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REVIEW

# Effects of energy and sports drinks on tooth structures and restorative materials

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## Abstract

Sports and energy drinks are consumed by more people than ever. Sports and energy drinks may enhance physical resistance, stimulate metabolism, prevent rehydration and replace electrolytes during high activity efforts. However, these drinks often have a low pH and are acidic, which can erode enamel and dentin, and increase dentine hypersensitivity. In addition to the adverse effects of sports and energy drinks on tooth structures, they often have the potential to damage restorative materials. These drinks often contain artificial colors which have potential to discolor resin composite materials and glass ionomers. The acidic nature of these drinks could also lead to a degradation, increase in wear, and roughening of the surface of the restorative materials. Many of the negative consequences of sport and energy drinks can be related to their over-consumption among children and teenagers. Patients should be advised to have a healthy diet, and consume soft and energy drinks in moderation, to avoid any negative dental or health consequences. The over-consumption of sports and energy drinks which are high in sugar and have the lowest pH are most likely to cause avoidable dental problems.

**Key words:** Energy drinks; Sports drinks; Dental caries; Dental erosion; Discoloration; Microhardness; Surface roughness



**Core tip:** Dentists have a duty to their patients to give them instructions on the consumption of drinks or foods which can damage dental health. Most food and drinks have little noticeable effects on dental health. Among the drinks that are most likely to damage teeth and restorative materials are sports and energy drinks which contain sugar to feed oral bacterial, and drinks which have a low pH which can erode teeth and increase their sensitivity. Patients who suffer poor oral health because of their over-consumption of sports and energy drinks need to be made aware of the likely causes of their dental problems.

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## INTRODUCTION

Intake of sports and energy drinks has gained popularity markedly in recent years[1]. The consumption of energy and sports drinks mainly by professional and amateur athletes, sportsmen, and adolescents has been on the rise with extensive advertisements since 1997, with the debut of Red Bull[2-7]. The purposes for producing each of these drinks are different, and the ingredients are mostly distinctive.

While sports drinks are consumed to boost performance, prevent rehydration, and replace electrolytes during high-activity sports[2,3,8-10], energy drinks are used to enhance physical resistance and a state of alertness, increase the rate of giving responses, supply greater concentration, and stimulate the metabolism during sports, driving, and leisure activities[11,12].

Sports drinks, which are used largely by consumers, contain great amounts of "carbohydrates, such as glucose, fructose, sucrose, and synthetic polymer maltodextrins that are also known as glucose polymers[13,14]. On the other hand, energy drinks are composed of "caffeine, herbal extracts such as guarana, ginseng, and ginkgo biloba, B vitamins, amino acids such as taurine, amino acid derivatives such as carnitine, and sugar derivatives"[10,11].

It is crucial to know the difference between energy drinks and sports drinks[9]. The main active ingredient in energy drinks is caffeine[15]. Caffeine-containing energy drinks have not been produced to support rehydration[16]. Energy drinks mainly have higher carbohydrate contents than sports drinks do[9]. Energy drinks also have both sugar-containing and sugar-free versions[11].

Problems related to consuming sports and energy drinks can be inspected in dental clinics. However, it may be difficult to distinguish the etiological factor because dentists generally do not think about soft drink users, who are very common in the population. In this section, the clinically visible effects of sports and energy drinks are evaluated for dental professionals to look over.

## EVALUATION OF DENTAL CARIES AND DENTAL EROSION CORRELATED WITH SPORTS AND ENERGY DRINKS

Many research studies have indicated that sugar-containing beverages can cause dental caries[13,17]. The sugars in drinks are metabolized by plaque microorganisms to compose organic acids that initiate demineralization[18]. However, a number of studies also support that sports drink consumption is not directly associated with dental caries[13,14]. Sports drinks have had the same cariogenicity as fruit juices, drinks, and carbonated beverages. The "diet" or "light" soft drinks have a reduced risk of caries compared to that of sugared drinks due to the lack of sugar[19]. Thus, although there is no precise evidence supporting a relationship with dental caries, the caries-causing potential of these drinks should be carefully considered[13].

Evidently, acidic drinks play a significant role in the pathogenesis of dental erosion[2,17,20-25]. Dental erosion is the loss of the outmost surface of enamel and exists when the surface pH reduces below to critical threshold value of 5.5[18,26]. When the critical pH reaches 5.5, the hydroxyapatite crystals begin to dissolve and the enamel begins to be at risk of decalcification[2,6]. Although a few studies with regard to the erosive potential of sports drinks have reported a lack of relationship between consumption of sports drinks and dental erosion[2,13,18], many other studies have stated that sports drinks and energy drinks have the potential to cause enamel surface loss and surface softening, leading to dental erosion due to their low pH and the existence of citric acid[6,14,26-30]. In a recent study, human tooth enamel samples were immersed in sports and energy drinks for repeated short exposure times. Researchers ensured that drinks had eroded the enamel layers. In the results of the study, it was also indicated that energy drinks had higher titratable acidity values than sports drinks. Besides the fact that titratable acidity is an important predictor of enamel dissolution, samples immersed in energy drinks also showed higher enamel loss. Unfortunately, the tissue loss is irreversible[31]. Another study investigating enamel loss showed that sports and energy drinks had the most aggressive enamel dissolution compared to Coca Cola and soft drinks[1].

Frequency, duration, temperature, and time of exposure to acidic drinks have been shown to affect the severity of erosion[32,33]. It has been revealed that prolonged contact time between a beverage and the enamel or root surface increases the possibility of dental erosion occurrence[13,34]. Therefore, according to their properties, sports and energy drinks can be highly detrimental for teeth if consumed frequently and improperly**.** Furthermore, it is inevitable to prevent dental erosion in patients at risk because of many etiological factors such as reduced salivary flow or buffering capacity, beverage-holding habits, or mouth breathing. Individuals with these conditions are at increased risk of erosion when consuming sports and energy drinks frequently[28]. Temperature differences also have an effect on the erosive potential of acidic drinks. It has been previously stated that acidic drinks are less erosive at lower temperatures[35]. It is obviously advantageous that sports and energy drinks are generally consumed at lower temperatures (*i.e.,* 4 ℃).

In comparison to soft drinks, sports drinks do not

contain much more acid than a wide variety of other drinks such as fruit juices, beer, and wine[13]. According to Cavalcanti *et al*[36], energy drinks have a high erosive potential, as they have low pH and a high non-reducing sugar content. The erosive potential of sports drinks is increased when they are consumed during periods of dehydration and low salivary flow, which could occur during exercising or sports activities[3]. It has also been revealed that sports drinks can reduce the surface hardness of enamel[29], and this could be an etiological factor for cervical dentine hypersensitivity, which can be severe and debilitating[37,38]. Another clinically relevant situation about sports and energy drinks is thought to be the increase in surface roughness at dental tissues. A recent study revealed that Gatorade, a sports drink, and Red Bull, an energy drink, showed significantly higher roughness results in enamel samples, compared to Coca Cola and coffee[39]. It is obviously seen from the above mentioned studies that sports and energy drinks are more responsible from initiating dental erosion than caries. It is clear that lowering the plaque pH to cause demineralization is in low possibility to happen when compared to their acidic potential which may soften, roughen and discolor the teeth.

Moreover, the erosive potential of sports drinks also depends on the type of acid and the ingredients in the formulation[40,41]. Citric acid, which is also called International Numbering Sytem for Food Additives 330 acidulant[26], is commonly used in soft drinks[42]. This acid is one of the most powerful ones due to its chelating capacity, which is responsible from calcium sequestration from saliva and teeth[26,28]. The citrate anion has the ability to chelate calcium with an additive effect to the erosive potential of the proton ions released[43]. Many studies have stated that beverages containing citric acid and having a low pH are thought to have the most erosive capacity[44-48]. Likewise, Meurman *et al*[48] compared sports drinks, all of which contained citric acid or maleic acid. It was determined that drinks containing citric acid had a higher erosive potential than that of those containing maleic acid. The pH scores of several sports and energy drinks are given in Table 1.

On the other hand, saliva provides calcium and phosphate ions for remineralization and proteins for the development of a protective pellicle[42]. The buffering capacity of saliva has also been considered to be important, even more than pH[22,40,49]. The citric acid in acidic drinks can be modified by incorporating calcium, phosphate, and fluoride or by diluting the drinks by adding water or reducing the total sugar concentration to reveal a significant and protective effect against enamel erosion[17,50].

Many additive materials are being used for reducing the damage done by sports and energy drinks. The addition of casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) at 0.2% to soft drinks diminishes their erosive potential. The reason for that is the increased availability of calcium and phosphate ions at the enamel surface[3,42,51,52]. In addition, treatment of eroded teeth due to acidic drinks with CPP-ACP has increased the hardness of the enamel[53,54]. An *in vitro* study showed that the enamel erosion caused by sports drinks could be eliminated by adding 0.09% to 0.25% CPP-ACP due to a rise in pH and decline in titratable acidity of the modified sports drink[3]. However, the modified beverages have lower palatability than more acidic sports beverages. Although product modification by adding calcium or phosphate can create a lower erosive potential in sports and energy drinks, consumers may refuse the altered palatability or texture and prefer the ones with lower palatability[14,41]. Another adverse effect of the low pH of sports and energy drinks is the potential for damaging the properties of composites. Factors such as temperature changes, salivary enzymes, the ionic composition of food or beverages, and pH level might also effect the properties of restorations in the oral cavity[55].

**Table 1 The pH scores of several energy drinks[1]**

| Energy drink | Brand name | pH score |
|---|---|---|
| Powerade | The Coca-Cola Co. Atlanta GA, United States | 3.79 |
| Gatorade | The Gatorade Co. Chicago IL, United States | 3.27 |
| Burn | The Coca-Cola Co. Atlanta GA, United States | 2.67 |
| X-IR | Nice Trading Inc. Istanbul, Turkey | 3.15 |
| Red bull | Red Bull GmbH Am Brunnen, Austria | 3.54 |
| Isostar | Isostar, Wander AG, Switzerland | 3.87 |

[1]Scores were cited from; Erdemir U, Yildiz E, Eren MM, Ozel S. Surface hardness evaluation of different composite resin materials: Influence of sports and energy drinks immersion after a short-term period.

## DISCOLORATION OF RESTORATIVE MATERIALS AND THE EFFECT OF SPORTS AND ENERGY DRINKS

As of now, a great spectrum of material diversity has been identified for practitioners. This diversity is not only for supporting aesthetic results of the anterior region but also for resisting the mechanical forces encroaching on the posterior region. However, regardless of which material is chosen, emphasis is generally on aesthetics. Moreover, color is one of the inseparable parts of the aesthetic view. Color stability of any dental material means to be able to maintain its original color. As the oral cavity is full of dynamic movements of microflora and intake of colored food and drinks, it is challenging to retain the colors of dental materials. After prolonged exposure to oral environment, discoloration of restorations is one of the major problems leading to failure of restorations[35,56]. In this part, effects of consuming sports and energy drinks on color stability and other physical properties of various dental materials is discussed.

## COMPOSITE RESINS

Color stability of resin composites is related to many factors. Both the structures of resins and the

**Table 2 Example of some of the energy drinks and their colorants with properties**

| Energy drink | Brand name | Colorant | Properties |
|---|---|---|---|
| Powerade | The Coca-Cola Co. Atlanta GA, United States | Brilliant Blue | Water soluable food dye, gives bright blue color |
| Gatorade | The Gatorade Co. Chicago IL, United States | Brilliant Blue | |
| Burn | The Coca-Cola Co. Atlanta GA, United States | Allura Red | Water soluable food dye, gives dark red color |
| Red bull | Red Bull GmbH Am Brunnen, Austria | Caramel, Riboflavin | Caramel can change the color from yellow to brown |
| Britvic ginger ale/sour lemon | Britvic Soft Drinks ltd. Chelmsford CM, England | Caramel, Chlorophyllin | |
| Reina premium | Alda Drinks Inc.ltd., Turkey | Caramel | |
| Rockstar | Fruko Drinks Inc. Ltd., Istanbul, Turkey | Caramel, Riboflavin | Riboflavin gives yellow or yellow-orange color |
| 28 black classic | Splendid Drinks AG Senningeberg, Luxembourg | Caramel | |

external behaviors of the patients have an influence on discoloration[57-59]. The discoloration of the resin composites may be caused by internal or external factors[35,60-63]. External discolorations result from adsorption and absorption of water-soluble substances through the resin matrix. Internal discolorations are permanent and can be caused by the resin material itself. The resin matrix, the interface between the matrix and the fillers, the type and amount of fillers, and polymer quality has a considerable influence on discoloration[64]. Studies have shown that internal discolorations are negligible after water storage when composites are completely polymerized[65,66]. At the same time, colorants, chemical dyes, or inadequately polymerized composites caused significant color changes[67]. Due to the hydrophobic/hydrophilic property of the resin matrix, the color susceptibilities of the composites vary[56]. If the resin matrix of the composite is more likely to absorb water, water-soluble pigments such as juices, tea, coffee, and soft drinks will stain composites[68,69]. Adversely, composites with low water sorption are more susceptible to discoloration by hydrophobic solutions[59]. Moreover, it became obvious that resins containing bisphenol A glycidyl methacrylate have lower susceptibility to discoloration due to their hydrophilic hydroxide groups than urethane dimethacrylate (UDMA)-containing resins with less hydrophilic aliphatic chains. Properties of fillers do have an important role in discoloration. Some studies revealed that increased filler content improved color stability[70-72]. Microhybrid composites with high organic filler content were shown to have more color stability than nanofilled and nanohybrid composites after two weeks immersion. The results were attributed to the filler size and morphology of the microhybrid composite[72]. The poor matrix-filler linkage also resulted in discoloration[56].

Certain dietary habits such as drinking coffee, tea, cola, red wine, and whiskey or oral habits like tobacco use in a pattern were found to stain composites in varying degrees[63,73-80]. Energy drinks had a risk of causing discoloration due to their wide variety of ingredients. Varying amounts of caffeine, guarana extract, taurine, and ginseng are the main ingredients of energy drinks[67]. Besides, the commonly used food dyes have the main responsibility for discoloration. These include Brilliant Blue, Allura Red, and Caramel, among others. Colorants of commonly used energy drinks are shown in Table 2. All these colorants could be absorbed and penetrated into the organic matrix[69,76]. There have been research effects about the colorant effect on restorative materials. Composite resins are the first to come up. Erdemir *et al*[35] showed that all tested sports drinks (Powerade, Red Bull, Burn) had clinically perceptible ($\Delta E > 3.3$) discoloration on varying composite discs after six months. In the same research, different types of composites had been investigated. At one- and six-month evaluations, nanofill composites showed lower discoloration than microhybrid composites. The smaller the particles of the resin matrix, the smoother the surfaces of the composites. Thus, larger particles were more prone to color stability than the small particles. That was the reason why microhybrid composites had lower color stability than nanofilled composites, which was explained in the study.

Indeed, the resin matrix of composites absorbs water from the environment and spreads it to the whole structure. However, inorganic glass fillers such as silica, $SiO_2$, are only able to absorb water over their surface[81,82]. The excessive amount of absorbed water could cause several problems, such as resin matrix plasticization, silane hydrolisation, and micro-cracks formation[65,66,82]. Through these cracks, colorants could penetrate, and discoloration may occur[65,83].

The acidic nature of the energy drinks could negatively affect the surface degradation as well. The subsurface ions such as Ca, Al, and silicone would be lost and surface degradation could begin. This may lead to a decrease in wearing resistance and roughening of the surface[57,65,84]. The roughening of the surface by wear and by chemical degradation may also affect "gloss" and consequently increase the extrinsic staining[67,85]. A study has reported that resin materials are susceptible to surface roughness degradation after immersion in sports drinks[63]. The pH's of energy drinks may tend composite resins to erode under acidic conditions. Acids inside these drinks could penetrate into the resin matrix and display the release of unreacted monomers to the environment. This may result in lower surface hardness scores of composite resins[35].

In addition, surface hardness of a restorative material depends on the duration of exposure time and the composition of the material[55,86]. However, previous

studies have shown that these beverages potentially cause dental erosion[2,13], and that may influence the material's mechanical and physical characteristics[86,87]. Furthermore, the kind of acid in the solutions might have reduced the surface hardness of restorative materials. It has been reported that organic fillers can be damaged by citric acid found in many sports and energy drinks[88-90]. Briefly, consuming both sports and energy drinks frequently, could damage the composites inside and may shorten the longevity of the restorations.

### *Other tooth-colored restorative materials*

The effect of color stability of glass ionomers and resin-modified glass ionomers has been tested with coffee, red wine, tea, and cola[65,91,92]. Glass ionomers have hydrophilic properties that may cause water sorption. On the other hand, resin-modified glass ionomers could show more color resistance than conventional glass ionomers due to their resin monomers inside. Gürdal *et al*[92] compared the level of color stability of a composite, a conventional glass ionomer, and a poly-acid modified resin composite. After being immersed in mouthrinses for 12 h, the composite resin showed the lower stability followed by conventional glass ionomer and poly-acid modified resin composite. The reason for a poly-acid modified resin composite showing the highest color stability was thought to be the matrix filled with UDMA inside. However, many other studies had conflictive results in favor of both composites and glass ionomers[65,93,94]. Ceramics have higher susceptibility to discoloration than composites due to their more hydrophobic nature[56]. Because of this reason, ceramics have not compared with resin composites generally.

## CONCLUSION

Dentists have a duty to their patients to give them instructions on the consumption of drinks or foods which can damage dental health. Most food and drinks have little noticeable effects on dental health. Among the drinks that are most likely to damage teeth and restorative materials are sports and energy drinks which contain sugar to feed oral bacterial, and drinks which have a low pH which can erode teeth and increase their sensitivity. Patients who suffer poor oral health because of their over-consumption of sports and energy drinks need to be made aware of the likely causes of their dental problems.

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