Clinical Oral Investigations (2025) 29:370
https://doi.org/10.1007/s00784-025-06445-8

RESEARCH

Energy drink-induced white spot lesions on labial and lingual tooth surfaces in adolescents treated with lingual appliances: a retrospective cohort study

Julia von Bremen[1] · **Dimitrios Kloukos**[2,3] · **Lara Bettenhäuser-Hartung**[4] · **Jonas Q. Schmid**[5]

Received: 13 May 2025 / Accepted: 20 June 2025 / Published online: 2 July 2025

Abstract

Objectives The consumption of energy drinks with high sugar and acid content is common among adolescents and may contribute to the development of white spot lesions (WSL) during orthodontic treatment. This study aimed to assess the incidence and localization of WSL in adolescents with high energy drink consumption treated with completely customized lingual appliances (CCLAs).

Materials and methods Eligible for inclusion in this retrospective cohort study were adolescents (< 18 years) who underwent orthodontic treatment with CCLAs, consumed ≥ 2 energy drinks daily, and developed ≥ 1 new labial WSL on a non-bonded surface. High-resolution intraoral photographs before (T0) and after (T1) treatment were evaluated for the presence of WSL (yes/no) on maxillary and mandibular incisors and canines. Differences in WSL rates between labial and lingual surfaces were analyzed using paired t-tests ($\alpha = 0.05$).

Results A total of 38 patients (mean age 15.2 ± 1.4 years; 11 females, 27 males) with 912 tooth surfaces were included. At T0, 70 (15.4%) labial surfaces and 5 (1.1%) lingual surfaces showed WSL. At T1, WSL increased to 243 (51.4%) labial surfaces and 45 (9.9%) lingual surfaces. Although the appliance was bonded only to the lingual surface, the incidence of WSL per patient was four times higher on the non-bonded labial surfaces: 4.3 ± 2.1 (36.0%) labial versus 1.1 ± 1.9 (8.8%) lingual. This difference was statistically significant ($p < 0.001$).

Conclusions Orthodontic treatment with CCLAs in adolescents with frequent energy drink consumption was associated with significantly fewer WSL on bonded lingual surfaces compared to non-bonded labial surfaces.

Clinical relevance Lingual orthodontic appliances are beneficial in patients at high-risk for WSL.

Keywords White spot lesions (WSL) · Energy drinks · Completely customized lingual appliances · Caries · Enamel demineralization

✉ Julia von Bremen
julia.v.bremen@gmx.de

1 Private Practice, Bad Essen, Germany

2 Department of Orthodontics and Dentofacial Orthopedics, University of Bern, Bern, Switzerland

3 Department of Orthodontics and Dentofacial Orthopedics, Hellenic Air Force Hospital, Athens 251, Greece

4 Department of Orthodontics, Hannover Medical School, Hannover, Germany

5 Department of Orthodontics, University of Münster, Münster, Germany

Introduction

The consumption of energy drinks has markedly increased during the last years, especially among adolescents, raising significant public health concerns. Numerous studies have analyzed the effect of these sugary, high-caffeine and acidic beverages on general health and reported an elevated prevalence of adverse effects, particularly on the cardiovascular and neurovegetative systems, as well as on neurodevelopmental processes, which is particularly alarming in the developing neural system of children and adolescents [1–7]. Furthermore, by adding extra calories and sugar to the diet without providing significant satiety, the excessive consumption of high-energy drinks contributes not only to a caloric surplus, but also to metabolic imbalances setting the stage for obesity and its associated comorbidities, including type 2 diabetes, cardiovascular disease, and other metabolic syndromes [8–10].

In addition to the serious systemic risks associated with a regular intake of energy drinks, these beverages, characterized by high sugar content and acidity, are reported to contribute to the development of dental caries through enamel demineralization [11, 12]. Currently commercially available energy drinks possess pH values as low as 1.45, presenting a serious erosive risk for dental enamel. The pH values of a large variety of so-called "energy drinks" or "pre-workout supplementation" from various commercial brands were analyzed in a recent study which reported an average pH value as low as 3.3, which is far below the critical threshold for erosive tooth wear risk (pH 5.5) [13]. Once the pH in the oral cavity drops to such critical values, it usually takes 30–45 min for recovery to normal values (approx. pH 6.7), but this depends on several extrinsic (pH, duration of exposure, and buffering capacity of food or drinks) and intrinsic factors (saliva composition and flow rate) [14–18]. The risk for enamel demineralization is particularly pronounced during orthodontic treatment, when the presence of fixed appliances can exacerbate plaque retention and hinder effective oral hygiene. One of the earliest clinical manifestations of this demineralization process is the formation of White Spot Lesions (WSL), which not only compromise the aesthetic outcome of orthodontic treatment but also serve as precursors to more severe carious lesions. This can be, in turn, considered as a substantial burden for public health provision [19–21].

Several clinical studies and reviews have investigated the association of WSL development and orthodontic treatment and came up with alarming incidences during and after treatment. Depending on the subject sample and the investigation method applied, research shows that between 33.8% [22] and 97% [23] of patients treated with conventional multibracket appliances develop at least one WSL during the course of treatment. In a recent systematic review and meta-analysis assessing prevalence, incidence and risk factors for WSL during orthodontic therapy, the risk of conventional fixed appliances was reported to be 4.73 times greater compared to other orthodontic appliances [24]. This increased risk could be attributed to the design of labial appliances, which tend to trap plaque and restrict natural self-cleansing by saliva, making oral hygiene procedures more laborious and challenging. Emerging evidence suggests that lingual appliances might reduce the risk of WSLs [24–26] since their position is advantageous for less plaque accumulation and better self-cleaning through the tongue, which might help in minimizing plaque accumulation. Considering also the higher saliva flow rate on the lingual surfaces, remineralization could be promoted, potentially lowering the occurrence of WSL.

As adolescents are often reluctant in oral hygiene preservation due to various puberty-related challenges, and energy drinks consumption is typically high in this age group, it could be claimed that they are at an increased risk for developing WSL during orthodontic treatment with fixed appliances. To our knowledge, until now there is no study evaluating the effect of energy drinks on WSL. The aim of the present research was to analyze the incidence and localization (labial/lingual) of WSL after orthodontic treatment with completely customized lingual multibracket appliances (CCLA) in a group of adolescents recorded to drink energy drinks at least twice daily. Furthermore, the paper aimed to explore the potential benefits of lingual orthodontic appliances as a preventive strategy against WSL during orthodontic treatment with fixed appliances. The null hypothesis was that there is no difference in the incidence of labial vs. lingual WSL developing during orthodontic treatment with CCLA.

Materials and methods

Study design and setting

This retrospective cohort study received approval from the Ethics Committee of the Hannover Medical School, Hannover, Germany (3151–2016). The study was reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines. The intraoral photographs of all patients, who had undergone orthodontic treatment between January 2014 and June 2024 in a private practice (Bad Essen, Germany) were screened. All patients were treated with the same kind of lingual appliances (DW Lingual Systems) bonded according to the same standardized bonding protocol.

Study sample

Variance between intervention and comparator in baseline characteristics that could be prognostic for the outcome (WSL) were controlled with strict inclusion criteria:

- Treatment with the same type of CCLAs.
- Age < 18 years before treatment (T0).
- ≥ 1 new labial WSL at debonding (T1) on a non-bonded labial surface.
- Energy drink consumption ≥ 2 drinks/day according to patient or parent interview.

Exclusion criteria we defined as follows:

Fig. 1 12 years old patient with upper and lower crowding and Class III tendency (**a-c**). After treatment with removable appliances the occlusion has improved but is still not acceptable with a frontal cross-bite and half a unit Class III on the left side. At T0 only one decalcification was detected on the labial surface of the upper right canine (**d-h**)

Fig. 2 Situation right after the bonding of a CCLA in both arches for further improvement of the occlusion (patient age: 14.5 years)

- tooth agenesis of incisors or canines.

No patient was excluded from the consecutive sample for any other reason (e.g. compliance, missing records, or missed appointments).

After appliance placement according to the standardized protocol, all patients received oral hygiene instructions by a dental assistant. Specifically, they were instructed to brush after every meal, with an additional use of interdental brushes and dental floss. Once per week they were to apply a high-fluoride gel. These instructions were also given to the patients and their parents as an illustrated handout.

Study assessments

The labial and lingual surfaces of all incisors and canines before (T0) and after (T1) orthodontic treatment were assessed on digital intraoral photographs, resulting in a total of 456 labial and 456 lingual registrations with a binary (yes/no) decision on WSL for each evaluated tooth surface (Figs. 1, 2 and 3). All pictures were taken chairside with the same camera type and the same camera settings, ensuring high quality and identical color on all images: Nikon D-200, AF Micro Nikkor 105 mm 1:2.8D, Macro Speedlight SB-29s (Nikon, Tokyo, Japan).

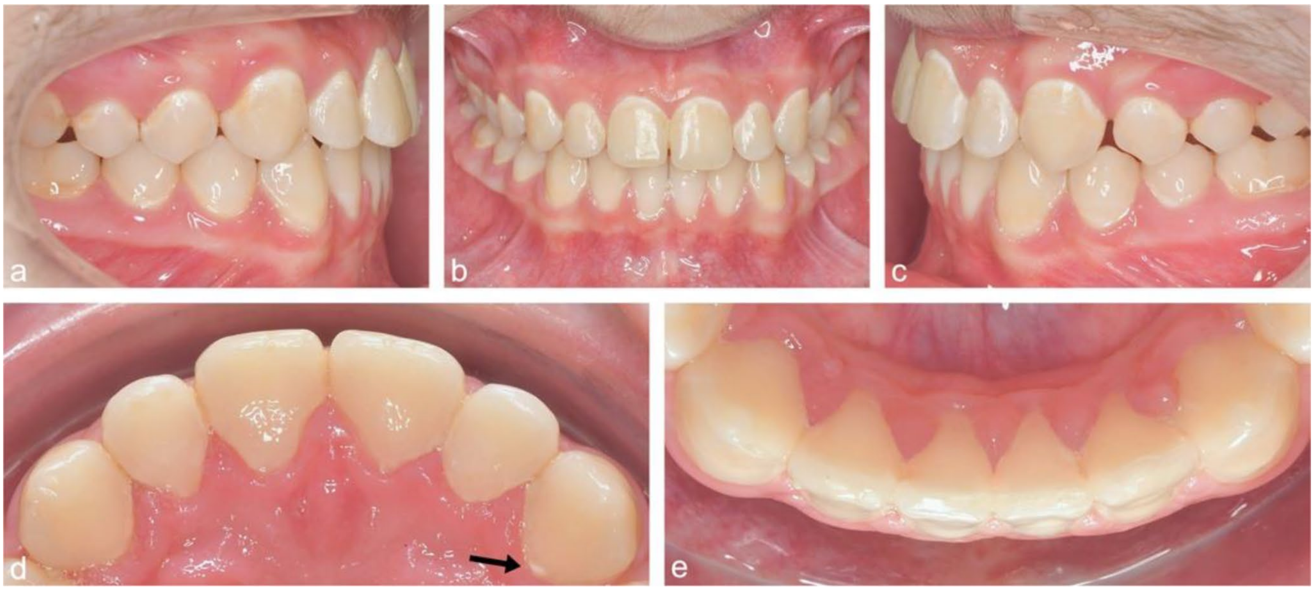

Fig. 3 14 months later the lingual fixed appliance was removed before schedule because of the exaggerated intake of energy drinks (a-c). Several new white spot lesions are visible on the labial surfaces at T1. On upper and lower lingual surfaces only one small white spot lesion is visible on the upper right canine at T1

Intra-rater repeatability

All measurements were made by one single calibrated observer (LB). To ensure intra-rater repeatability and reduce method error, measurements were repeated twice with an interception of 2 weeks on 10% of the patient sample.

Statistical analysis

All data were descriptively summarized for each location (lingual, labial) and presented as mean ± standard deviation and median values, as well as min, max. The WSL rate per patient and location was represented as the number of WSLs divided by the maximum number of teeth (12). The difference in WSL rate between lingual and labial was analyzed using a paired t-test at a significance level of $\alpha = 0.05$. A p-value of $p < 0.05$ was considered statistically significant. Due to the exploratory nature of the study, no alpha correction was performed.

A possible association between the categorical values labial and lingual WSL was assessed with contingency tables. All statistical analyses were conducted using the statistical software SAS v 9.4 (SAS Institute, Cary, NC, USA).

Table 1 Baseline characteristics of total patient sample ($n = 38$; 11 females, 27 males)

Variable	Mean	SD	Min	Max
Pre Tx age (yrs.)	15.2	1.4	12.2	17.8
Post Tx age (yrs.)	17.9	2.1	14.1	23.9
Active Tx duration (yrs.)	2.7	1.1	1.1	6.3

Results

A total of 38 patients (11 females, 27 males) with a mean age of 15.2 ± 1.4 years were included in the present study. Baseline characteristics and treatment duration are presented in Table 1.

All included participants were analyzed after study commencement without any deviation from the planned intervention. Prior treatment (T0), 70 out of 456 labial tooth surfaces (15.4%) and 5 out of 456 lingual tooth surfaces (1.1%) analyzed had WSL. At debonding (T1), 243 labial surfaces (51.4%) and 45 (9.9%) lingual surfaces exhibited WSL. This corresponds to an increase of 36.0% (labial) vs. 8.8% (lingual) with significantly more demineralization on labial tooth surfaces ($p < 0.001$) (Fig. 4).

On average, 1.05 (±1.87) teeth (8.8%) were affected by WSL on the lingual surface and 4.32 (± 2.21) teeth (36.0%) on the labial surface (Table 2). This WSL rate difference was statistically significant ($p < 0.001$).

Although all patients reported a high consumption of energy drinks, the distribution of WSL differed significantly. Whereas some patients exhibited only 1 or 2 labial WSL, one patient had as many as 11 labial and 7 lingual tooth surfaces affected (Fig. 5).

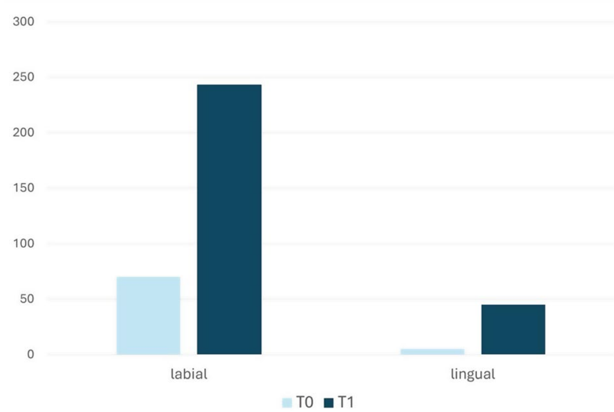

Fig. 4 Total number of WSL before (T0) and after (T1) treatment in relation to location (labial vs. lingual)

Of the 23 patients who did not present with lingual WSL at T1, the number of labial WSL varied between 1 (1/23 = 4.35%) and 8 (1/23 = 4.35%) with a median of 3 labial WSL. Only 6 patients with lingual WSL had less than 4 labial WSL at T1 (Table 3).

Discussion

The increasing consumption of soft- and energy drinks among children and adolescents poses a significant challenge to general, but also oral health, especially in patients undergoing orthodontic treatment. These beverages bear a two-fold risk for the teeth; their high sugar content and acidity each independently contribute to an increased risk of both dental caries and erosive lesions. The impact of these risks can vary depending on the type of orthodontic appliance in situ (labial or lingual multibracket appliances, clear aligners) due to differences in appliance design and their interaction with the oral environment.

Multiple studies have demonstrated a drop of the salivary pH almost immediately after consumption of a soft- or energy drink from its normal pH range of 6.5–7.5 to around 5 or lower, due to acids like phosphoric acid, citric acid, and carbonic acid. This increases the risk of enamel demineralization and uncontrolled bacterial growth. Under normal circumstances, saliva works to neutralize acidity within 20–30 min by releasing bicarbonate ions. However, frequent soft drink consumption can slow down this recovery process, leading to prolonged acidity [12, 13, 27].

Additionally, high-sugar beverages provide an ideal substrate for cariogenic bacteria, such as streptococcus mutans and lactobacilli, which metabolize sugars to produce acids that lower the pH in dental plaque. This additional acidification can boost enamel demineralization and further increase the risk of caries. Moreover, sugar-free drinks, containing

Table 2 Amount of labial and lingual WSL at T1 with corresponding WSL rate (number of WSL divided by number ($n = 12$) of analyzed teeth x 100) and paired t-test results

		Lingual					Labial					t-test
Variable	*N*	Mean	SD	Med	Min	Max	Mean	SD	Med	Min	Max	*p*
WSL (n)	38	1.05	1.87	0.00	0.00	7.00	4.32	2.12	4.00	1.00	11.00	< 0.001
WSL rate (%)	38	8.77	15.61	0.00	0.00	58.33	35.97	17.66	33.33	8.33	91.67	< 0.001

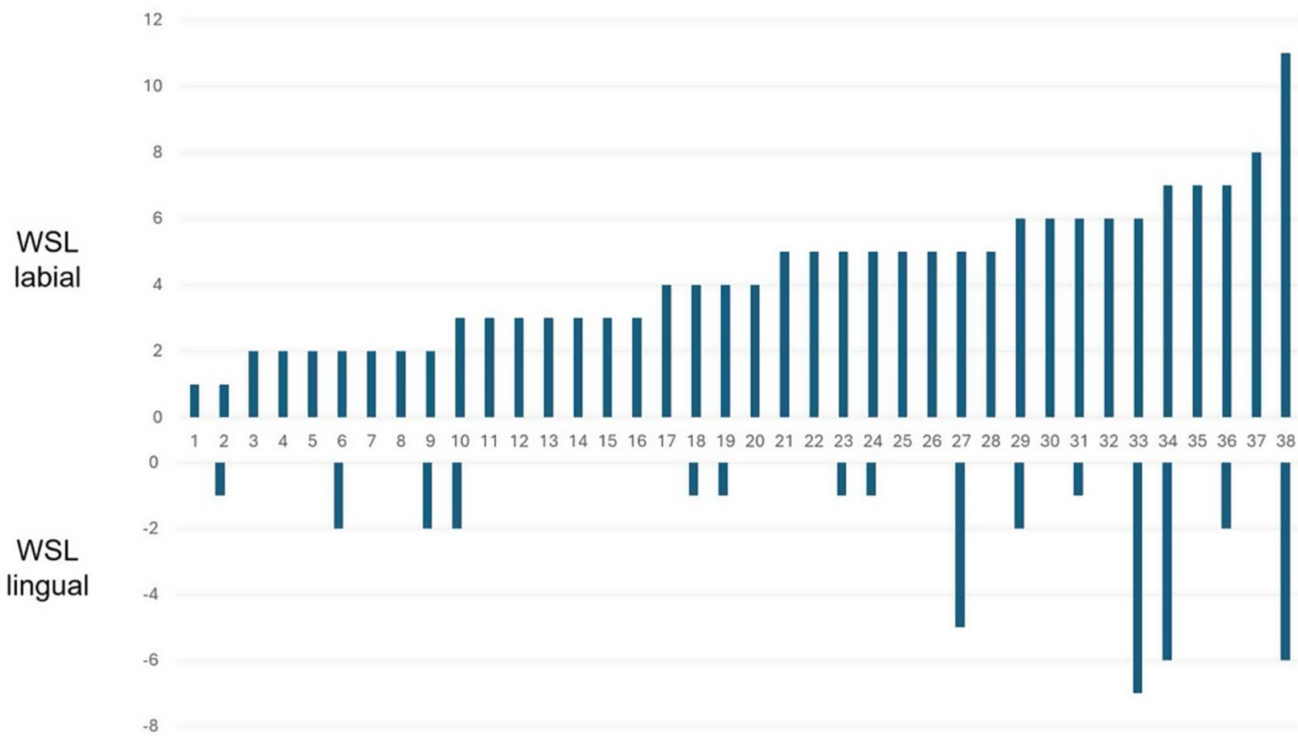

Fig. 5 Number of WSL per patient (labial and lingual) in increasing order of labial WSL at T1

Table 3 Contingency table for association between lingual and labial WSL at T1. Cells present n (% of total/row %). Row and column totals are n (% of total cohort, $n=38$)

Number of lingual WSL at T1	Number of labial WSL at T1									
n (% of total/row %)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**11**	**Row Total** n (%)
0	1 (2.63/ 4.35)	5 (13.16/ 21.74)	6 (15.79/ 26.09)	2 (5.26/ 8.70)	5 (13.16/ 21.74)	2 (5.26/ 8.70)	1 (2.63/ 4.35)	1 (2.63/ 4.35)	0 (0.00/ 0.00)	23 (60.53)
1	1 (2.63/ 16.67)	0 (0.00/ 0.00)	0 (0.00/ 0.00)	2 (5.26/ 33.33)	2 (5.26/ 33.33)	1 (2.63/ 16.67)	0 (0.00/ 0.00)	0 (0.00/ 0.00)	0 (0.00/ 0.00)	6 (15.79)
2	0 (0.00/ 0.00)	1 (2.63/ 20.00)	2 (5.26/ 40.00)	0 (0.00/ 0.00)	0 (0.00/ 0.00)	1 (2.63/ 20.00)	1 (2.63/ 20.00)	0 (0.00/ 0.00)	0 (0.00/ 0.00)	5 (13.16)
5	0 (0.00/ 0.00)	0 (0.00/ 0.00)	0 (0.00/ 0.00)	0 (0.00/ 0.00)	1 (2.63/ 100.0)	0 (0.00/ 0.00)	0 (0.00/ 0.00)	0 (0.00/ 0.00)	0 (0.00/ 0.00)	1 (2.63)
6	0 (0.00/ 0.00)	0 (0.00/ 0.00)	0 (0.00/ 0.00)	0 (0.00/ 0.00)	0 (0.00/ 0.00)	0 (0.00/ 0.00)	1 (2.63/ 50.00)	0 (0.00/ 0.00)	1 (2.63/ 50.0)	2 (5.26)
7	0 (0.00/ 0.00)	0 (0.00/ 0.00)	0 (0.00/ 0.00)	0 (0.00/ 0.00)	0 (0.00/ 0.00)	1 (2.63/ 100.00)	0 (0.00/ 0.00)	0 (0.00/ 0.00)	0 (0.00/ 0.00)	1 (2.63)
Column Total n (%)	2 (5.26)	6 (15.79)	8 (21.05)	4 (10.53)	8 (21.05)	5 (13.16)	3 (7.89)	1 (2.63)	1 (2.63)	38 (100.00)

aspartame/ acesulfame K have been shown to favor bacterial proliferation of the dental biofilm, once again increasing the risk for WSL [27]. During orthodontic treatment, fixed appliances can complicate oral hygiene routines by creating niches for plaque accumulation, thereby exacerbating the development of WSL.

In the present study sample at least one new labial WSL had to be present at debonding. This was considered as an indication for a high cariogenic activity and the inception for further inquiry about the patient's energy drink consumption frequency. Although no brackets or attachments were placed on any labial tooth surface (whereas all lingual tooth surfaces were bonded with CCLA) there was a 36% increase in labial WSL after treatment compared to an 8.8% increase for lingual WSL. Under orthodontic treatment with conventional labial multibracket appliances these bracket-surrounding decalcifications are a constant concern of orthodontists; this potential esthetic compromise may possibly require further conservative treatment. Of approximately 3,000,000 US-American patients with WSL after orthodontic treatment, up to 750,000 were assumed to need further conservative treatment, summing up to estimated costs of 500,000,000 USD per year [20]. A comparable study calculating the potential long-term costs for follow-up treatment of WSL after orthodontic therapy in Germany [19] came to the conclusion that "the use of lingual appliances reduces the extent of post-orthodontic enamel damage and long-term follow-up costs in comparison to those caused by vestibular fixed orthodontic treatment". Considering the amount of new WSL for the present patient sample, this conclusion certainly seems justified.

Not all WSL require further therapy, but even if these decalcifications pose only esthetic issues, this is surely less annoying on a lingual surface than on a labial surface in the esthetic zone, where they may compromise smile esthetics.

Several studies and systematic reviews have confirmed that lingual appliances seem beneficial upon reducing of WSL formation on the bonded surfaces of the teeth [24–26, 28–31], possibly due to a more favorable oral environment. The natural cleansing action of saliva and the enhanced salivary flow in the lingual region can help dilute and neutralize sugars, potentially reducing the risk of caries. In a randomized controlled trial on the influence of labial and lingual appliances on the oral environment, no influence on saliva flow rate or buffer capacity was found [32]. However, even if the region of bracket placement has no influence on salivary factors, it still seems obvious that lingual tooth surfaces, which are constantly bathed in saliva due to anatomic/physiological reasons, are much more exposed to a natural self-cleaning effect than labial tooth surfaces, which have a higher risk of drying out. Already 15 years ago, Van der Veen et al. [25] reported the number of WSL that developed or progressed during orthodontic treatment to be 4.8 times higher on labial than on lingual tooth surfaces, which certainly is in alignment with the results of the present paper. In addition, if lingual WSL lesions were evident at T1, it has to be remarked that these were much smaller and less severe than the labial WSL, as seen in Fig. 3. In the current study, all patients were bonded according to the bonding protocol described by Beyling et al. [33], where an extra layer of a hydrophilic resin is added to the teeth, which presumably reduced the incidence of lingual WSL even more.

Aligners are suggested to be a possible alternative to multibracket appliances in cases with a high caries risk, since they can be removed during exposure to food or beverages and the non-bonded teeth are easier to clean. However, aligners may also inadvertently encourage prolonged exposure to cariogenic beverages if patients consume these drinks while wearing the aligners, thereby trapping sugars and acids against the enamel surface. Several reports have been published demonstrating the deleterious effect of unthoughtful aligner wear when or after drinking soft drinks [34, 35]. Therefore, the overall cariogenic risk with aligners is highly dependent on patient compliance with recommended practices, such as removing the appliance when consuming sugary drinks and performing adequate oral hygiene afterwards. In their recently published paper Liu and Song [36] found that 35% of the adolescents treated with aligners developed WSL during treatment, mainly due to inadequate oral hygiene, a high frequency of drinking carbonated beverages plus a high number of anterior attachments. Furthermore, the authors reported a low frequency of aligner cleaning after eating while wearing them, which naturally hinders pH recovery. It has to be kept in mind, that after exposure to energy drinks, the natural recovery to a normal pH value in the oral cavity may take approximately 30–45 min, a time frame in which the aligner should not be worn because of the risk of "trapping" the acidic surrounding and hindering the self-cleaning/remineralization [36]. Aligners require, thus, strict patient adherence to guidelines regarding beverage consumption to minimize erosion risks. Therefore, it seems questionable if adolescents who commonly consume large amounts of energy drinks are the right patient cohort for this adherence-intensive treatment approach. Additionally, it has been shown, that not all malocclusions can be treated with aligners, especially if precise, 3-dimensional movement of the teeth are desired [37, 38].

Based on the available research and the knowledge of an extreme increase of the consumption of energy drinks and their effect on general and oral health it is surprising that recent 'Consensus Statements' for the prevention and management of WSL during orthodontic treatment do not mention any relevant dietary recommendations [39]. A thorough education of both patients and parents concerning the general and dental risks of a regular consumption of energy drinks is absolutely mandatory, given the high increase of the consumption of these drinks among adolescents in recent years. In their energy drink market research, the Allied Market Research describes the global energy drinks market size to be valued at $45.80 billion in 2020, with an expected increase to $108.40 billion by 2031 [40]. This corresponds to a growth rate of 8.2% from 2022 to 2031 and should be alarming for all general practitioners that obviously face an increasing challenge. Adequate oral hygiene and fluoridation protocols will probably not be the only solution of this problem. In addition, given the available data concerning a lower risk of WSL formation around lingual appliances vs. labially placed brackets, as well as the results of the present research, the benefits of lingual appliances should at least be considered and discussed with patients and caregivers to give them the opportunity to think about this possible alternative. In their recently published systematic review on the effectiveness of lingual appliances as an alternative to conventional labial appliances, Ahmed et al. [41] conclude that there is sufficient evidence that lingual appliances can handle the same malocclusions as labial appliances. Therefore, it seems advisable to at least consider treating high risk patients, such as adolescents regularly consuming soft- or energy drinks with lingual appliances to minimize the risk of WSL, in addition to educating them and their families on dietary recommendations.

On the basis of the findings in this study, the null hypothesis had to be rejected. The main limitation of this paper is its retrospective design. Nevertheless, substantial efforts were applied to minimize selection and performance bias. Given the high incidence of WSL described throughout the international orthodontic literature for patients treated with conventional labial multibracket appliances [22–24], it seems questionable to expose adolescents with a high energy drink consumption frequency to the additional high risk that labial appliances bear. Furthermore, if there is knowledge about a high frequency of energy drink consumption prior to treatment, dietary modification should be attempted.

Summarizing, it can be stated that it is important for clinicians to emphasize comprehensive oral health education which addresses not only proper oral hygiene practices during orthodontic treatment but also the importance of dietary moderation. This dual approach is essential for mitigating the deleterious effects of sugar and acid on dental hard tissues, particularly in a patient cohort increasingly exposed to high-risk beverages. Overall, the current scientific literature supports the notion that labial orthodontic appliances are associated with a higher risk of WSL, whereas lingual appliances may offer a protective advantage, especially for patients at increased risk due to frequent energy drink consumption.

Conclusions

In the frame of the current study, there was a quadruple increase in labial WSL after treatment with CCLA compared to lingual WSL. It seems therefore advisable to consider treating orthodontic patients increasingly exposed to high-risk beverages with lingual multibracket appliances to minimize their risk for WSL development.

Author contributions JvB designed the study. JvB and LBH collected the data. LBH performed the measurements. JQS provided the statistical analysis. DK contributed to the interpretation of the data. JvB and JQS and wrote the manuscript. JvB and JQS created the figures. DK and LBH critically reviewed the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding This article was supported by the Open Access Publication Fund of the University of Münster. Besides, this research received no external funding.

Data availability The data presented in the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate The study was conducted in accordance with the Declaration of Helsinki and approved by the the Ethics Committee of the Hannover Medical School, Hannover, Germany (3151–2016).

Consent for publication Informed consent was obtained from all participants in this study.

Competing interests The authors declare no competing interests.

References

1. Costantino A, Aniello M, Lazzari J, Casula C, Turillazzi E, Frati P, Fineschi V (2023) The dark side of energy drinks: A comprehensive review of their impact on the human body. Nutrients 15:3922. https://doi.org/10.3390/nu15183922
2. Cadoni C, Peana AT (2023) Energy drinks at adolescence: awareness or unawareness? Front Behav Neurosci 17:1080963. https://doi.org/10.3389/fnbeh.2023.1080963
3. Larson N, DeWolfe J, Story M, Neumark-Sztainer D (2014) Adolescent consumption of sports and energy drinks: linkages to higher physical activity, unhealthy beverage patterns, cigarette smoking, and screen media use. J Nutr Edu Beha 46:181–187. https://doi.org/10.1016/j.jneb.2014.02.008
4. Nadeem IM, Shanmugaraj A, Sakha S, Horner NS, Ayeni OR, Moin Khan M (2020) Energy drinks and their adverse health

effects: A systematic review and Meta-analysis. Sports Health 13(3):265–277. https://doi.org/10.1177/1941738120949181
5. Kozuchowaska K, Pilarz D, Szewczyk M, Morawska M, Tomczyk A, Ufnal J, Lewandowska D et al (2025) The impact of energy drinks on health of children and young adults - review of latest research. J Edu Health Sport 78:57745. https://doi.org/10.12775/JEHS.2025.78.57745
6. Ajibo C, Van Griethuysen A, Visram S, Lake A (2024) Consumption of energy drinks by children and young people: a systematic review examining evidence of physical effects and consumer attitudes. Public Health 227:274–281. https://doi.org/10.1016/j.puhe.2023.08.024
7. Clapp O, Morgan MZ, Fairchild RM (2019) The top five selling UK energy drinks: implications for dental and general health. Br Dent J 226(7):493–497. https://doi.org/10.1038/s41415-019-0114-0
8. Malik VS, Pan A, Willett WC, Hu FB (2013) Sugar-sweetened beverages and weight gain in children and adults: a systematic review and meta-analysis. Am J Clin Nutr 98(4):1084–1102. https://doi.org/10.3945/ajcn.113.058362
9. Hu FB (2013) Resolved: there is sufficient scientific evidence that decreasing sugar-sweetened beverage consumption will reduce the prevalence of obesity and obesity-related diseases. Obes Rev 14(8):606–619. https://doi.org/10.1111/obr.12040
10. Daradkeh G, Al-Muhannadi A, Chandra P, Al-Hajri M (2018) Energy drinks consumption among adolescent and its relation to obesity in the state of Qatar. Adv Obes Weight Manag Control 8(2):45–47. https://doi.org/10.15406/aowmc.2018.08.00226
11. Kitchens M, Owens BM (2007) Effect of carbonated beverages, coffee, sports and high energy drinks, and bottled water on the in vitro erosion characteristics of dental enamel. J Clin Pediatr Dent 31(3):153–159. https://doi.org/10.17796/jcpd.31.3.1157l653t8206100
12. Khan K, Qadir A, Trakman G, Aziz T, Khattak MI, Nabi G, Alharbi M, Alshammari A, Shahzad M (2022) Sports and energy drink consumption, oral health problems and performance impact among elite athletes. Nutrients 14:5089. https://doi.org/10.3390/nu14235089
13. Martínez LM, Lietz LL, Tarín CC, García CB, Tormos JIA, Miralles, EGl (2024) Analysis of the pH levels in energy and pre-workout beverages and frequency of consumption: a cross-sectional study. BMC Oral Health 24:1082. https://doi.org/10.1186/s12903-024-04843-0
14. Kumar N, Amin F, Dahri WM, Khan S, Zaidi H, Rahman S et al (2024) Impact of acidic beverages on composition and surface characteristics of human teeth: scanning electron microscopic, stereomicroscopic and energy dispersive x-ray analyses. BMC Oral Health 24:837. https://doi.org/10.1186/s12903-024-04491-4
15. Schlueter N, Amaechi BT, Bartlett D, Buzalaf MAR, Carvalho TS, Ganss C et al (2020) Terminology of erosive tooth wear: consensus report of a workshop organized by the ORCA and the cariology research group of the IADR. Caries Res 54:2–6. https://doi.org/10.1159/000503308
16. Vainionpää R, Tuulaniemi K, Pesonen P, Laitala ML, Anttonen V (2019) Erosive tooth wear and use of psychoactive substances among Finnish prisoners. BMC Oral Health 19:97. https://doi.org/10.1186/s12903-019-0796-3
17. Erdemir U, Yildiz E, Saygi G, Altay NI, Eren MM, Yucel T (2016) Effects of energy and sports drinks on tooth structures and restorative materials. World J Stomatol 5:1–7. https://doi.org/10.5321/wjs.v5.i1.1
18. Rabelo MA, Reis A, Thiemi M (2012) Saliva and dental erosion. J Appl Oral Sci 20:493–502. https://doi.org/10.1590/s1678-77572012000500001
19. Knösel M, Vogel Alvarez R, Blanck-Lubarsch M, Helm H-J (2019) Comparison of potential long-term costs for preventive dentistry treatment of post orthodontic labial versus lingual enamel cavitations and esthetically relevant white spot lesions: a simulation study with different scenarios. Head Face Med 15:22. https://doi.org/10.1186/s13005-019-0204-x
20. Ren Y, Jongsma MA, Mei L, van der Mei HC, Busscher HJ (2014) Orthodontic treatment with fixed appliances and biofilm formation–a potential public health threat? Clin Oral Investig 18:1711–1718. https://doi.org/10.1007/s00784-014-1240-3
21. Inchingolo AM, Malcangi G, Ferrante L, Del Vecchio G, Viapiano F et al (2023) Damage from carbonated soft drinks on enamel: A systematic review. Nutrients 15:1785. https://doi.org/10.3390/nu15071785
22. Geiger AM, Gorelick L, Gwinnett AJ, Griswold PG (1988) The effect of a fluoride program on white spot formation during orthodontic treatment. Am J Orthod Dentofac Orthop 93:29–37. https://doi.org/10.1016/0889-5406(88)90190-4
23. Boersma J, van der Veen M, Lagerweij M, Bokhout B, Prahl-Andersen B (2005) Caries prevalence measured with QLF after treatment with fixed orthodontic appliances: influencing factors. Caries Res 39:41–47. https://doi.org/10.1159/000081655
24. Hussain U, Wahab A, Kamran MA, Alnazeh AA, Almoammar S et al (2024) Incidence and risk factors of white spot lesions associated with orthodontic Treatment– A systematic review and Meta- analysis. Orthod Craniofac Res 0:1–21. https://doi.org/10.1111/ocr.12888
25. van der Veen MH, Attin R, Schwestka-Polly R, Wiechmann D (2010) Caries outcomes after orthodontic treatment with fixed appliances: do lingual brackets make a difference? Eur J Oral Sci 118:298–303. https://doi.org/10.1111/j.1600-0722.2010.00733.x
26. Wiechmann D, Klang E, Helms HJ, Knösel M (2015) Lingual appliances reduce the incidence of white spot lesions during orthodontic multibracket treatment. Am J Orthod Dentofac Orthop 148:414–422. https://doi.org/10.1016/j.ajodo.2015.05.015
27. Barajas-Torres GC, Klünder-Klünder M, Garduño-Espinosa J, Parra-Ortega I, Franco-Hernández MI et al (2022) Effects of Carbonated Beverage Consumption on Oral pH and Bacterial Proliferation in Adolescents: A Randomized Crossover Clinical Trial. Life 12, 1776. https://doi.org/10.3390/life12111776
28. Mistakidis I, Katib H, Vasilakos G, Kloukos D, Gkantidis N (2016) Clinical outcomes of lingual orthodontic treatment: a systematic review. Eur J Orthod 38(5):447–458. https://doi.org/10.1093/ejo/cjv061
29. Nandakumar S, Tandon A, Chandrasekaran D et al (2024) Implications of lingual orthodontics compared to conventional orthodontics. Cureus 16(10):e72588. https://doi.org/10.7759/cureus.72588
30. Lazar L, Vlasa A, Beresescu L, Bud A, Lazar AP et al (2023) White Spot Lesions (WSLs)—Post-Orthodontic Occurrence, Management and Treatment Alternatives: A Narrative Review. J Clin Med 12, 1908. https://doi.org/10.3390/jcm12051908
31. Heymann G, Grauer D (2013) A contemporary review of white spot lesions in orthodontics. J Esthet Restor Dent 25(2):85–95. https://doi.org/10.1111/jerd.12013
32. Lombardo L, Ortan YÖ, Gorgun Ö, Panza C, Scuzzo G, Siciliani G (2013) Changes in the oral environment after placement of lingual and labial orthodontic appliances. Prog Orthod 11:14:28. https://doi.org/10.1186/2196-1042-14-28
33. Beyling F, Schestke-Polly R, Wiechmann D (2013) Lingual orthodontics for children and adolescents: improvement of the indirect bonding protocol. Head Face Med 9:27. https://doi.org/10.1186/1746-160x-9-27
34. Birdsall J, Robinson S (2008) A case of severe caries and demineralisation in a patient wearing an Essix-Type retainer. Prim Dent Care 15(2):59–61. https://doi.org/10.1308/135576108784000203
35. Alowid A, Helaby B, Alqarni L (2021) A case report of caries incident in a patient wearing an Essix type retainer. Saudi J Oral

Dent Res 6(10):445–449. https://doi.org/10.36348/sjodr.2021.v06i10.003
36. Liu Q, Zhixin Song Z (2024) Incidence, severity, and risk factors for white spot lesions in adolescent patients treated with clear aligners. Orthod Craniofac Res 27:704–713. https://doi.org/10.1111/ocr.12791
37. Robertson L, Kaur H, Fagundes NCF, Romanyk D, Major P, Flores MC (2020) Effectiveness of clear aligner therapy for orthodontic treatment: A systematic review. Orthod Craniofac Res 23(2):133–142. https://doi.org/10.1111/ocr.12353
38. Haouili N, Kravitz ND, Vaid NR, Ferguson DJ, Makki L (2020) Has invisalign improved? A prospective follow-up study on the efficacy of tooth movement with invisalign. Am J Orthod Dentofac Orthop 158(3):420–425. https://doi.org/10.1016/j.ajodo.2019.12.015
39. Sardanaa D, Schwendicke F, Kosanc E, Tüfekçi E (2023) White spot lesions in orthodontics: consensus statements for prevention and management. Angle Orthod 93:621–628. https://doi.org/10.2319/062523-440.1
40. Allied Market Research (2022) Energy Drinks Market by Type (Alcoholic, Nonalcoholic), by End User (Kids, Adults, Teenagers). Global opportunity analysis and industry forecast, 2020–2031. Available from: https://www.alliedmarketresearch.com/energy-drink-market. Accessed 07 May 2025
41. Ahmed S, Alghabban R, Alqahtani A et al (2024) Evidence of effectiveness of lingual orthodontics as an alternative to conventional labial orthodontics. Syst Rev Cureus 16(1):e51643. https://doi.org/10.7759/cureus.51643