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Evaluation of the erosive potential and resistance of isotonic drinks to dental fracture

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Abstract

The practice of sports in general predisposes the athletes to trauma, whether the sport is individual or collective. Isotonic solutions can generate tooth erosion, make the dental structure more fragile and enhance tooth wear. The aim of the present study is to assess dental resistance to fracture after exposure to isotonic drinks. An in vitro study was carried out with human teeth, which were divided into a test group and a control group. Two main stages were developed: in the first stage, the erosive potential of isotonic drinks was analyzed and, in the second stage, the analysis of resistance to dental fracture was performed, based on the mechanical test. The isotonic drinks had low pH (hydrogen potential) values, indicating high acidity and the isotonic lemon flavor had a higher value for TA (Titratable Acidity). Regarding the analysis of fracture resistance, the samples in the test group showed less resistance to dental fracture than the samples in the control group and the specimens in the test group that remained longer

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in isotonic drinks showed greater structural fragility. This study showed that the longer the exposure to the erosive challenge, the more susceptible to fracture the dental element is, due to the wear of the enamel structure caused by the isotonic.

Keywords: Athletes; Isotonic solutions; Sports; Tooth erosion; Tooth wear

INTRODUCTION

Dental trauma can keep athletes away from training and competitions, hindering their performance and career (Needleman et al., 2016; Galic et al., 2018; Fernandes et al., 2019). The practice of sports in general predisposes the athlete to trauma, either in individual or collective sports (Bergman et al., 2017; Polmann et al., 2019; Fronza et al., 2020; Oliveira et al., 2020). Much has been done to indicate and encourage the use of mouthguards for sports, well adapted and made of materials with a great capacity for absorbing and dissipating energy capable of causing any damage to the dental element (Coto et al., 2012; Gialain et al., 2016; Padilha et al., 2021). However, not only situations of exposure to trauma put the integrity of the teeth at risk, eating habits can weaken their integrity, making them more prone to fractures (Soares et al., 2018). The intake of isotonic drinks is an example of this (Ostrowska et al., 2016). They are offered during training and competitions as hydroelectrolytic replenishers with the function of replenishing water and mineral salts (Lussi et al., 2016; Ehlen et al., 2008). Studies show that the ingestion of isotonic solutions can cause tooth erosion (Antunes et al., 2017). That is due to chemical loss of mineralized tooth substance caused by the exposure to acids not derived from oral bacteria (Schlueter et al., 2020; Caneppele et al., 2012).

It is known that Individuals who consume sports drinks daily have a 4 times greater risk of developing injuries by dental erosion (Järvinen et al., 1991; Hasselkvist et al., 2016). Therefore, the combination of risk factors to trauma inherent in sport and the continuous use of isotonic drinks can increase the risk of weakening of the enamel hydroxyapatite crystals in athletes (Noble et al., 2011; Tanabe et al., 2013).

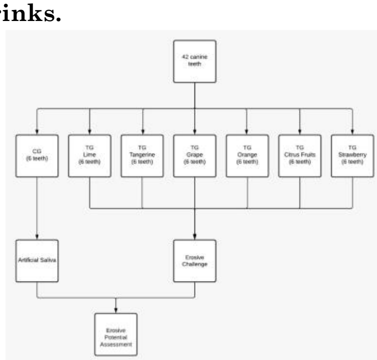
Understanding whether there is a relationship between the use of isotonic drinks and dental fracture is necessary. Based on these facts, this study evaluates “in vitro” dental resistance to fracture after exposure to isotonic drinks in a systematic way with ecological validity (Berard et al., 2020).

MATERIALS AND METHODS

This study had two stages: erosive challenge and mechanical test.

For the erosive challenge, a longitudinal in vitro experimental study with ecological validity has been proposed; 42 healthy canine teeth were divided into 7 groups of 6 specimens each. Six test groups (TG) were submitted to erosive challenges with different isotonic flavors (lemon, tangerine, grape, orange, citrus and strawberry) and one control group (CG) was submitted only to artificial saliva as shown in Figure 1. One specimen from each group was analyzed every 30 days for a total of 180 days.

Figure 1. **Flow of the evaluation of the erosive potential for first study of isotonic drinks.**



Each numbered and separated tooth was immersed in 50 mL of each drink for 30 seconds, simulating the moment of ingestion, then put in contact with artificial saliva. The same procedure was performed 5 times a day, with an interval of 24 hours between each cycle. During that interval, the teeth were kept in artificial saliva.

Each group, one at a time (TG0 to TG180), underwent surface roughness analysis with the aid of an optical profilometer (3D model, Talysurf CCI®). The data were analyzed by the Proscan® Software. The difference in reference surface height and the exposed sample area was quantified in micrometers (μm). For this purpose, the Sa roughness parameter (mean value in 3D of the maximum height between the peak and the roughness profile valley within the sampling lengths) was used.

Each tooth had its buccal surface measured 6 times, 3 times at the region of 2mm above the cervical line, covered by enamel, and 3 times at the region of 1mm below the cervical line, cement region.

In this phase, it was observed that the lemon flavor isotonic presented higher erosive potential than the others at measurements taken at 30, 90 and 180 days.

From this data, a new erosive challenge was proposed only with the lemon flavor, observed at intervals 30, 90 and 180 days followed by mechanical testing at each interval to observe the mechanical resistance to the impact of the dental elements subjected to the erosive challenge.

In parallel, pH (hydrogen potential) and TA (Titratable Acidity) measurements were performed.

A pH meter (K39-1014B-Kasvi, São Paulo, SP, Brazil), with variation, + / - 0.02, was used for the reading and recording of the pH of vials containing 50 mL (milliliters) of the solution for each of the isotonics immediately after opening the vials. All the products were on their expiration dates, and consisted of water, sucrose, glucose, sodium chloride, sodium citrate, monobasic potassium phosphate, acidic citric acid, flavoring and artificial color. All without the presence of gluten.

TA was measured for each flavor of isotonic by means of a volumetric pipette with 50 mL of each drink. Then, 1M (Mol) NaOH (Sodium hydroxide) base solution was added, so that the solution reached a pH value between 5.5 and 7.0. Upon reaching this value, the spent volume of sodium hydroxide was observed and the degree of acidity of each flavor of isotonic was verified.

The analysis of the mechanical resistance to the impact used the information obtained in the first phase of this study to create the new TG (Test Group). Groups TG1, TG2 and TG3 were formed, with 5 teeth each, which were subjected to the isotonic lemon flavor and removed for impact analysis, in periods of 30, 90 and 180 days, as shown in Figure 2. The control group (CG) was exposed only to artificial saliva for 180 days. The groups, after their respective erosive challenges, were included in PMMA acrylic resin up to one millimeter below the tooth cervical line in a format that would allow them to be coupled to the MMS (low energy impact hammer). The MMS was loaded with a 6 kg impacting agent, the contact surface with a rounded tip of about 20 mm in diameter. The set was set 45 degrees in relation to the horizontal plane[23]. The impacts occurred at an average speed of 1 m/s (Figure 3).

Figure 2. **Flow of the evaluation of the erosive potential for second study of mechanical test.**

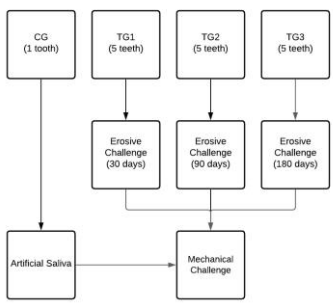
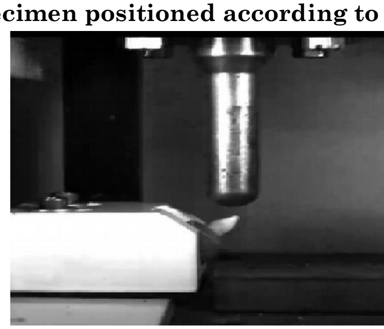


Figure 3. **Frame of the film obtained by the high-speed camera at the MIBE, with the specimen positioned according to Soares et al., 2005**.



A Photron FastCam® SA5 camera was attached to the set, recording at 7000 f.p.s. (frames per second) to analyze how the impact occurred, as well as the Laser Polytec® OFV 3020 vibrometer controler, to analyze the detail and the speed of the impact. Thus, it was possible to observe the work (J) performed by the impact force necessary to cause the fracture in each tooth. This study was submitted to and approved by the Research Ethics Committee of the School of Dentistry of the University of São Paulo. CAAE: 68728817.3.0000.0075.

RESULTS

After the erosive challenge, it was observed that the lemon isotonic flavor presented a greater loss of dental structure in the studied specimens, in the observation times of 30, 90 and 180 days. Figure 5 (before the challenge) and Figure 6 (after the challenge) show the TG90.

The pH value of the flavors studied varied between 3.30 and 3.44 (Table 1). Indicating they are acidic drinks with high erosive potential.

In the measurement of TA, the lemon flavor isotonic presented a greater need to increase the volume of basic solution (NaOH) to neutralize its acidity, while the citrus fruit flavor isotonic presented a lower TA (Figure 4).

Table 1. pH values of isotonic flavors.

Isotonic flavor	pH
Strawberry	3.30
Lemon	3.44
Grape	3.32
Orange	3.34
Citrus fruits	3.40
Tangerine	3.32

Figure 4. Comparison of Titratable Acidity (TA) of all isotonic flavors.

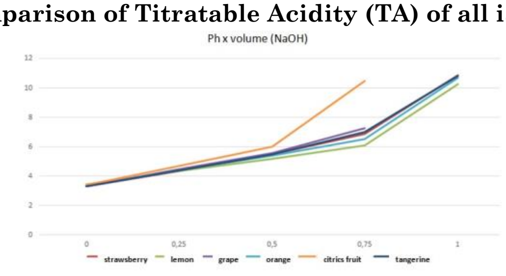


Figure 5. **Dental enamel surface in 3D view before immersing a TG90 sample in isotonic (lemon flavor).**

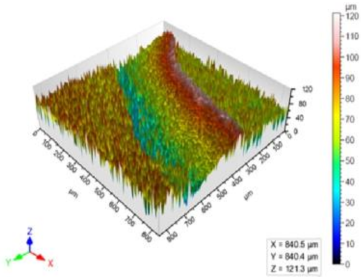
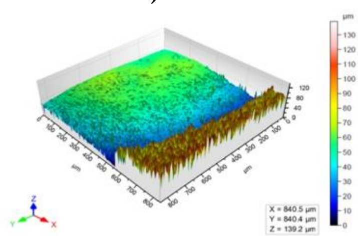


Figure 6. **Dental enamel surface in 3D view after immersing an TG90 sample in isotonic (lemon flavor).**



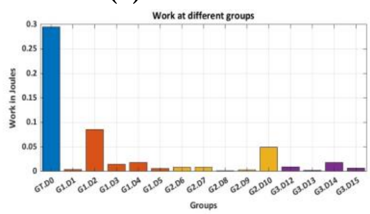
According to Figure 7, where the work (J) performed by the force necessary to cause the fracture in each tooth was measured, it can be seen that the samples in group 1 (TG30) showed greater resistance to dental fracture among the test groups, and samples from group 3 (TG180) showed less resistance. The control group showed high resistance to dental fracture.

The data were analyzed using the ANOVA method and the Tukey Krames method, with alpha equal to 5%, indicating that the difference in fracture toughness was statistically significant when compared between the control and test groups and the tests between them (table 2).

Table 2. Difference between Groups in relation to dental fracture. The value of p <0.05 indicates that there was a statistically significant difference between the groups.

Groups	Groups variation	p-Valor
CG E TG1	0.26886	p<0.05
CG E TG2	0.28058	p<0.05
CG E TG3	0.28565	p<0.05
TG1 E TG2	0.01172	p>0.05
TG1 E TG3	0.01679	p>0.05
TG2 E TG3	0.00507	p>0.05

Figure 7. Work required for the fracture of each tooth in their respective groups in Joules (J).



DISCUSSION

In the ingestion of isotonic drinks, flavoring agents, especially citric acid, are capable of causing the removal of the calcium present in the enamel, in addition to removing the calcium present in the saliva, reducing the buffering capacity and potentiating the process of dental wear (Barbour et al., 2008; Carvalho et al., 2016). The salivary pH is around 7 and is considered critical when it reaches 5.5 or below, a situation in which enamel demineralization begins. Drinks that have a pH below this value enhance the process of dental erosion (Wang, Lussi, 2010). In addition to pH, other properties, such as the type of acid present (citric, lactic, maleic and phosphoric) and its concentration, the titratable acidity, the chelating potential and the presence of sugars can influence the effect of acids on the dentinal surface (West et al., 2011; Needleman et al., 2013). TA is directly related to the erosive potential of a drink, as it corresponds to the necessary concentration of adding a base (OH^-) so that the acidic drink can reach neutral pH (Cairns et al., 2002). Thus, the greater the volume of the alkaline solution (NaOH) needed to neutralize an acidic solution, the greater its erosive potential (Shellis et al., 2010). It is valid to reaffirm that the dental erosion process has a multifactorial etiology and all the components involved in this process (chemical, biological and behavioral) must be evaluated together and not separately (Lussi et al., 2016; Atalay, Ozgunaltay, 2018).

Regarding the beverages analyzed in the present study, in absolute values, the isotonic lemon flavor was the one that caused the largest surface loss in micrometers, in addition to causing a structural loss in more than half of the samples in its test group. The absence of loss of surface of some samples in the test group (TG) is due to the formation of the acquired film between the intervals of the erosive challenges, when the teeth were in continuous contact with artificial saliva (Buzalaf et al., 2018; Souza et al., 2020). This also justifies the absence of structural loss in the control group (CG) samples, since they remained only in saliva and did not come into contact with acidic drinks.

In figures 5 and 6, the surface of the dental structure of the same sample (TG 90) is observed in 3D, before and after the erosive challenges. After immersing this sample in isotonic lemon flavor, it can be seen from the image that the enamel prisms were noticeably smaller in height and that the dental structure became flatter and more polished than the initial image, in which the enamel prisms were much clearer and less worn out.

When the teeth subjected to the erosive challenge were mechanically tested (according to Table 2), considering the fracture values in Joules (J), TG 30, 90 and 180 days, the ones which remained longer in contact with the isotonic presented less fracture resistance due to the weakening caused by structural wear. Therefore, the control group showed high resistance to fracture, as it was not exposed to acidic drinks and did not suffer structural tooth loss.

Studies carried out "in vitro" show greater control of variables that may interfere with research. However, it is relevant to highlight that, amongst the limitations of the present study is the difficulty of extrapolating the findings to human beings. It is worth emphasizing the importance and the need to carry out additional studies in vivo, so that the harmful effect of these drinks on the structure of the dental element can be further analyzed and the results compared, mainly regarding resistance to dental fractures.

CONCLUSION

This study showed that the longer the exposure to the erosive challenge, the more susceptible to fracture the dental element is, due to the wear of the enamel structure caused by the isotonic.

Potential conflict of interest
No conflicts of interest with potential potential for this article have been reported.

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