, Helsinki, Finland). The radiodensity of each specimen was obtained and data were compared by ANOVA following Tukey test (P < 0.05). The results showed that human and bovine enamel presented similar radiodensity, which was higher than the one from swine enamel; bovine and swine dentin presented similar radiodensity, and only bovine dentin presented greater similarity to human dentin. Bovine teeth seems to be more similar to human teeth in respect to radiodensity.

Introduction

Dental hard tissues characteristics are the principal factor when analysing the possibilities of substituting the usage of human teeth by animal teeth on in vitro researches. The more animal teeth are similar to human ones the valuable and significant will be the results of any research. Previous introductory anatomical and histochemical researches have revealed that all mammalian teeth are essentially similar. As a substitute for human teeth, bovine permanent incisors have been employed on adhesion tests on microleakage tests, on trace elements studies, and on studies headed to identify its morphologic characteristics. In spite of the fact that there is still some concern whether data obtained from animal teeth can be applied to human teeth and to the clinical situation, ethics committees have stimulated the substitution of human teeth.

One of the clinical important properties of teeth or restorative materials is the radiopacity. The radiopacity of dental material has become important to clinicians, especially for secondary caries diagnosis and marginal defects detection.
radiopacity degree required for ideal clinical performance has been established according to the composition of the material. Voids, marginal defects, or recurrent caries are best detected when the radiopacity of the restorative materials is close to match the radiopacity of dental enamel.\textsuperscript{15,16} Since 1987, alternatives to silver-halide receptors for intraoral radiographic imaging have included CCD-based systems,\textsuperscript{17} and more recently, storage phosphor technology has been applied.\textsuperscript{17} Digital intraoral radiography reduces patients’ exposure to X-rays,\textsuperscript{18} permits the improvement of image quality by image manipulation,\textsuperscript{19} it is faster and cheaper than conventional techniques and easy to use.\textsuperscript{19}

To the best of our knowledge no data are available on the radiographic characteristics of bovine and swine hard dental tissues compared to human teeth. Therefore, the aim of this study was to determine the radiodensity of enamel and dentin of human, bovine and swine teeth employing a digital phosphor plate radiographic system.

Materials and methods

Ten human third molars, 10 bovine central incisors and 10 swine central incisors, recently extracted were selected and stored in 0.2% tymol. All human teeth were collected after patients had signed an informed consent, in accordance with the ethics committee of Federal University of Uberlândia. The teeth were sectioned transversally with a diamond saw (KgSorensen, Barueri, Brasil) and ground with a 600-grit silicon carbide paper under a stream of running water in order to produce superficial dentin samples of 2 mm in thickness, or enamel samples of 2 mm in thickness. The samples were divided into six groups ($N=5$): G1, human enamel; G2, bovine enamel; G3, swine enamel; G4, human dentin; G5, bovine dentin; and G6, swine dentin. The samples were then positioned over a phosphor plate and the radiographic exposition was performed using an X-ray machine—GE 1000 (General Electric, Milwaukee, USA)—exposing it for 0.2 s at 70 kV and 10 mA, with a source-to-sample distance of 40 cm. Three exposures were performed for each sample. The radiographs were transferred from the phosphor plate to the computer via Digora scanner (Digora, Soredex, Helsinki, Finland).

The radiodensity of the samples were determined with the resident software provided by the manufacturer. The Digora system has an windows based software, Digora for Windows 2.0, that is capable to measure density curves of digital radiographies obtained by X-ray impregnation on the image phosphor plate. Each digital image had its radiodensity measured immediately after scanning, without any modification in contrast or brightness. This software shows data concerning the highest and the lowest radiodensity of the sample, and an average value, which was considered to be the sample’s initial radiodensity. Since each sample was submitted to three exposures the sample’s final radiodensity was considered to be the mean among those values. As the data presented a normal and homogeneous distribution, one-way ANOVA following Tukey test ($P < 0.05$) was employed on the statistical analysis.

Results

ANOVA results showed differences on enamel and dentin radiodensity among the experimental groups, being the enamel radiodensity always higher than dentin radiodensity. When comparing enamel groups (Fig. 1), Tukey test ($P < 0.05$) showed that human and bovine enamel presented similar radiodensity, which was higher than the one from swine enamel (Table 1). For dentin (Fig. 2),

![Figure 1 Digital radiograph of human (H), bovine (B) and swine (S) enamel.](image)

<table>
<thead>
<tr>
<th>Enamel</th>
<th>Radiodensity (pixels) compared by Tukey test ($\alpha = 0.05$).</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Enamel Radiodensity values (S.D.) Statistical category</td>
</tr>
<tr>
<td>Human</td>
<td>70.52 (3.37) A</td>
</tr>
<tr>
<td>Bovine</td>
<td>66.94 (3.99) A</td>
</tr>
<tr>
<td>Swine</td>
<td>45.77 (4.83) B</td>
</tr>
</tbody>
</table>

Different letters means statistical significant differences ($P < 0.05$).
Tukey test ($P < 0.05$) showed that bovine and swine dentin presented similar radiodensity, and only bovine dentin presented greater similarity to human dentin (Table 2).

### Table 2 Dentin radiodensity (pixels) compared by Tukey test ($\alpha = 0.05$).

<table>
<thead>
<tr>
<th>Dentin</th>
<th>Radiodensity values (S.D.)</th>
<th>Statistical category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td>50.73 (7.99)</td>
<td>A</td>
</tr>
<tr>
<td>Bovine</td>
<td>45.24 (3.57)</td>
<td>AB</td>
</tr>
<tr>
<td>Swine</td>
<td>42.36 (3.70)</td>
<td>B</td>
</tr>
</tbody>
</table>

Different letters mean statistical significant differences ($P < 0.05$).

Discussion

When an X-ray beam interacts with the matter the X-ray photons are either absorbed by its atoms or scattered without loss of energy. The photoelectric effect is considered to be an example of the absorption phenomena, and it is responsible by 30% of the interaction of X-ray photons with the matter; the Compton effect is an example of the scattering phenomena and approximately 62% of the photons undergo Compton interactions. Irrespective of the type of X-ray-to-matter interactions, it is always directly proportional to either the atomic number of the absorber or to its electric density. Thus, depending on the atomic composition of the matter the radiodensity of a radiographic image will be differently influenced. Besides atomic composition, the density of each atom in the matter, its physical structure and its thickness may also influence radiodensity. In this study a 2 mm standardised thickness of the samples ensured the elimination of this factor on the final radiodensity of tooth structures. Thus, the differences could only lie on the atomic composition, density of atoms and physical arrangement of each tissue.

Human dental enamel, which is the hardest tissue in the body, is composed by 92–96% of inorganic matter, 1–2% of organic material and 3–4% of water in weight. Most of the inorganic matter is $Ca_{10}(PO_4)_6(OH)_2$, hydroxyapatite, but other atomic elements can be detected as P, Cu, K, Cl, Zn, Fe, Ti, Sr, V, Mn and Zr. On the other hand, human dentin has a reduced inorganic content and is considered to be a hydrated biological composite composed of 70% inorganic material, 18% organic matrix, and 12% water (wt.%). These different composition not only affects the mechanical properties of each tooth tissue, but since teeth of different animal species may have different composition, radiodensity of tooth structures are also expected to be influenced.

At this point, literature is too contradictory. Some authors state that all mammalian teeth are essentially similar, but Rizzutto et al. concluded that the trace element concentration in the enamel of human and swine teeth are more similar to each other than to bovine teeth. Lane and Peach found different trace elements in human enamel, varying sex, age and geographical location. Vernois et al. postulated that individual’s general metabolism has a determinant effect on the composition of human enamel. These facts suggest that animal teeth may similarly vary their composition according to the same parameters. Thus, although the results from the study of Rizzutto et al. indicates the possibility of a greater similarity between human and swine enamel, it was not a surprisingly finding that human and bovine enamel presented similar radiodensity, which was higher than the one from swine enamel.

In relation to dentin, there are no studies comparing the composition of human, swine and bovine ones. However, according to Schilke et al. bovine and human dentin have similar number and diameter of coronal dentinal tubules, and this fact would ensure, at least form the aspect of physical structure, similar radiodensity, as observed in this study. Swine and bovine dentin presented similar radiodensity, but only bovine dentin was considered to be similar to human dentin. Probably the composition of bovine and human dentin is more similar to each other than to swine dentin.

The results of this study indicates that although bovine and swine teeth presented always lower values of radiodensity when compared to human tooth, bovine ones can substitute in a more reliable manner human teeth in studies that employ the
analysis of radiodensity. For sure, there is still the necessity of establishing standardised parameters in order to collect animal teeth that would present better radiodensity similarity than human ones. This is a pioneer study that emphasises the possibility of employment of animal teeth in radiodensity researches and certainly requires more studies. New studies will now search to answer how important should be to obtain teeth from animals of the same sex, age, geographic location and alimentation.

References