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**CLINICAL AND EXPERIMENTAL JUSTIFICATION OF THE EFFECTS OF REGULAR
ENERGY DRINK CONSUMPTION ON ORAL HEALTH STATUS AND DENTAL
ENAMEL**



Scientific Supervisor: Rizayev Jasur Alimdjanovich

Samarkand State Medical University

sammu@sammu.uz

<https://orcid.org/0009-0000-5354-5491>



Scientific Supervisor: Oripov Firdavs Suratovich

Samarkand State Medical University

firdavs.oripov1809@gmail.com

<https://orcid.org/0000-0002-0615-0144>



Bobonazarov Dilshod Ilhom o'g'li

Samarkand State Medical University

drbobonazarov007@gmail.com

<https://orcid.org/0009-0008-9146-0892>

Abstract: This study aimed to clinically and experimentally evaluate the effects of regular energy drink consumption on oral health and dental enamel. Fifty participants were enrolled in the study. Clinical assessment included the DMFT, OHI-S, GI, and BEWE indices, together with salivary pH and buffering capacity. Experimental evaluation assessed enamel microhardness and morphological changes. The findings demonstrated that regular consumption of energy drinks was



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associated with enamel demineralization, dental erosion, reduced enamel microhardness, and deterioration of oral hygiene status. The results provide scientific evidence supporting the importance of preventive dental care and public awareness regarding the harmful effects of excessive energy drink consumption.

Keywords: Energy drinks, oral health, dental enamel, dental erosion, demineralization, enamel microhardness, dental caries, saliva.

КЛИНИКО-ЭКСПЕРИМЕНТАЛЬНОЕ ОБОСНОВАНИЕ ВЛИЯНИЯ РЕГУЛЯРНОГО УПОТРЕБЛЕНИЯ ЭНЕРГЕТИЧЕСКИХ НАПИТКОВ НА СОСТОЯНИЕ ПОЛОСТИ РТА И ЗУБНУЮ ЭМАЛЬ

Аннотация: Настоящее исследование посвящено клинической и экспериментальной оценке влияния регулярного употребления энергетических напитков на состояние полости рта и зубную эмаль. В исследовании приняли участие 50 человек. Проведена оценка индексов DMFT, OHI-S, GI и BEWE, а также определены pH и буферная ёмкость слюны. В экспериментальной части изучены микротвёрдость эмали и её морфологические изменения. Полученные результаты показали, что регулярное употребление энергетических напитков способствует деминерализации эмали, развитию эрозии зубов, снижению микротвёрдости эмали и ухудшению состояния полости рта. Полученные данные могут быть использованы для совершенствования профилактики стоматологических заболеваний.

Ключевые слова: Энергетические напитки, полость рта, зубная эмаль, эрозия зубов, деминерализация, микротвёрдость эмали, кариес, слюна.

ENERGETIK ICHIMLIKLARNI MUNTAZAM ISTE'MOL QILISHNING OG'IZ BO'SHLIG'I HOLATI VA TISH EMALIGA TA'SIRINI KLINIK-EKSPERIMENTAL ASOSLASH

Annotatsiya: Ushbu tadqiqot energetik ichimliklarni muntazam iste'mol qilishning og'iz bo'shlig'i holati va tish emaliga ta'sirini klinik hamda eksperimental jihatdan baholashga bag'ishlangan. Tadqiqotda 50 nafar ishtirokchi tekshirildi. Klinik baholashda DMFT, OHI-S, GI va BEWE indeksleri, shuningdek, so'lakning pH ko'rsatkichi va buferlik xususiyati aniqlandi. Eksperimental bosqichda tish emalining mikroqattiqligi va morfologik o'zgarishlari o'rganildi. Natijalar muntazam energetik ichimlik iste'moli tish emali demineralizatsiyasi, eroziyasi, mikroqattiqligining pasayishi hamda og'iz bo'shlig'i gigiyenik holatining yomonlashishi bilan bog'liqligini ko'rsatdi. Tadqiqot natijalari stomatologik kasalliklarning oldini olish va profilaktik chora-tadbirlarni takomillashtirish uchun ilmiy asos bo'lib xizmat qiladi.

Kalit so'zlar: Energetik ichimliklar, og'iz bo'shlig'i, tish emali, dental eroziya, demineralizatsiya, mikroqattqlik, kariyes, so'lak.

Introduction

Oral health is an essential component of general health and quality of life. The integrity of dental enamel and the maintenance of oral homeostasis are influenced by numerous endogenous and exogenous factors, including dietary habits, oral hygiene practices, and the frequent consumption of acidic beverages. In recent years, the widespread consumption of energy drinks, particularly among adolescents and young adults, has become a growing public health concern because of their potential adverse effects on oral tissues and dental hard structures. Energy drinks typically contain high concentrations of caffeine, sucrose, glucose-fructose syrup, citric acid, phosphoric acid, taurine, carbon dioxide, and various flavoring agents. Although these beverages are marketed as products that improve physical endurance and mental performance, their acidic composition and high sugar content



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create favorable conditions for dental enamel demineralization, erosion, and caries development. The pH of most commercially available energy drinks ranges from approximately 2.3 to 3.5, which is well below the critical pH of 5.5 required for enamel dissolution. Consequently, repeated exposure to these beverages may result in irreversible mineral loss and structural deterioration of enamel.

From a clinical perspective, regular consumption of energy drinks has been associated with reduced salivary pH, decreased buffering capacity, impaired remineralization, increased dental plaque accumulation, and a higher prevalence of dental erosion and hypersensitivity. The acidic environment created by these beverages promotes hydroxyapatite dissolution, while the high sugar concentration enhances the metabolic activity of cariogenic microorganisms, leading to an increased risk of dental caries and periodontal inflammation. These pathological changes may ultimately compromise both the functional and esthetic properties of the dentition. Experimental studies have demonstrated that prolonged exposure of enamel specimens to energy drinks significantly decreases surface microhardness, increases surface roughness, and accelerates mineral loss. Furthermore, scanning electron microscopy has revealed pronounced morphological alterations in enamel surfaces following repeated acidic challenges. Despite these findings, relatively few studies have comprehensively combined clinical observations with experimental investigations to evaluate the relationship between habitual energy drink consumption and oral health status.

Relevance

The increasing consumption of energy drinks, particularly among young people, has become an important public health issue due to their potential adverse effects on oral health. The high acidity and sugar content of these beverages contribute to dental enamel demineralization, erosion, and an increased risk of dental caries. Despite numerous studies, comprehensive clinical and experimental evidence regarding their effects on oral tissues remains limited. Therefore, investigating the impact of regular energy drink consumption on oral health and dental enamel is scientifically and clinically relevant for developing effective preventive and therapeutic strategies in modern dentistry.

Aim

To provide a clinical and experimental justification of the effects of regular energy drink consumption on oral health status and dental enamel by evaluating changes in oral hygiene, salivary characteristics, dental hard tissues, and enamel microhardness.

Main part

Energy drinks have become one of the most widely consumed functional beverages worldwide, particularly among adolescents, university students, and young adults. They are commonly used to improve physical performance, increase alertness, and reduce fatigue. The principal ingredients of energy drinks include caffeine, taurine, glucuronolactone, carbohydrates, B-complex vitamins, citric acid, phosphoric acid, carbon dioxide, artificial sweeteners, preservatives, and flavoring agents. Although these substances provide temporary stimulation of the central nervous system, their long-term and frequent consumption may negatively affect oral health. One of the most important characteristics of energy drinks is their high acidity. The pH of most commercial products ranges between 2.5 and 3.5, which is to such acidic conditions initiates the dissolution of hydroxyapatite crystals, resulting in the release of calcium and phosphate ions from the enamel surface. Repeated episodes of acid exposure progressively weaken the enamel structure and increase its susceptibility to erosion. The high concentration of fermentable sugars further enhances the cariogenic potential of these beverages. Oral bacteria, particularly *Streptococcus mutans* and *Lactobacillus* species, metabolize these sugars into organic acids that reduce plaque pH and accelerate enamel demineralization. As a result, regular energy drink consumers exhibit an increased risk of dental caries, enamel erosion, and dentin hypersensitivity.

Regular consumption of energy drinks has become an important risk factor for the development of various oral diseases. Clinical studies indicate that individuals who frequently consume these beverages exhibit a significantly higher prevalence of dental erosion, enamel wear,



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dental caries, dentin hypersensitivity, and gingival inflammation than non-consumers. These pathological changes are mainly associated with the acidic pH and high sugar content of energy drinks, which adversely affect the oral environment. Comprehensive clinical assessment includes evaluation of oral hygiene status, dental caries experience, periodontal health, salivary characteristics, and the presence of erosive tooth wear. Standardized indices such as the Decayed, Missing, and Filled Teeth (DMFT) index, Plaque Index (PI), Gingival Index (GI), Simplified Oral Hygiene Index (OHI-S), and Basic Erosive Wear Examination (BEWE) are commonly applied to determine the severity of oral alterations. These indices provide objective information regarding the relationship between the frequency of energy drink consumption and deterioration of oral health. Salivary analysis is an essential component of clinical evaluation because saliva plays a fundamental role in maintaining oral homeostasis. Frequent consumption of acidic beverages decreases salivary pH, buffering capacity, and mineral saturation, thereby reducing the natural remineralization potential of dental enamel. Consequently, plaque accumulation increases, cariogenic microorganisms proliferate, and the susceptibility to enamel demineralization becomes greater. Clinical examination often reveals initial enamel opacity, loss of surface gloss, shallow erosive defects, cervical lesions, and increased tooth sensitivity to thermal and chemical stimuli. In severe cases, progressive enamel destruction exposes dentin, resulting in pain during mastication and deterioration of dental function. Early identification of these clinical manifestations allows timely preventive interventions and minimizes irreversible damage to dental hard tissues. Therefore, routine clinical assessment is essential for monitoring oral health in individuals with habitual energy drink consumption.

Experimental studies provide important evidence regarding the mechanisms by which energy drinks damage dental enamel. In vitro investigations commonly use extracted human permanent teeth or enamel specimens that are repeatedly immersed in commercially available energy drinks under standardized laboratory conditions. Changes in enamel microhardness, mineral content, surface roughness, and morphological characteristics are subsequently evaluated using modern analytical techniques. Surface microhardness is generally measured using Vickers or Knoop microhardness tests before and after exposure to acidic beverages. Most studies demonstrate a significant reduction in enamel hardness following repeated immersion, indicating progressive demineralization. Surface profilometry and atomic force microscopy reveal increased roughness and irregularities, while scanning electron microscopy demonstrates dissolution of enamel prisms, enlargement of interprismatic spaces, and destruction of the enamel surface architecture. Chemical analysis has shown that acidic energy drinks promote the release of calcium and phosphate ions from hydroxyapatite crystals, resulting in irreversible mineral loss. The severity of enamel damage depends on several factors, including beverage pH, titratable acidity, exposure duration, consumption frequency, and the protective effects of saliva. Beverages containing citric acid generally exhibit a stronger erosive potential because citrate ions bind calcium and inhibit the natural remineralization process.

Saliva is one of the most important protective factors in maintaining oral health because it regulates pH, provides minerals for enamel remineralization, and controls the growth of oral microorganisms. Regular consumption of energy drinks significantly affects the physicochemical properties of saliva due to their high acidity and sugar content. Frequent exposure to acidic beverages lowers salivary pH and reduces its buffering capacity, creating favorable conditions for enamel demineralization. In addition, repeated intake of energy drinks may alter salivary flow rate, resulting in prolonged acid contact with the tooth surface. These changes impair the natural remineralization process and increase the susceptibility of dental tissues to erosion. The acidic environment also promotes the growth of acidogenic and cariogenic bacteria while reducing beneficial oral microorganisms, leading to microbial imbalance. Consequently, dental plaque accumulation increases, gingival inflammation becomes more pronounced, and the risk of periodontal diseases rises. Evaluation of salivary pH, buffering capacity, flow rate, and microbial composition provides



valuable information regarding the biological mechanisms through which energy drinks influence oral health.

A comparative evaluation of clinical and experimental findings provides a comprehensive understanding of the adverse effects of energy drinks on oral tissues. Clinical examinations frequently reveal dental erosion, enamel wear, increased caries prevalence, gingival inflammation, and dentin hypersensitivity among habitual consumers. Experimental investigations support these observations by demonstrating significant reductions in enamel microhardness, increased surface roughness, and structural damage following repeated exposure to acidic beverages. The consistency between laboratory and clinical findings confirms that the acidic composition of energy drinks plays a central role in the development of enamel demineralization. Furthermore, both approaches demonstrate that the severity of dental damage depends on the frequency and duration of beverage consumption, oral hygiene status, and individual salivary characteristics. Integrating clinical observations with experimental evidence strengthens the scientific validity of the study and improves understanding of the biological mechanisms responsible for oral tissue deterioration.

The prevention of energy drink-related oral diseases requires a comprehensive approach involving patient education, dietary modification, and regular dental care. Individuals should be advised to limit the frequency of energy drink consumption and avoid prolonged exposure of teeth to acidic beverages. Drinking water immediately after consumption and using a straw may reduce direct contact between acids and dental enamel. Tooth brushing should be postponed for at least 30 minutes after consuming acidic drinks to prevent additional enamel abrasion. The regular use of fluoride-containing toothpaste, fluoride varnishes, and remineralizing agents containing calcium and phosphate can enhance enamel resistance against acid attack. Routine dental examinations are essential for the early detection of erosive lesions and the implementation of preventive treatment. Public health education programs should increase awareness of the oral health risks associated with excessive energy drink consumption, particularly among adolescents and young adults. The application of these preventive strategies may significantly reduce the incidence of dental erosion, caries, and other oral diseases associated with long-term consumption of energy drinks.

Results

A total of 50 participants were included in the study, comprising 25 regular energy drink consumers and 25 healthy controls. Clinical examination demonstrated that individuals who regularly consumed energy drinks exhibited significantly poorer oral health than the control group. Dental erosion was detected in 64.0% of participants in the energy drink group, whereas only 16.0% of the control group presented mild erosive lesions. The mean DMFT index was significantly higher among regular energy drink consumers (6.8 ± 1.6) than in the control group (3.9 ± 1.2 , $p < 0.001$). Similarly, both the Plaque Index and Gingival Index were significantly elevated in the energy drink group, indicating poorer oral hygiene and a greater degree of gingival inflammation.

Salivary analysis revealed a significant reduction in salivary pH (6.25 ± 0.21) and buffering capacity among regular consumers compared with the control group (6.89 ± 0.17 , $p < 0.001$). Salivary flow rate was also moderately decreased in participants with habitual energy drink consumption. Experimental evaluation demonstrated a marked reduction in enamel microhardness following repeated exposure to energy drinks. The mean Vickers hardness value decreased from 316.4 ± 11.8 HV before exposure to 264.7 ± 9.9 HV after exposure ($p < 0.001$). Surface roughness increased significantly, while scanning electron microscopy revealed partial dissolution of enamel prisms, irregular surface morphology, and early erosive lesions. Correlation analysis demonstrated a strong positive association between the frequency of energy drink consumption and the severity of enamel erosion ($r = 0.69$, $p < 0.001$). These findings indicate that regular consumption of energy drinks is significantly associated with deterioration of oral health, decreased enamel microhardness, and an increased risk of dental erosion and dental caries.



Discussion

The findings of the present study demonstrate that regular consumption of energy drinks has a significant negative impact on oral health and dental enamel. Participants who frequently consumed energy drinks showed a higher prevalence of dental erosion, increased DMFT scores, poorer oral hygiene, and greater gingival inflammation compared with the control group. These results suggest that habitual intake of acidic energy beverages contributes to the deterioration of both dental hard tissues and periodontal health. The reduction in salivary pH and buffering capacity observed among regular consumers may explain the increased susceptibility of enamel to demineralization. Saliva is the primary protective factor against acidic challenges because it neutralizes acids and promotes enamel remineralization. Therefore, impairment of salivary protective functions may accelerate the development of erosive lesions and dental caries.

The experimental findings also confirmed the clinical observations. A significant decrease in enamel microhardness and the presence of morphological surface alterations after repeated exposure to energy drinks indicate that these beverages directly damage enamel structure. The low pH and high titratable acidity of energy drinks facilitate hydroxyapatite dissolution, while their sugar content enhances the metabolic activity of cariogenic bacteria, further increasing the risk of enamel destruction. The positive correlation between the frequency of energy drink consumption and the severity of enamel erosion suggests a dose-dependent relationship. Individuals consuming these beverages more frequently exhibited more pronounced clinical and experimental changes, emphasizing the importance of limiting their intake. The present findings are consistent with previous studies reporting that energy drinks are important dietary risk factors for dental erosion and caries. The combined clinical and experimental approach used in this study provides stronger evidence regarding the harmful effects of these beverages on oral tissues and highlights the need for preventive strategies. Patient education, dietary counseling, regular dental examinations, and the use of fluoride-containing preventive agents should be recommended to minimize the adverse effects of energy drinks on oral health.

Conclusion

Regular consumption of energy drinks has a significant adverse effect on oral health and dental enamel. The clinical findings demonstrated that habitual consumers had a higher prevalence of dental erosion, increased DMFT scores, poorer oral hygiene, and greater gingival inflammation than the control group. Experimental analysis confirmed a significant reduction in enamel microhardness and evident morphological changes following repeated exposure to energy drinks. The decrease in salivary pH and buffering capacity observed among regular consumers may accelerate enamel demineralization and increase the risk of dental caries and erosive tooth wear. Furthermore, the positive correlation between the frequency of energy drink consumption and the severity of enamel damage indicates that prolonged and frequent intake substantially increases the risk of oral diseases. The combined clinical and experimental results provide strong evidence that energy drinks are an important risk factor for the deterioration of dental hard tissues and oral health. Reducing the consumption of these beverages, promoting oral health education, maintaining good oral hygiene, and implementing preventive measures such as fluoride therapy and regular dental examinations are essential for preserving dental enamel and preventing erosion-related complications.

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