

GRADUATION PROJECT

Degree in Dentistry

DENTAL PROBLEMS ASSOCIATED WITH CHRONIC ENERGY DRINKS CONSUMPTION

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RESUMEN Y PALABRAS CLAVE

Introducción : El consumo crónico de bebidas energéticas puede conducir a problemas dentales desastrosos que son desconocidos por la mayoría de los consumidores. Una mejor comprensión de sus componentes y sus efectos sobre los dientes ayudaría a evitar dañarlos;

Objetivos: Evaluar los diferentes efectos nocivos que el consumo crónico de bebidas energéticas puede tener sobre los dientes y explicar por qué mecanismo estas bebidas pueden producirlos. Además, identificar los principales consumidores, su razón de consumo y promover la prevención del consumo excesivo en la población joven;

Material y Método : Se realizó una revisión sistemática basada en una búsqueda bibliográfica digital en las bases de datos PubMed, Dentistry and Oral Science Source y Cochrane. El estudio abarcó desde 2001 hasta 2023. Se investigaron publicaciones en inglés, francés, español y portugués. Se establecieron criterios de inclusión y exclusión;

Resultados: se identificaron 1.974 artículos y se eliminaron 695 duplicados. 1.045 fueron excluidos mediante la evaluación de títulos y resúmenes y solo 14 artículos de texto completo cumplieron con los criterios de inclusión.;

Conclusiones: Los datos sugieren que el consumo crónico de bebidas energéticas conduce a problemas dentales como erosión, bruxismo nocturno y caries. La extensión de los efectos varía mucho según la marca, ya que los ingredientes y las concentraciones difieren. Los principales consumidores son los adolescentes y adultos jóvenes que carecen de información sobre los efectos adversos. La sensibilización es fundamental para la prevención. La regulación en materia de publicidad como la colocación de etiquetas de advertencia en botellas y latas, podría ser una solución eficaz para reducir el consumo.

Palabras claves : Odontología; bebidas energizantes; erosión; bruxismo; caries.

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1. INTRODUCTION

1. Energy drinks: definition

Energy drinks are beverages sold to populations with the promise of physical, mental and cognitive stimulation. In addition, producers claim it will improve endurance, allow faster feedback, as well as improving focus.(1) They typically contain high amount of caffeine, sugars, additives and legal stimulants which include taurine, guarana or L-carnitine. (2) Moreover, high amounts of citric acid are found as well, which are damaging to the teeth. Their consumption is constantly rising especially among adolescents and young adults. In fact, even though athletes were firstly targeted by manufacturers at first, the consumer focus is now on a much larger and younger population. In 2013, the annual consumption rose above 5,8 billion liters around 160 countries. (3) This number being so high from the fact that customers nowadays consume energy drinks regularly and not occasionally.



Figure 1. Various brand of energy drinks (4)

1.2 Chemical composition of energy drinks

Energy drinks are made from a unique combination of ingredients which interact with each other in order to create a stimulating effect on the body. Quantities can vary from one brand to another. However primary ingredients such as caffeine, sugar and acids are almost always included in every energy drink composition. Other elements can be

added to modify taste, color and carbonation amount, depending on the brand and population targeted.

1.2.1 Caffeine

The first ingredient always found in energy beverages is caffeine. In fact, caffeine is a well-known stimulant which affects numerous neurotransmitters as well as endocrine pathways. Caffeine inhibits phosphodiesterase which, as a result, will enhance signaling of adrenergic receptors and pathways, affecting the central and peripheral nervous system. (5) Some of the effects include increased cardiac inotropy and chronotropy which will amplify cardiac frequency and contractility, having the blood pressure rise. Other ingredients such as taurine, guarana and L-carnitine participate in that neurologic stimulation as well. (3,5)

1.2.2 Taurine

Taurine is a non-essential amino acid that can be synthesized endogenously or exogenously. It means our body can build it itself or it could come from an external origin such as our diet. As a matter of fact, taurine is found in meat (6), fish, dairy products, and supplements. In the organism, taurine is found largely in the brain as a support for neural progenitor cells proliferation and synapses formation in regions responsible for long-term memory. That is the reason why taurine levels of energy drinks bring great attention as above average values could hypothetically disrupt hemostasis in the brain. Nowadays, experimental studies are still limited to animals and should be pursued in order to obtain accurate information of the potential long-term effect on the human body. However, most papers describe taurine as being mainly a neuroprotector used by older animal bodies when under the action of a disruptive factor such as stress. In opposition, chronic consumption of taurine in child and adolescent animal populations resulted as a worsening of visual discrimination as well as increased fear levels. These findings bring great inquietude knowing the population targeted by energy drinks is getting younger. Also, caffeine and taurine combination should be further studied as they already showed in in-vitro animal experiments to clearly intensify the activity of mices. (5)

1.2.3 Guarana

Guarana comes from a plant native to the Amazon. It is a natural stimulant which seeds have great concentration of caffeine, about 4 times the amount found in a coffee bean, in addition to other natural chemicals. It favors mental concentration, attention, as well as helping with weight management. A study observing the locomotor activity and convulsive response of Planarian worms have shown that when Guarana is combined to caffeine or sugar, others major components of energy drinks, a significant rise in stimulation is observed which is higher than when consumed alone. (7)



Figure 2. Guarana plant (8)

1.2.4 Sugar

Energy drinks also contain great amount of sugars, even superior than popular soft drinks. This sugar content can lead consumer to weight gain and obesity as well as increasing the risk of type 2 diabetes.(3) Furthermore, a diet too high in sugar is known as one of the main risk factor for caries. In fact, monosaccharides and disaccharides we consume in our diet have high cariogenic potential, some being more damaging than others. As for reference, fructose which is a combination of glucose and sucrose, is very well metabolized by cariogenic bacteria such as Streptococcus Mutans.

1.2.5 Acid

Energy drinks contain high amount of acids which act as a preservative while providing a sour or tangy taste. They have low pH level, between 3 and 6 (9) for citric acid. Phosphoric acid has an even lower pH of 1,5. (10) Studies have shown that high concentrations of citric acid causes enamel demineralization leading to erosive lesions

on teeth. In addition, energy drinks record the highest concentrations of citric acid with a mean of $7,3 \pm 0.06$ g/L compared to 1.76 ± 0.04 g/L in soft drinks. (11)

1.2.6 Others

Sweeteners, vitamins, colorants, or other herbs such as ginseng could be found as well. The ingredients contained in energy beverages are not considered dangerous individually. However, energy drinks being considered as food supplements, they are not required to follow the same safety regulations or testings for premarket approval by the U.S Food and Drug Administration as other food products would. Furthermore, often times concentrations are not specified because of the lack of regulations when it comes to energy beverages which make it even harder to establish the possible effects of the ingredients, let alone their interactions with one another. (5,7)

1.3 Consumers and reasons for consumption

More than half of the global consumer market for energy drinks is made of adolescents and adults younger than 35 years of age. (13) About 1/3 consume them on a regular basis. (3) Even though short and long term adverse effects keep being studied, as others are being discovered, consumption is still remarkably rising globally. A study in a university of Lebanon about student's consumption and their perception of energy drinks showed it is a common and growing trend among students. Whether it is for its ability to improve and maintain concentration when studying, or to boost physical performance for students enrolled in a sport team. Also, it showed that student athletes would often mistake energy drinks as having the same effects as sports drinks although it does not have the same ability to rehydrate the body after exercise. (13) Furthermore, a cross sectional study of 46 studies with the objective of examining the attitude of

Supplement Facts		
Serving Size 8.0 fl.oz. (240 mL)		
Servings Per Container: 2		
Amount Per Serving	% Daily Value	
Calories	100	
Total Carb	27g	9%*
Sugars	27g	†
Riboflavin Vit B2	1.7mg	100%
Niacin Vit B3	20mg	100%
Vitamin B6	2mg	100%
Vitamin B12	6mcg	100%
Sodium	180mg	8%
Taurine	1000mg	†
Panax Ginseng	200mg	†
Energy Blend	2500mg	†
L-Carnitine, Glucose, Caffeine, Guarana, Inositol, Glucuronolactone, Maltodextrin		
*Percent Daily Values are based on a 2000 calorie diet. † Daily Value not established.		

Figure 3. Nutrition label (12)

young people of 11-18 years old towards energy drinks, only revealed a few participants perceiving energy beverages as having harmful and negative health effects. This previous finding shows the lack of information and awareness of younger population groups. (14)

Advertising plays a key role in the consumption evolution. The target of manufacturers has been expanded to young population of students, athletes, workers when it used to be focused on athletes only. Product advertisements are displayed on TV, internet, video games and even sports sponsorships. It is also the main single source of information. Population mainly drinks them for the taste, flavor, packaging, as an energy source and for sport performance. The knowledge about the other effects of energy drinks or even the composition is very limited. (3,13,14)

1.4 Acute side effects after consumption

As a consequence of the combination of various stimulants in the same beverage that enhance each other, energy drinks consumption produces immediate effects on the body that are common features of caffeine intoxication. It increases heart rate as well as systolic and diastolic blood pressure, creates arrhythmia, (15) produces insomnia, stress, nervousness or even induces a depressive mood as well as provoking gastrointestinal upset or muscle twitching (3,16) A more frequent and long term consumption could lead to worse effects.

1.5 Chronic side effects after consumption

A repeated and prolonged consumption of energy drinks would lead to chronic side effects. Those include issues of the heart as it is being overstimulated over a long period of time as well as gastro-intestinal issues due to acids and perturbations of the neurologic system. (3) Also, energy drinks being often combined with alcohol by young people, have an exacerbated toxicity that is damaging to the body. (5,13,14) Other long-term effects on adolescents brains are still being discussed. (3,5,14) Well known chronic side effects on every population are at the dental level. In fact, energy drinks are devastating to the teeth.

1.5.1 Dental problems

Dental issues are common to every human being. They can have a bacterial origin such as caries or gingivitis, or a non-bacterial origin such as tooth wear. Tooth wear has many causes that could be classified as intrinsic such as genetics and gastric reflux or extrinsic such as our diet, habits, and lifestyle.

Tooth wear can have a few causes. On one hand, attrition is the loss of tissue on the incisal and occlusal surface of teeth caused by tooth-to-tooth contact. The most common cause is bruxism. Bruxism is the involuntary prolonged grinding and clenching of the teeth during the day, at night or both. On the other hand, abfraction also happens when the antagonist tooth apply pressure while biting creating stress, however in this case, it results in a cervical defect lesion. (17) Furthermore, abrasion is the damage caused by the interaction between materials such as a porcelain crown and a natural tooth. Last but not least, erosion is the dissolution and followed loss of enamel caused by acidity (18). The causes can be extrinsic such as acidic beverages and food consumption as well as intrinsic such as gastric reflux or repeated emesis associated with eating disorders such as bulimia. (19)

1.5.1.1 Energy drinks and erosive tooth wear

Energy drinks demonstrate to be one of the main causes to irreversible erosive tooth wear. The acidity of the beverage comes from its large amounts of caffeine, guarana and citric acid which have acidic pH. They have various capacities of demineralizing the enamel. In fact, many factors must be taken into account in addition to the pH of the solution in order to evaluate the actual harm it can produce to the teeth. Those factors being the buffer capacity, titratable acidity, consistency, as well as calcium, phosphate, fluoride ions concentrations which can all be investigated and studied through in vitro experiments. (2) Moreover, frequency of use and time of exposure play major roles in energy drinks harmful effects to the teeth. (18) In fact, drinking with a straw could help reduce prolonged contact with the teeth and avoid tooth erosion. Avoiding to retain the drink in the mouth while swishing it is also advised.(20)



Figure 4. Patient with acid erosion from years of drinking soda (21)

1.5.1.2 Energy drinks and bruxism

Bruxism is the involuntary prolonged grinding and clenching of the teeth during the day, at night or both. Among the factors that could exacerbate its intensity we could find stress, anxiety, or even suppressed anger and frustration, as well as genetic predisposition. Caffeine is a central nervous system stimulant. It speeds up the transmission of signals between our brain and the nervous system as well as its overall activity. High consumption of caffeine has been proven to be positively associated with sleep bruxism (22) as well as weekly bruxism (23) when consumption is superior to 8 cups a day. Knowing a cup of coffee contains a mean of 40 mg of caffeine and a can of “TNT Hydro Blast V2 Energy drink” have up to 81,7 mg only 4 cans a day can induce or increase bruxism manifestations.



Figure 5. Attrition from chronic bruxism (24)

1.5.1.3 Energy drinks and caries

Energy drinks often contain large quantities of sugar, between 21 and 34g per oz. As an example, a can of Monster energy drinks contains 54g of sugar which is the equivalent of about 13 tablespoons. As for what type of sugar, it contains mainly sucrose, glucose and fructose, the last one being a chemical combination of the two previous. (3) This amount of sugar consumption is harmful to teeth. Bacteria in our mouth will metabolize it, producing acids which will cause the mouth pH to drop under the « critical pH » value of 5,5 which would consequently dissolve the enamel and produce a cavitation in the tooth. (2) Furthermore, when the outer layers of our teeth are already damaged and the causing factor is still present, as with chronic consumers, acids can seep deeper into the tissues, progressing closer and closer to the pulp.



Figure 6. Patient with tooth decays (25)

1.6 Justification

Energy drinks consumption keeps rising among populations, especially within younger individuals. It is responsible for various dental issues that can become irreversible if not treated. Avoiding the early onset of dental erosion, caries and bruxism is fundamental for an overall better oral health. Raising awareness on the effects of energy drinks can have a beneficial impact on prevention and treatment. In fact, most consumers are unaware of the negative aftermath energy drinks have, especially on teeth. Therefore, this review will analyze and compare the dental problems produced by different energy drinks in order to inform population about the existing risks towards oral health. In

addition, advocating for additional regulations such as correct advertising from factories should be the next step towards promoting dental health.

Research question : Do energy drinks produce dental problems in chronic consumers ?

2. OBJECTIVES AND HYPOTHESES

2.1 Hypotheses

H₀ : Chronic energy drink consumption produces erosion and caries.

H₁ : Caffeine content in energy drink induces bruxism in chronic consumers.

2.2 Objectives

Main objectives:

- Assess the different harmful effects chronic energy drinks consumption can have on teeth
- Explain from what mechanism components of energy drinks can produce harm to the teeth.

Secondary objectives:

- Identify energy drinks main consumers and reason for consumption
- Promote prevention in younger population

3. MATERIALS AND METHODS

The study is a systematic review, conducted in depth in international databases, such as Pubmed, Cochrane, and the Dentistry and Oral Science Source. Searches were performed by seeking references through the university library service: Crai Dulce Chacón, which allows access to full documents.

Main and secondary objectives were developed and searched through all databases. The search strategy for the main objectives was done using the following keywords and Boolean operators: « *energy drinks* » OR « *energy beverages* » NOT « *soft drinks* » NOT « *juices* » AND « *dental effects* » AND « *dental erosion* » AND « *dental caries* ». The final search question was as follows: «*energy drinks*» [All Fields] OR *energy beverages* [All Fields] NOT « *soft drinks* » [All Fields] NOT « *juices* » [All Fields] AND « *dental effects* » [All Fields] AND «*dental erosion*» [MeSH terms] AND «*dental caries* » [MeSH terms].and « *bruxism*» [MeSH terms]. The search strategy for bruxism had to be different as no article linking energy drinks directly with bruxism exist. The keywords and Boolean operators used were « *caffeine* » OR «*caffeinated drinks* » AND « *bruxism* » AND « *tooth grinding* ». The resulting search question was as follows: « *caffeine* » [All Fields] OR «*caffeinated drinks* »[All Fields] AND « *bruxism* »[All Fields] AND « *tooth grinding* »[All Fields].

The search strategy for the third objective was performed using the following keywords and Boolean operators: « *energy drinks* » OR « *energy beverages* » NOT « *soft drinks* » NOT « *juices* » AND « *consumption* » OR « *use* » AND « *habits* » AND «*consumers*» [All Fields]. The final search question was as follows: «*energy drinks*» [All Fields] OR *energy beverages* [All Fields] NOT « *soft drinks* » [All Fields] NOT « *juices* » [All Fields] AND « *consumption* » [All Fields] OR « *use* » [All Fields] AND «*habits*» [All Fields] AND «*consumers*» [All Fields].

The search strategy for the last objective was performed using the following keywords and Boolean operators: « *energy drinks* » OR « *energy beverages* » NOT « *soft drinks* » NOT « *juices* » AND « *prevention* » AND « *habits* ». The final search question was as follows: «*energy drinks*» [All Fields] OR *energy beverages* [All Fields] NOT « *soft drinks* »

[All Fields] NOT « juices » [All Fields] AND « prevention » [All Fields] AND «knowledge» [All Fields] AND «awareness».

Articles were selected when fully accessible in English, French, Spanish or Portuguese. Once the search of documents in the database had been carried out, and the duplicates had been removed, the inclusion and exclusion criteria were applied to select final articles.

Table 1. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion criteria
Energy drinks/beverages	Soft drinks or juices focus
Clinic human/animal studies	Articles published prior 2000
In vitro/In vivo	Articles not fully available in French/ English/Spanish/Portuguese

4. RESULTS

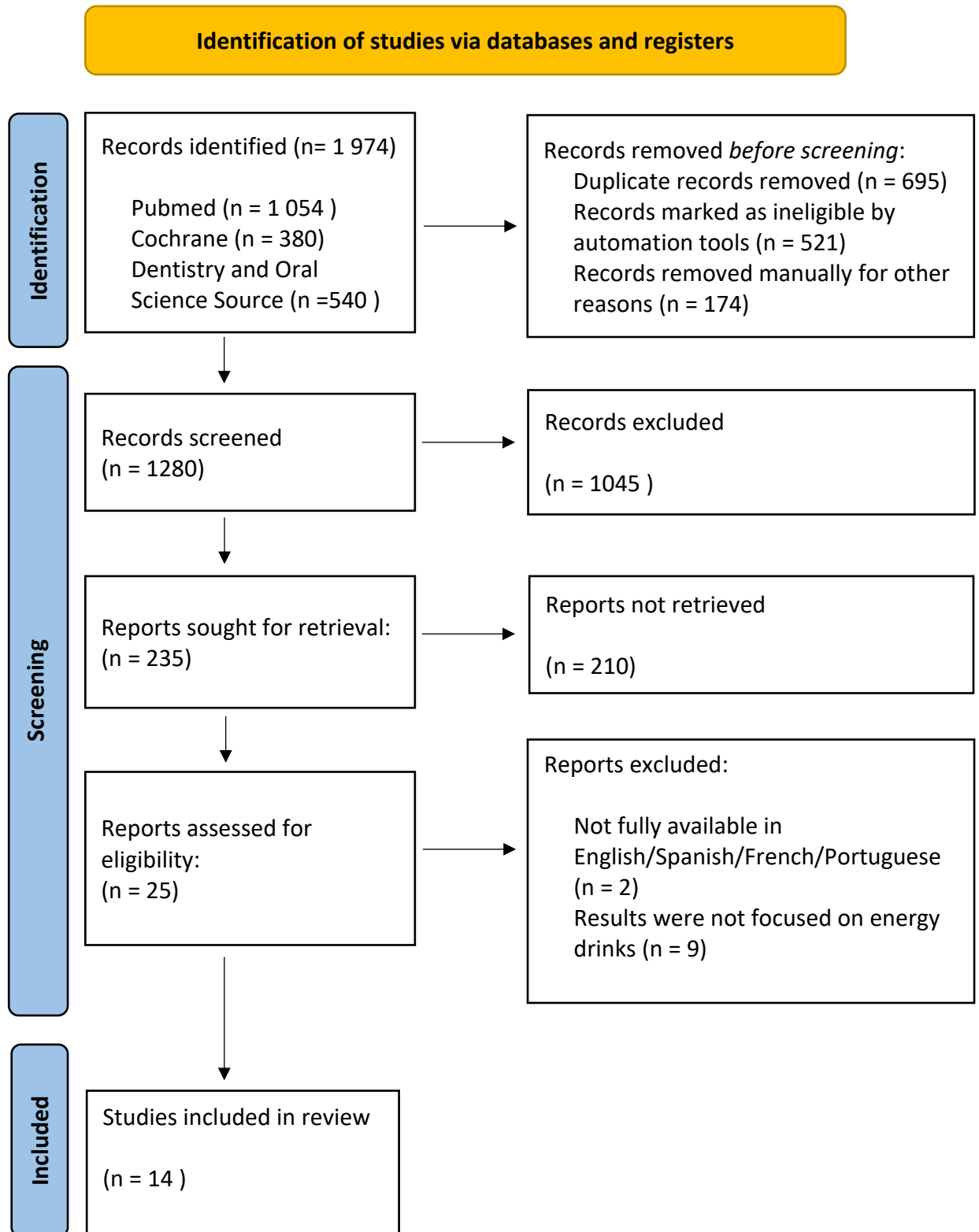


Figure 6. Flowchart of the included studies

Table 2. Erosive potential of energy drinks

Study	Study Design	Sample	Measured Parameters	Protocol	Results
Cavalcan ti. A.L et al., 2010 (26)	In vitro experimental study	N= 9 commercially available energy drinks	pH Titration Acidity	3 measurements for each sample recording the mean.	pH value ranged from 1,52 to 3,20 Titration Acidity ranged from 0,56 to 1,04 mL
Beltrán. K. and Cardon. W. 2017 (27)	In vitro experimental study	Mr. Big® Kem Extreme® Red Bull® Monster Energy®	pH values Titration acidity Erosive test	pH tested in different combinations of energy drinks, artificial saliva and alcohol. Titration acidity of energy drinks alone N = 20 non-erupted human third molars vertically sectioned in half exposed to different combinations of energy drinks, artificial saliva, and alcohol for 30 min and 60 min.	pH values ranging from 2.55 to 3.46 in energy drinks alone When mixed with artificial saliva and alcohol pH had risen a mean of +1,38 Titration acidity ranging from 3,5mL to 5,7 mL The elemental structure of the tooth was altered by the solutions. Alcohol did not seem to worsen the demineralization effect.

Matumo et al., 2018 (28)	In vitro experimental study	N= 10 commercially available energy drinks	pH	With gas and without gas at 25°	The pH values ranged from 2.1 to 3.25. They showed no variations with or without gas.
			Titration acidity		Titration acidity ranged from 1,2 mL to 3,75 mL.
		Control Group Group 1: Red Bull Light® Group 2: Red Bull®	Erosive test	N= 18 sound premolars Divided in 3 groups of N= 6 Immersed 6 times in 10mL of liquid for 5 min with intervals of 12 hours. Erosive test was performed.	Microhardness Means Group 1 Baseline = 384,85 HK* Final = 129,65 HK Group 2 Baseline = 434,62 HK Final = 156,90 HK
Costa Silva. J-G. et al., 2020 (2)	In vitro experimental study	G1-TNT Energy Drink® (n= 8)	pH values		pH values ranging from 2.36 to 3.41
		G2- Red Bull® (n= 10) G3- Monster Energy® (n= 10), G4- Coca-Cola® (n= 10) as a control	Titration acidity	Buffering capacity	
			Erosive test	38 extracted human third molars were immersed in 50 mL of drink for 30 minutes with gentle stirring	Percentage loss of surface microhardness ranging from 29,48% to 35,47%.

*HK = Knoop Microhardness

Table 3. Association of caffeine consumption and bruxism

Study	Study Design	Sample	Protocol	Results
Ohayon. M. et al; 2001 (29)	Case Control Study	13,057 subjects Group 1 : 568 Sleep Bruxism Group 2 : 491 Tooth grinding alone Control group: 11 896	Interview questionnaire and Sleep EVAL expert system for bruxism diagnosis	[6 cups coffee] OR = 2,0; [3-5 cups coffee] OR=1,2
Rintakoski. K.and Kaprio.J. 2013 (23)	Cohort Study	12 502 twin individuals	103 multiple-choice questions dealing with alcohol and tobacco use, coffee consumption and bruxism.	[0-8 cups coffee] OR=1 [>8 cups coffee] OR=1,9
Maddalena Dias. I. et al ; 2014 (30)	Case Control Study	100 patients 50 cases of night bruxism 50 controls	Questionnaire about exposure to alcohol, cigarettes, caffeine, drugs consumption, noise exposition	[caffeine consumption alone] OR = 0,576 [exposition to more than one factor] OR = 5,159
Berger. M. et al; 2016 (31)		113 subjects Group 1 Rare awake bruxism = 13 Group 2 Frequent awake bruxism = 4 Control group = 96	Questionnaire about tobacco use, coffee consumption and awake bruxism.	There is no connection between caffeine use and awake bruxism.

Lacusta. V. et al ; 2017 (32)	Cross Sectional study	100 patients with primary sleep bruxism.	Questionnaires and series of investigations	<p>[>6 cups coffee] Sympathetic autonomous activity disturbances In 81.8% pathological sleep</p> <p>[4-6 cups coffee] Increased values of bruxism-related discomfort as well as temporomandibular joint-associated abnormalities</p>
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Table 4. Cariogenic potential of energy drinks

Study	Study Design	Sample	Protocol	Follow up	Evaluation	Results
LaQuia A.V. et al ; 2018 (33)	In vitro RCT	SD group: 10 ED group: 10 Sweeteners groups: 15 Control group: 2	Streptococcus Mutans culture in Tryptic Soy Broth on microtiter plates. Addition of various dilutions of drinks, as well as various concentrations of sweeteners.	Incubation for 16 hours at 37 degrees Celsius in sterile 96-well microtiter plates	Biofilm formation assessment S. Mutans metabolic activity measurement.	S. Mutans biofilm formation and metabolic activity was inhibited by most drinks. Gatorade Protein Recovery Chocolate Shake® (SD) and Starbucks Doubleshot Energy® (ED) as well as Sucrose significantly increased S. Mutans formation and activity..
Michaelis. J. et al ; 2021 (34)	In vitro RCT	T *: 105 Group 1 SD**: 15 Group 2 SD: 15 Group 3 SD: 15 Group 4 ED***: 15 Group 5 ED: 15 Group 6 ED: 15 Group control: 15	15-minutes expositions to test liquid, 3 times a day, with 5–7-hours intervals between each session at 20°C.	At the beginning of the experiment (T ₀), after 14 days (T ₁) and 28 days (T ₂) of testing	Canary number readings Ambient light / Fluorescent photographs of the facial surface test area.	Canary value significantly rose between (T ₀) and (T ₁) as well as between (T ₁) and (T ₂) of every drink as well as showing White Spot Lesions development.

*T= Teeth **SD= Sport Drinks ***ED= Energy Drinks

Table 5. Chronic consumers identification and reason for consumption

Study	Study Design	Sample	Protocol	Results
Gallimberti. L. et al ; 2013 (35)	Cross-sectional Study	916 students 52,5% Males 47,5 % Females Average age of 12,2 years	Questionnaire of 63 multiple choice questions	Drink at least once a week [6 th grade] Males :6,2% Females :0,6% [7 th grade] Males :10,3% Females :1,7% [8 th grade] Males :16,5% Females :8,6% 18,8% of drinkers think energy drinks are not bad for their health. Amongst which 69,3% are at least weekly drinkers 56,7% of drinkers think energy drinks are bad for their health. Amongst which 6,4% are at least weekly drinkers
Alabbad. M.H. et al ; 2019 (36)	Cross-sectional Study	1255 students 44,7% Males 55,3% Females Average age of 20,2 years	Questionnaire	73,5% of consumers were male 26,5% of consumers were female 61,4% drink energy drink for the ability to stay awake longer 28% to increase endurance and strength in exercising
Pavlovic. N. et al ; 2021 (37)	Cross-sectional Study	424 students 26,2% Male 73,8 % Female Average age of 22,8 years	Questionnaire	[1-5 Energy Drink / month] = 81,1% [6-10 Energy Drink / month] = 9,5% [11-20 Energy Drink / month] = 6,3% [21 or + Energy Drink / month] = 3,2% 64% males consumed ED 48,2% females consumed ED 52,3% drink energy drink to stay awake 4,5 % to increase physical resistance

Table 6. Prevention of energy drinks

Study	Study Design	Sample	Measured Parameters	Protocol	Results
Caruso. J. et al ; 2021 (38)	RCT	435 participants aged 18-39 years old	Sensitivity to energy drinks labels	Survey Group 1 was shown a cardiac effect label Group 2 was shown an obesity label	Intentions to reduce consumption were similar between groups.
Wiggers. D. et al., 2020 (39)	RCT	2040 participants aged 12-24 years old	Sensitivity to energy drinks labels	Survey	Participants exposed to caffeine content label on the front of the can were most likely to recall it unlike when it is placed at the back. They would rate the product as less safe. Presence of a border around the label had a significant effect on patient memory of it. The formulation “High source of caffeine” was remembered more often than the statement “160mg of caffeine”
Blend. H. et al; 2021 (40)	In vitro experimental study	Tap water Green tea extract Red Bull Red Bull Light Green tea extract	Green Tea extract effect on erosive dentine wear	15 bovine dentine samples subjected to four erosive cycles of 10 minutes at 25° followed by remineralization 60 min at 37°C	Erosive tooth wear of Green Tea Extract was – 1,0 µm Erosive tooth wear of Red Bull and Red Bull Light alone was +3,3 µm Erosive tooth wear of Red Bull and Red Bull Light with green tee supplementation was respectively +1,2 and +2,0 µm

5. DISCUSSION

1. Energy drinks and erosive tooth wear

In the four articles selected for this specific area of the review, common parameters of energy drinks were measured using different assessment techniques. Those parameters being pH values, titrable acidity and erosive effect on teeth. All were in-vitro experiments using various brands of energy drinks and human third molars or premolars depending on the study.

In Cavalcanti. A.L et al. (26) paper, Flash Power[®] had the lowest pH equal to 1,52 while Red Bull[®] had the highest equal to 3,20. In regard to titrable acidity using 0,1N KOH, the highest volume of 1,04mL was needed to raise Bad Boy Power drink[®] pH to neutral while 0,56 mL was sufficient for 220V[®].

In Beltrán. K. and Cardon.W. study (27) Krem Xtreme[®] had the lowest pH equal to 2,55 while Monster energy[®] had the highest, equal to 3,46. Besides, pH was also measured in different combination of energy drink, artificial saliva and alcohol. When all three are mixed together it showed that Mr Big[®] had the lowest pH in that case, followed closely by Krem Xtreme[®]. In regard to titrable acidity using 0,1N NaOH, the highest volume of 5,7mL was needed to raise Red Bull[®] pH to neutral while 3,5 mL was sufficient for Mr Big[®]. Erosive effect of drinks was measured using energy dispersive x-ray spectroscopy after exposing 20 third molars to the different combinations of drinks for 30 and 60 minutes. It was found that Mr Big[®] and Monster energy[®] showed clear signs of demineralization at 30 minutes with net loss of Calcium and Phosphorous content disrupting dental apatite structure.

In Matumoto M.S.S et al (28) article, pH was measured primary with gas and secondary without it using a magnetic agitator to remove it. Flying Horse Lite[®] had the lowest pH equal to 2,1 while Pepsi energy[®] had the highest equal to 3,25. Measurements showed no significant variations without gas. In regard to titrable acidity using 1N NaOH, the highest volume of 3,75 mL was needed to raise Red Bull[®] pH to neutral while 1,2 mL was sufficient for Pepsi energy[®]. 18 premolars were immersed 6 times in 10 mL of either Red Bull[®] or Red Bull Light[®] for 5 min with 12 hours intervals between each immersion to

mimic chronic consumption. Knoop microhardness analysis using a microdurometer expressed in Knoop Hardness Number (HK) showed a loss of 255,2 HK with using Red Bull® while the group in Red Bull Light® suffered a bigger loss equal to 277,72 HK. In Costa Silva. J-G. et al. study (2), TNT energy drink® had the lowest pH equal to 2,36 while Monster energy® had the highest equal to 3,41. In regard to titrable acidity using 1M NaOH, the highest volume of 5,73mL was needed to raise TNT energy drink® pH to a neutral state while 4,80 mL was sufficient for Monster energy®. Only in this article was measured the buffering capacity of the beverages. It informs on the amount of acid that can be added to a solution before the pH changes significantly. In other words, the quantity of energy drinks that can be consumed without causing a drop in the pH of our saliva yet. Therefore, a higher buffering power means a higher quantity of solute is needed to lower the pH. Red Bull® had the biggest buffering capacity while TNT energy drink® had the smallest with values of 26,36 and 22,18 respectively. Finally, the erosive effect of drinks was assessed using profilometry and quantitative light induced fluorescence to evaluate surface and mineral loss. 38 third molars were immersed in 50 mL of each drink for 30 minutes. Percentage loss of surface microhardness was equal to 35,47 % in TNT energy drink® while equal to 29,48 % in Monster energy®. In this article it was clear that the same drink: TNT energy drink® reunited the most harmful values regarding erosive tooth wear. It has the lowest pH and buffering capacity while having the highest titrable acidity and erosive potential.

Some authors such as Costa Silva J-G. et al. (2) demonstrated that TNT energy drink® had the lowest pH, the lowest buffering capacity while having the highest titrable acidity and erosive potential of the four tested drinks. Besides, Matumoto M.S.S et al (28) showed that Pepsi Energy® had the highest pH and lowest titrable acidity of the 9 tested drinks. These findings suggest a direct relationship respectively between pH / buffering capacity and between titrable acidity / erosive potential. Meanwhile it demonstrates an indirect relationship between pH / titrable acidity and pH / erosive potential and buffering capacity / titrable acidity. The more acidic a drink, the more erosive potential it seems to have. However, Beltrán. K. and Cardon.W. (27) as well as Cavalcanti. A.L et al. (26) did not attest of any direct relationship in between parameters measured in their experiments. The drink with the lowest pH did not necessarily have the highest titrable

acidity. Matumoto M.S.S (28) proved that Red Bull Light[®] caused the biggest loss of microhardness even though Red Bull[®] had higher titrable acidity. We understand the erosive potential of an energy drink depends on many factors. Beltrán. K. and Cardon.W. (27) noticed the pH could be modified when drinks are mixed with alcohol which is often the case especially in younger people consumption. Matumoto M.S.S (28) demonstrated presence of gas had no effect on pH. Additionally, the in-vitro experiments were performed on healthy human teeth while people consuming energy drink chronically might not have perfectly sound teeth. In vivo findings could help evaluate more accurately the effects and consequences of chronic drinking.

2. Energy drinks and bruxism

We were not able to find scientific papers linking energetic drink consumption to bruxism directly. However, various research about the association of caffeine consumption and bruxism were conducted. As previously mentioned, caffeine is one of the main components of energetic drinks, and is present in large quantities. Caffeine content can range anywhere from 50 mg up to 505 mg per can ,making caffeine intoxication easily attainable (41). On one hand, Ohayon. M. et al (29) 13,057 subjects study calculated an odds ratio equal to 2,0 of sleep bruxism when drinking equal or more than 6 cups of coffee daily. We understand drinking this amount of caffeine every day will make an individual twice more susceptible to develop sleep tooth grinding than someone that does not consume any. It can be considered as a risk factor for sleep bruxism. On the other hand, Rintakoski. K and Kaprio. J (23) in their 12,502 subjects study found about the same odd ratio equal to 1,9 when consuming more than 8 cups a day. From 0 to 8 cups daily, the odds ratio was equal to 1 demonstrating no positive nor negative association between caffeine consumption and weekly bruxism. Maddalena Dias. I. et al (30) in a case control study of 50 cases of night bruxism and 50 controls found out that caffeine consumption alone presented a negative relationship with nightly bruxism. In fact, the study demonstrated an odds ratio of 0,576 meaning people consuming caffeine were less susceptible of suffering from bruxism at night. However, we did not have any precision on the amount of caffeine consumption unlike the two previous studies,

questioning the accuracy of findings. Despite caffeine not being considered a risk factor; when combined to one or more other factor among alcohol, cigarettes, drugs, or noise exposition the odd ratio jumped to 5,129. The study exposed the multifactorial profile of bruxism and how it is not linked to one habit only. Berger. M. et al (31) in another case control study of 113 dental students, revealed there were no connection between caffeine use and awake bruxism. Last but not least Lacusta. V.et al (32) found out in patients suffering from primary sleep bruxism, statistical differences in coffee consumers versus abstinent individuals. Consuming more than 6 cups a day led to disturbances in the sympathetic autonomous manifestations of the stomatognathic system.

The five studies helped us understand excessive caffeine consumption is a risk factor for bruxism at night while it is not for bruxism during the day. Critical quantities vary depending on the study and other factors such as drinking and smoking should be considered, as they can exacerbate bruxism incidence. In addition, it would be interesting to have studies directly investigating the effects of energy drinks on awake and nightly bruxism to have a better idea of their effect. Furthermore, quantities of caffeine should be referred to in milligrams instead of « cup » in order to obtain more accurate results on a possible threshold quantity.

3. Energy drink and caries

LaQuia A.V. et al (33) in an in vitro experiment as well, questioned Streptococcus Mutans growth and activity when in presence of energetic drinks. He placed S.Mutans culture on a Tryptic Soy Broth and added different concentrations of sport drinks, energy drink as well as different types of sugars and sweeteners. In the 18 drinks tested, the experiment resulted in the bacteria being inhibited by most drinks except Gatorade Protein Recovery Chocolate Shake® a sport drink, and Starbucks Doubleshot Energy®, an energy drink. As for the sugars and sweeteners, sucralose decreased biofilm formation but increased metabolic activity whereas sucrose significantly increased both. We understand the type of sugar in addition to its amount contained in an energetic drink is an important variable regarding its effect on oral health. In fact, both drinks, Gatorade

Protein Recovery Chocolate Shake® and Starbucks Doubleshot Energy® contain sucrose, awarding them great cariogenic potential through Streptococcus Mutans action.

Michaelis. J. et al (34) realized an in vitro experiment where they exposed 105 sound premolars to various energy and sport drinks. The Food Drug Administration did not assess clear differences when it comes to differentiating the two. It belongs to the manufacturer to decide on the title given, according to the population he is targeting. However, sport drinks intend to allow quick hydration and absorption from the body when exercising. (13) 15 minutes expositions, 3 times a day with 5-7 hours intervals between each sessions aimed to imitate chronic consumption. Evaluations as well as ambient light and fluorescent photographs were performed at the beginning of the experiment, after 14 days and after 28 days. The Canary System is a precise, laser instrument able to detect early presence of decay. Readings showed canary number values had significantly augmented in both evaluations. Photographs taken also displayed white spot lesions appearance and evolution. The study included a control buffer solution that did not generated any of these findings. It exhibits the impact of energy drinks on teeth and how they favor they appearance of caries.

4. Consumer identification and reason for consumption

All three cross sectional studies were focused on students of disparate ages. Gallimberti. L et al (35) showed consumption can start as early as 11 years old. He also showed its use greatly increases approaching adolescence. In fact, consumption in male 8th graders was 10% higher than male 6th graders. We also took note of the difference in consumption between drinkers aware of the bad effects of energy drinks and drinkers that were not. Conscious drinkers were less likely to be chronic drinkers than unconscious ones. Respectively 6,4% against 69,3% were weekly drinkers. Pavlovic N. et al (37) gathered questionnaires of 424 students with an average age of 22,8 years old and found out 52,4% consumed energy drink regularly whom the majority, about 81,1%, consumed 1-5 energy drink per month. More than half declared to consume energy drink in order to stay awake while only 4,5% utilize the beverage for the purpose of increasing physical resistance. Alabbad M.H et al (36) also discovered 61,4% of the

students he questioned used energy drink for the ability to stay awake longer. In addition, each authors demonstrated a tendency in male to consume energy drinks more than females do. As a matter of fact, 79% of weekly drinkers were male in Gallimberti. L et al (35) report while Pavlovic N. et al (37) observed 64% of males from his sample consumed energy drinks against 48,2% in females asked. Finally, Alabbad M.H et al (36) perceived 73,5% of energy drinks consumers among the 1,255 students interrogated were male.

5. Energy drinks and prevention

We realized energy drink consumption comes from disinformation and lack of regulation. In fact, population does not use energy drink for the reason it was created for. Its use is deviated from its original objective of providing energy. It is very popular with students as they use it to stay awake especially when having close exams or project deadlines. Having this information, we realize prevention must come from raising awareness in population especially in young people. Caruso. J et al (38) evaluated sensitivity to cardiac and obesity warning labels added on energy drinks presented to 435 participants aged 18-39 years old. He realized intentions to reduce consumption when exposed to any of the two labels were high and similar. It shows adding warning labels on beverages, whatever they are as long as they inform of the risk of consumption, can help reduce intake frequency. Wiggers. D et al (39) realized a similar experiment focusing on a caffeine warning label. With reactions gathered from 2,040 participants aged 12-24 years old he concluded warning labels were more impactful when placed on the front of the can. They were recall by participants more often as well. Presence of a border around the label had a positive effect on people's memory as it helped remember it. Authors also proved formulation of labels has an impact. Participants reminisced the label "High source of caffeine" more than "160mg of caffeine". In fact, not everyone is aware of healthy limits of caffeine intake.(41) Regulations should be adopted in order to pressure the energy drinks industry to add simple formulated labels in front of cans and bottles where they can easily be seen. G. Jean (42) wrote an article directed to the World Health Organization in order to restrict sport and energy drinks sales to children

under 18 years old. According to the Convention on the Rights of the Child, governments must develop legislations aimed to protect children's health.

Finally Blend. H et al (40) in an in vitro study demonstrated green tea extract protective effect towards erosive tooth wear. He subjected 15 bovine dentine samples to four erosive cycles of 10 minutes followed by 60 min of remineralization. He found out Red Bull and Red Bull Light produced erosive tooth wear of + 3,3 μ m. However, when green tea extract was added to the beverages tooth wear was reduced to respectively +1,2 μ m and +2,0 μ m.

6. CONCLUSIONS

1. Chronic energy drinks consumption can have dramatic effects on teeth. Their high concentration in acids, caffeine and sugars have direct consequences on the oral cavity. Erosive tooth wear arises from the low pH of the acid contained in the beverages, often phosphoric or citric acid. Other factors such as titrable acidity and buffering capacity must be considered, as the lowest pH drink does not always produce the most critical defects.
2. High concentration of caffeine produces night bruxism that can initiate dental attrition. It is highly worsened by risk factors such as smoking and drinking. Critical quantities vary between 6 and 8 cups depending on the author. However, it does not seem to produce bruxism during the day. No studies directly associating chronic energy drinks to bruxism were conducted yet
3. Sugar is a well-known element in dentistry. Bacteria metabolize it and produce caries. Sucrose has a much higher cariogenic power than other sugars. No regulations limiting caffeine nor sugar content of energy drinks exist at the moment.
4. Energy drinks are mostly consumed by male students. However, its use can start as early as 11 years old. Most consumers drink them in order to stay awake even though it is not its real purpose. Largest consumers are not aware of the adverse effects.
5. Prevention must be achieved by raising awareness. Population should know the real reason why energy drink must be used, their composition and the negative effects it can produce. All this should be taught from an early age since the consumers demographics is becoming younger. In addition, strict regulations such as warning labels placement should be adopted by the state to promote transparency and accountability from energy drink brands.

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8. ANNEXES

Tables :

Table 1. Inclusion and exclusion criteria

Table 2. Erosive potential of energy drink

Table 3. Association of caffeine consumption and bruxism

Table 4. Cariogenic potential of energy drink

Table 5. Chronic consumers identification and reason for consumption

Table 6. Prevention of energy drinks

Figures :

Figure 1. Various brands of energy drinks (4)

Figure 2. Guarana plant (8)

Figure 3. Nutrition label (12)

Figure 4. Patient with acid erosion from years of drinking soda (21)

Figure 5. Attrition from chronic bruxism (24)

Figure 6. Patient with tooth decays (25)

Figure 7. Flow chart of the included studies