Original Article

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Human teeth *versus* bovine teeth: cutting effectiveness of diamond burs

Laiza Maria Grassi Fais[1], Caroline Canhizares Marcelo[1], Regina Helena Barbosa Tavares da Silva[2], Dalton Geraldo Guaglianoni[3], Lígia Antunes Pereira Pinelli[2]

[1]MSc, Department of Dental Materials and Prosthodontics, Araraquara Dental School; São Paulo State University, Brazil
[2]PhD, Associate Professor, Department of Dental Materials and Prosthodontics, Araraquara Dental School; São Paulo State University, Brazil
[3]MSc, Professor of Statistics, Mathematics and Statistics Department, Araraquara Science and Language School, São Paulo State University, Brazil

Abstract

Aim: In this study, a mass-loss method was used to verify whether bovine enamel has the same wear pattern as human enamel in cutting efficiency tests of diamond burs. **Methods**: Seventy-two teeth were used: 36 human molars (HT) and 36 bovine mandibular central incisors (BT). The enamel of the teeth was cut using diamond bur #1092 attached to a high-speed handpiece under controlled pressure (50-80 g). Each bur (n=12) cut for a total of 72 min, divided into 6 periods of 12 min each (12-min, 24-min, 36-min, 48-min, 60-min, and 72-min). The amount of enamel removed was determined by the difference between pre- and post-cut tooth masses. **Results:** The mean amounts (g) of enamel removed were: HT- 12-min=0.11; 24-min=0.12; 36-min=0.11; 48-min=0.11; 60-min=0.10; 72-min=0.12; BT- 12-min=0.12; 24-min=0.15; 36-min=0.15; 48-min=0.13; 60-min=0.16; 72-min=0.14. Data were analyzed using ANOVA followed by Tukey's test, and the results showed statistically significant differences between human and bovine teeth (p<0.001) and among the cutting periods (p<0.001).**Conclusions:** It was concluded that the cutting efficiency of the burs was different between the tested substrates, and that bovine enamel underwent greater mass loss than did human enamel.

Keywords: teeth; dental enamel; cattle; efficiency, diamond.

Introduction

The development of dental materials and technologies over time has facilitated the use of new clinical techniques, including rotary instruments. A new metallic binder between crystals and adhesion systems of diamond burs of different sizes and shapes has been introduced to increase their efficiency[1]. In this context, studies have been conducted to analyze the cutting efficiency of diamond burs, and particularly, their service life cycle when submitted to frequent use and sterilizing processes[2-3].

Several studies have been performed on extracted human teeth to analyze different dental materials and instruments[4-8]. However, the use of human teeth in laboratory research has been restricted due to ethical limitations, difficulty in obtaining the appropriate sample size and impossibility of standardization[9-10].

In an endeavor to find an ideal substitute for human teeth, enamel and dentin from different animal species, such as bovine and swine, have been used as substitutes for human substrates, since mammalian and human teeth are morphohistologically similar to each other, but the constant use of bovine teeth in dental research has stimulated a number of studies seeking to certify their suitability[11- 12].

Some of these studies have focused on enamel and dentin demineralization[13-

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Correspondence to:
Lígia Antunes Pereira Pinelli
Faculdade de Odontologia de Araraquara - UNESP
Rua Humaitá, 1680- 14801-903
Araraquara-SP, Brasil
Phone: +55 16 3301-6413 / Fax: +55 16 3301-6406
E-mail: ligia@foar.unesp.br

[15]. Other investigations have compared various properties, such as microhardness[16] and tensile strength[6], and several studies have been performed to examine whether bovine teeth could be used as substitutes for human teeth when testing different bonding methods or bonding substrates[5,7-9,17-20].

There has been extensive research into analyzing the effectiveness of rotary cutting instruments[21-25], but limited work has been done as regards comparisons between human and bovine teeth as substrates for these types of experiments. Therefore, considering the difficulty in obtaining human teeth for laboratory research, the aim of this study was to evaluate, by a mass-loss method, whether bovine enamel has the same wear pattern as human enamel in cutting efficiency tests of diamond burs. The null hypothesis was that bovine enamel has the same resistance to abrasion as human enamel.

Material and methods

Specimen Preparation

In this study, approved by the Research Ethics Committee, Araraquara Dental School,São Paulo State University, under the certificate #9102, freshly extracted human molars (n = 36) and bovine central incisors (n = 36) were used. The recently extracted human teeth were cavity-free, and the patients' permission and authorization were obtained to use them. The recently extracted bovine teeth were obtained from a slaughterhouse. Both human and bovine teeth were stored in 10% formaldehyde for 24 h for disinfection[26]. Afterwards, they were stored in distilled water under refrigeration to prevent dehydration. The remaining periodontal ligament and calculus were removed with periodontal curettes, and the teeth were submitted to prophylaxis with pumice-stone and water using a Robinson brtistle brush (KG Sorensen, Barueri, SP, Brazil).

The teeth were analyzed under a Zeiss stereoscopic magnifying glass (×10) (model 475200/9901, Jena, West Germany, Germany) in order to detect possible cracks or structural alterations that could lead to experimental errors. The areas that were not involved in the experiment were coated with nail varnish to avoid any alteration in the real mass of teeth. After this phase, the teeth were kept in distilled water at 37ºC.

Experimental Groups

Twelve cylindrical shaped diamond burs (KG Sorensen # 1092) were used: 6 for the human teeth (HT) and 6 for the bovine teeth (BT). The human tooth crown was divided into six abrasion zones: mesiobuccal (zone 1), distobuccal (zone 2), distal (zone 3), distolingual (zone 4), mesiolingual (zone 5) and mesial (zone 6) (Figure 1). Because the bovine teeth were central incisors, only the buccal surface was divided into six parts (Figure 1). Statistics indicated the need for division of the tooth surface, so that the cut by the diamond burs would be similar in human and bovine teeth.

For both, HT and BT, six repeated cutting periods were evaluated in accordance with the time of abrasion of 12, 24, 36, 48, 60 and 72 min. Six teeth were used for each period.

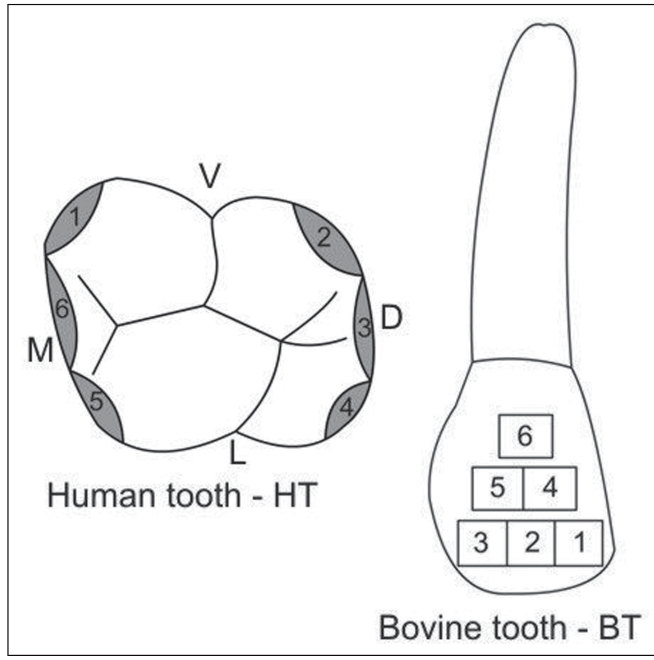

Fig. 1. Zones for cutting in human teeth (HT) and bovine teeth (BT).

Abrasion Test and Mass-loss Method

A mass-loss method was used to measure the amount of enamel abraded by the diamond burs. Immediately before the cutting, each tooth was cleaned under running water and dried with a 30 s air stream and weighed on an analytical scale (Sartorius-Werke AG, Gottingen, Germany) with capacity of 200 g and accurate to 0.0001 g; thus obtaining the initial mass.

A sensitive cutting pressure device was used during the cutting of the teeth because it allows a standardized pressure during the test. This machine is equipped with an alarm that would go off if the cutting pressure was outside the range from 50 to 80 gf[27].

The diamond burs were attached to a high speed handpiece (Dabi MS 350, Gnatus Medical and Dental Products Ltd., Ribeirão Preto, São Paulo, Brazil) at 350,000 rpm, and applied for 2 min in each of the tooth zones, according to the following order and sequence: bur #1 was applied for 2 min in zone 1 of tooth 1, then for 2 min in zone 1 of tooth 2, 2 min in zone 1 of tooth 3, and so on, until the six teeth of the 12-min period had been abraded, totalizing 12 min of use of bur #1. Thereafter, bur #2 was applied for 2 min in zone 2 of tooth 1, then for 2 min in zone 2 of tooth 2, 2 min in zone 2 of tooth 3, and so on, until the six teeth of the 12-min period had been abraded, totalizing 12 min of use of the bur #2. These procedures were repeated with burs #3, 4, 5, and 6. The teeth were then cleaned, dried and reweighed. The difference between the final and initial mass represented the amount of enamel removed during the 12-min cutting period.

All burs were then cleaned with steel brush under running water and applied to other the six teeth, which were selected for the 24-min cutting period, using the same order and sequence described above. After that, these teeth were cleaned, dried and reweighed, thus obtaining the amount of enamel removed during the 24-min cutting period.

These procedures were repeated until all burs had been used to abrade all the 36 teeth (human and bovine), so that the amount of enamel removed during each cutting period, as well as the total amount of wear (12-min + 24-min + 36-min + 48-min + 60-min + 72-min), could be obtained. Data were entered to the Excel software and analyzed by 2-way ANOVA and Tukey's post-hoc tests for statistical comparisons ($\alpha = 0.05$).

Results

Table 1 shows the results of ANOVA for the effect of the type of teeth and cutting period on enamel mass loss All p values of probability were lower than 0.05 ($p<0.05$), showing that the human dental enamel differs from bovine dental enamel, and that the amount of cut varies over time. The p value for interaction between the two main factors (*tooth type* and *cutting period*) was also lower than 0.05 ($p<0.05$).

The total mass loss of human and bovine enamel after 72-min cutting was 0.6725 g and 0.8520 g, respectively. The mean mass loss values for the 12-min cutting periods are shown in Figure 2. For the factor *cutting period*, there were statistically significant differences between the 12-min and 24-min, 12-min and 36-min, 12-min and 60-min, 12-min and 72-min, 24-min and 48-min, 36-min and 48-min, 48-min and 60-min, and 48-min and 72-min periods.

Table 1. Two-way ANOVA for mass loss.

Variation source	SS	df	MS	F value	P
Cutting periods	0.005257	5	0.001051	22.59825	<.001
Teeth	0.032213	1	0.032213	692.3923	<.001
Interaction	0.013671	5	0.002734	58.76903	<.001
Residue	0.006141	132	4.65E-05		
Total	0.474374	503			

*$p<0.01$ – highly significant difference.

Discussion

Intensive research has been conducted to verify the cutting efficiency and durability of the diamond burs using human enamel and dentin[28-30]. It has been difficult to conduct such studies due to the limited amount of the available material used to prepare the samples. Several articles have reported that bovine teeth are an alternative for replacing human teeth[6,20] because they have a similar microscopic structure[5,17] and are easily obtained in large number[31], and because the size of bovine mandibular incisors allows more than one sample to be prepared from one tooth[15]. Furthermore, there are ethical concerns involving the use of human teeth[31], which have led many investigators to search for materials that can be used as a substitute for human teeth in several tests, without compromising the quality of the results. However, other studies have pointed out some discrepancies between the values obtained in adhesion[18], shear bond strength[7] and tensile bond strength[19] tests applied to human and bovine teeth[7,18-19].

In this study, a highly significant statistical difference was observed when the mass loss of human and bovine enamel was compared (Table 1). Bovine enamel showed greater mass loss than human enamel, which suggests that the former is less resistant than the latter. Human enamel, which is the hardest tissue in the body, is composed of 92-96% inorganic matter, 1-2% organic material and 3-4% water by weight[32]. Most of the inorganic matter is $Ca_{10}(PO_4)_6(OH)_2$ hydroxyapatite. At a microstructural level, enamel consists of mineral-rich prisms of 3-6 mm cross-sectional diameter embedded in a matrix of inorganic and organic components[33]. Human enamel has a slightly lower density, and a lower Vickers hardness, but shows a slightly higher calcium and phosphorus content when compared with bovine enamel[13]. Although there are some minor quantitative differences with respect to calcium content, an analogous behavior of calcium distribution from outer to inner levels of human and bovine enamel has been observed. Bovine enamel reveals a higher porosity with larger crystals than human enamel[13], and this aspect might explain why, in this study, bovine enamel was more easily abraded than the human enamel.

According to Fonseca et al.[12] human enamel shows low interprismatic substance and distinct prisms while bovine enamel has a larger amount of interprismatic substance with an indicative appearance of the presence of fibrils. According to the authors, this difference would be explained by the possibility of the collagen fibrils not having been removed from enamel in the course of mineralization and maturation. Therefore, this different microstructure may be the reason for the difference in microhardness, and could explain the differences between human and bovine groups found in this study.

With regard to the effect of cutting time, irrespective of the type of tooth, the results indicated that there was no gradual decrease in the cutting power of the burs. After the first cutting period (12-min) there was a slight increase in the amount of wear, which remained constant up to 36-min, reduced between 36-min and 48-min and increased again and remained constant up to 72-min This pattern of increases in the amount of wear of enamel, interspersed with periods of stabilization, may be attributed to the loss of diamond particles, which could compromise the cutting power of the bur, or to an increase in the area of contact between the bur and the tooth, when the diamond particles are broken instead of being pulled out, thus increasing the cutting power. A photomicrographic analysis of the burs used in the present study demonstrated that during cutting human and bovine enamel, a gradual alteration on the bur surface was noted[26]; nevertheless, the most significant alterations for the burs used on human enamel were seen after 48 min of cutting while for bovine enamel, the most significant alterations only occurred after 60 min of cutting[26]. This was explained by the result obtained in an adjustment of the linear regression equation, which have indicated that the speed of wear of the diamond tips was 7% higher when cutting human teeth compared to cutting bovine teeth[26].

The results of the present study also demonstrated that the interaction between the factors *tooth type* and *cutting period* was significant. This is illustrated in Figure 2, which demonstrates that the increases and decreases in the amount of enamel wear produced by the burs were not equivalent for the two types of teeth in the evaluated periods. From the 24- to the 36-min period, the amount of wear of bovine teeth remained the same, while for the human teeth there was a decrease in the amount of enamel wear. From the 36- to the 48-min period, the amount of wear of human teeth remained

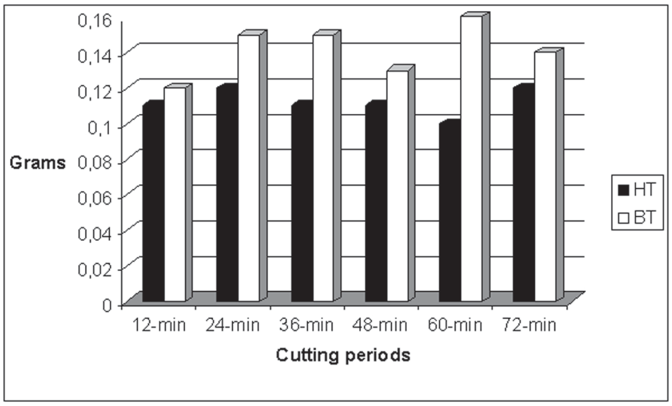

Fig. 2. Mean mass loss values (in g).

the same, while for the bovine teeth there was a decrease in the amount of enamel wear. The amounts of enamel wear for the human teeth decreased from 48-min to 60-min and then increased at the 72-min cutting period. By contrast, an opposite trend was observed for the bovine teeth when these three cutting periods are considered. These different patterns were responsible for the interaction between the evaluated factors. As already mentioned, the reasons for such differences may be the differences in the microstructure and/or hardness of the substrates evaluated, which might have influenced the alterations on the surface of the burs (loss of diamond particles or increase in the area of contact with the tooth).

Although the use of the bovine teeth as substitute for human teeth has been used successfully for in vitro studies that evaluate microleakage[5], in the present investigation the null hypothesis was rejected, thus demonstrating that the use of bovine teeth instead of human teeth may not be indicated for studies that analyze the cutting efficiency of diamond burs by the mass-loss method. In spite of the differences in the wear pattern between human and bovine teeth, the results of the present study must be interpreted with caution, since no structural analyses of the teeth used were performed. Moreover, in addition to diamond burs, other types of rotary cutting instruments must also be evaluated using the same methodology.

It may be concluded that the cutting efficiency of the burs was different on the tested substrates, and that bovine enamel underwent greater mass loss than did human enamel.

Acknowledgements

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