The Effects of Sports Drinks on Teeth

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Abstract
With a push towards a more active lifestyle, the sports drink industry has grown substantially in recent years. However, despite their popularity, sports drinks contain acid, giving them extremely low pHs, which can cause erosion. There have been many studies, including self-administered surveys, studies in vitro, and studies in situ that have shown sports energy drinks cause dental erosion, leading to permanent loss of tooth volume and a softening of the outer layer of the tooth.

Introduction
Sports drinks were initially created for the purpose of rehydration and electrolyte replacement for athletes during intense physical activity. (Mathew et. al. 2002) The drinks have proven to increase concentration, stimulate metabolism, and eliminate harmful substances from the body (Pinto et. al. 2013). However, sports drinks have become popular today among amateur athletes and ordinary exercisers looking for a drink after a workout. With the push for a healthier lifestyle, more people have begun to exercise and many drink sports drinks on a regular basis. In 2000, the sports drink market was estimated at 1.2 billion dollars and has been growing since (Hooper et. al. 2005). Current research has demonstrated that these drinks have negative effects on teeth and can eventually lead to teeth rotting. With the growth in the sports drinks industry, it is critical to understand the effects sports drinks have on the body. This paper attempts to examine sports drinks from the perspective of oral health and review the current knowledge on the effects of sports drinks on teeth.

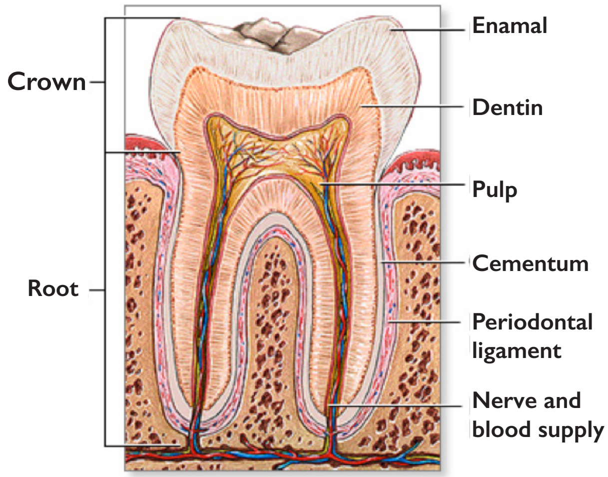

Figure 1. The anatomy of a tooth. The enamel being most superficial and moving deep, the cementum, dentine, and pulp. (https://medlineplus.gov/ency/images/ency/fullsize/1121.jpg)

Tooth structure
Teeth are composed of three different types of tissues: enamel, cementum, and dentin. The enamel is the most superficial of all three and is the hardest substance in the entire body. The enamel is composed of 96% minerals with the rest being water and organic content. The hardness and density of enamel both decrease further from the surface (Lussi et. al. 2011). Because the enamel comes into contact with the outside, it is the most affected by acid producing bacteria, which can cause dental caries. The cementum, which is avascular, is the part of the tooth that covers the root of the tooth. Collagen fibers project out of the cementum, forming most of the periodontal ligament, which keeps the tooth attached to in its socket. Deep to both the enamel and cementum is the dentin (Ross et. al. 2003). The dentin makes up most of the tooth and is in contact with the dental pulp. The dentine is made up of 47% minerals and 33% organic content (Lussi et al. 2002). This dental pulp is both highly vascularized and very innervated (figure 1).

Effects of Acid on Teeth
Dental erosion is the dissolution of tooth mineral caused by external sources and not from bacteria, like plaque (Arnauteanu et. al. 2015). It is characterized by initial softening of the enamel surface. This leads to further dissolution of the enamel crystals, which will cause permanent loss of tooth volume and a softened surface layer (Lussi et. al. 2002). Erosion, as opposed to tooth decay, leads to a widespread thinning of the tooth surface without causing dental caries (Milosevic 2004.) Erosion occurs when the pH of the solution around the enamel is lower than 5.5. At this low pH, the hydrogen ions dissolve the minerals which allows the calcium and phosphate ions to diffuse out of the teeth (Adhani et. al. 2015). In dentine only the mineral portion dissolves in acid while the organic component remains (Lussi et. al. 2011)(figure 2).

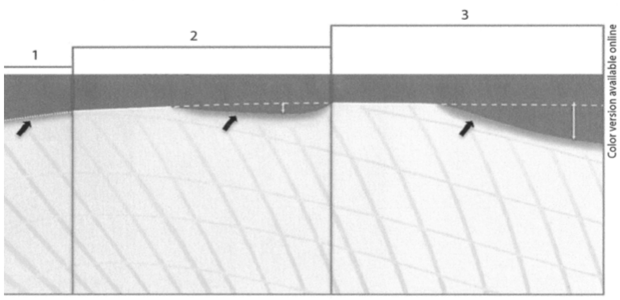

Figure 2. The different stages of dental erosion. On the left the softening of the enamel without tooth material loss. In the middle there is partial tooth material loss and softening of the underlying surface. On the right is significant tooth material loss. (Lussi et. al. 2011)

A study was done in which tooth samples were incubated in two different solutions, one at pH of 7 and the other at a pH of 4. Both showed a decrease in the minerals of calcium, zinc, and phosphate, with the solution at pH of 4 showing a greater decrease. This demineralization is characteristic of teeth in acidic conditions (Adhani et. al. 2015).

While erosion affects all teeth, the extent of erosion will differ for each type of tooth. A study was conducted using different types of teeth to compare the effects of acid and also to examine how the buccal/labial and lingual/palatal sides are affected (figure 3). The results showed that the lingual/palatal surface of the teeth showed greater loss due to acid dissolution than the buccal/labial side of the corresponding tooth. The palatal side of all maxillary teeth showed greater susceptibility than the lingual surface of the mandibular teeth. The teeth in the mandible showed great variation among teeth and based on surface, while the maxillary teeth showed similar dissolution for the palatal side and little variation among the buccal/labial sides. The difference can be due to the fact that the lingual/palatal sides of the teeth generally are observed have more wear due to being exposed to food for longer periods of time than the buccual/labial sides (Tucker et. al. 1998).

Acidity of Sports Drinks

The acidity of many sports drinks is much lower than the critical pH of 5.5, which has been shown to cause dental erosion.

Product	**pH**
Monster Assault	3.49
Red Bull	3.37
Gatorade Fruit Punch	3.27
Propel Mango	3.23
Gatorade Lemon-Lime	3.07
Full Throttle Energy Drink	2.94
Gatorade Cool Blue	2.92
5-Hour Energy	2.81
Powerade Red	2.77
Rockstar	2.53

Figure 3. The pH of many common sports drinks. (http://www.sheltondentistry.com/patient-information/ph-values-common-drinks/)

Erosion Caused by Sports Drinks

A study was performed to determine if there is an association between drinking sports drinks and dental erosion. Seven hundred and ninety-five patients filled out a self-administered questionnaire, which included their background, dietary habits, and frequency of tooth brushing. The patients then were checked for dental erosion, checking twenty surfaces in total among fourteen different teeth for each patient. A patient with three or more surfaces exhibiting erosion was considered to be affected. Of the people who had a low consumption of sports drinks, less than 0.24 liters/day, 26 percent were affected. Of those with moderate consumption, 0.25-0.75 liters/day, 41 percent were affected and of those with high consumption, more than 0.75 liters/day, 77 percent were affected. An athlete during training will drink at least 1.5 liters/day, which is much higher than those considered in the high consumption group for this study, and would therefore be highly susceptible to dental erosion due to these sports drinks. This study showed that there is an association between drinking sports drinks and dental erosion (Sovik et. al. 2015).

In a two-part experiment the erosive potential of 5 sports drinks was first checked in vitro for erosive potential and then the most erosive drink was tested to determine how it affected teeth in situ. The in vitro part took Gatorade, powder and liquid, Isotar, powder and liquid, and Isotar liquid and immersed six enamel samples for each solution for a total of four hours, checking the erosion every hour. The Gatorade liquid was the most erosive and therefore was used for the in situ part. In this experiment ten adults wore intraoral appliances that contained two teeth. The adults were then put on a drinking regimen of the Gatorade for ten days. Upon completion the samples were checked for erosion. The results showed marked erosion in three, mild erosion in two, and slight erosion for the remaining five. This showed how there is variability among individual susceptibility to enamel erosion. This variation can be due to many components including drinking habits, amount of saliva, and biological variation in tooth specimens. It also showed that individuals that are susceptible can have major erosion due to sports drinks (Hooper et. al. 2005).

In another experiment, Sting, a sports drink with citric acid with a pH between 2-3, was investigated for its effects on tooth enamel. Anterior teeth were submerged in Sting for five minutes every six hours for fifteen days. The results showed surface irregularities, pitting and structural loss of enamel. This experiment confirmed previous studies that beverages with "higher concentrations of citric acid have an aggressive effect on the enamel surface leading to its dissolution" (Kazmi et. al. 2016).

In another study, three sports drinks were tested for their erosive potential. The three drinks were Gatorade Citron, 5-Hour energy, and Powerade Cherry. Fourteen premolars were chosen for the study and were divided into groups for each drink. The teeth were exposed to the specified drink for four times for two minutes each over a one hour span every day for fourteen days. Compared to the control group held in artificial saliva, the Gatorade was the most erosive with an average loss of 10% of calcium ions and 8% of phosphorous ions. The Gatorade was followed by Powerade in erosive potential, having an average loss of

9% of calcium ions and 6% of phosphorous ions. The least erosive of the three drinks was 5-hour Energy, which showed an average loss of 5% of calcium ions and 3% of phosphorous ions. The results showed that each of the drinks caused erosion of the enamel and loss of calcium and phosphorous ions, with Gatorade showing the most erosive potential (Arnauteanu et. al. 2015).

In a study, three beverages and medicated cough syrup (Johnson and Johnson) were tested on teeth with and without restorations. The drinks were a carbonated drink (The Coca-Cola Complany), a non-carbonated drink (Parle Agro), high-energy sports drink (Red Bull). The sports drink had a pH of 3.26 but also compared to the other drinks had the highest neutralizable acidity. The specimens were in the high-energy sport drink for 350 hours over fourteen days, equaling fourteen years of normal beverage consumption. The teeth without restorations showed erosion and the restored teeth showed microleakage, due to the erosive effects of the sports drink. The drink contained citric acid which can "bind to calcium and phosphorous thereby promoting increased titratable acidity levels." The citric acid added to the drinks for flavoring agents leads to an increase in the sports drinks erosive potential. The microleakage caused by long term use of the sports drinks can eventually lead to restoration failure or secondary caries (Trivedi et. al. 2015).

Another problem for people who drink sports drinks is the hyposalvation that occurs during exercise. Due to the strenuous activity, an athlete can lose up to 1.5 liters of liquid from perspiration. This leads to a decrease in saliva resulting in xerostomia, dryness of the mouth. Saliva normally acts as a buffer and can neutralize the acidity of consumed liquids or foods. The saliva will also clear the liquids and foods quicker from the mouth thereby lessening the harmful effects of the acid. Even as acids cause ions to release from the teeth, the saliva can provide calcium and phosphorous to replenish the teeth. However, when there is less saliva in the mouth during an exercise the sports drinks' acidity will have an even greater effect than normal and cause more erosion than during rest. Also, because of this dryness in the mouth a person will usually drink more and therefore will have more acidic drink with less buffer (Noble et. al. 2011).

In the future drink companies are looking for ways to combat the erosive potential of sports drinks. By adding calcium, companies can see a pH adjustment which will reduce the erosive potential of the sports drinks, as it has been done for soft beverages (Arnauteanu et. al. 2015). This concept of adding calcium has also been tried with Ribena ToothKind. Compared to regular Ribena, the Ribena Toothkind showed significantly less enamel loss. (Milosevic 2004). If these results can be duplicated with sports drinks then their erosive potential will be decreased and be healthier for athletes.

Conclusion

Originally developed for professional athletes, sports drinks have become increasingly popular among the general population as well. However, studies indicate that the acidity levels found in sports drinks can cause dental erosion. Sports drinks have a pH well below the critical pH of 5.5 and therefore have harmful effects on teeth. The low pH of the drinks causes the minerals to diffuse out of the tooth and cause a loss in tooth volume. The acid also causes a loss in hardness, which can lead to further tooth damage. New ways of making these drinks may help mitigate the adverse negative effects of sports drinks on dental health.

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