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EFFERVESCENT VITAMIN SUPPLEMENTS AND THEIR EFFECTS ON DENTAL ENAMEL AND RESIN-BASED RESTORATIVE MATERIALS: A NARRATIVE REVIEW

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ABSTRACT

Effervescent vitamin supplements are widely used because they are convenient, dissolve rapidly in water, and provide an alternative to conventional tablets or capsules. Their formulations commonly contain organic acids that can create an acidic oral exposure after dissolution. This narrative review summarizes the available evidence on the effects of effervescent vitamin supplements on dental enamel and resin-based restorative materials. Literature was identified through PubMed/MEDLINE, Google Scholar, Scopus, and Web of Science Core Collection, supplemented by screening the reference lists of relevant publications. Direct experimental evidence indicates that some effervescent formulations can reduce enamel microhardness, increase surface roughness, and, under repeated laboratory exposure, cause measurable enamel loss. Erosive potential differs substantially between products and is influenced not only by pH but also by buffering properties, calcium and phosphate content, acid type, and the overall chemical composition of the dissolved preparation. Resin-based restorative materials show a more heterogeneous response. Changes in microhardness and surface roughness are inconsistent across studies and appear strongly material dependent, whereas clinically relevant color changes have been demonstrated in selected material-supplement combinations. Differences in resin chemistry, filler characteristics, and filler-matrix stability may contribute to this variability. Most direct evidence is derived from in vitro studies, limiting direct translation to routine clinical use. Current findings support minimizing prolonged contact of acidic effervescent solutions with dental surfaces, particularly in individuals at increased risk of erosive tooth wear. Further in situ and clinical studies are needed to determine the long-term clinical relevance of these effects.

KEYWORDS

Effervescent Vitamins, Dental Enamel, Dental Erosion, Resin-Based Composites, Surface Roughness, Microhardness, Color Stability

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1. Introduction

Effervescent vitamin supplements are commonly used because they are easy to administer, dissolve rapidly in water, and provide an alternative to conventional tablets or capsules. Their formulations typically combine vitamins or minerals with an effervescent acid-base system, flavoring agents, and sweeteners. Organic acids such as citric, ascorbic, malic, or tartaric acid react with bicarbonates or carbonates after contact with water and contribute to the characteristic release of carbon dioxide. Many commercial products consequently form distinctly acidic solutions after dissolution (Wegehaupt et al., 2016; Jeong et al., 2019; Sozen Yanik et al., 2024).

From a dental perspective, repeated exposure to acidic solutions is relevant because it may contribute to erosive tooth wear. Current consensus defines erosive tooth wear as a chemical-mechanical process that results in cumulative loss of dental hard tissue and is not caused by bacterial activity (Carvalho et al., 2015; Schlueter et al., 2020). Extrinsic acids may originate from foods, beverages, medications, and dietary supplements. The effect of a particular product is not determined by its initial pH alone. Acid concentration, titratable acidity, buffering capacity, calcium and phosphate concentrations, degree of saturation with respect to dental mineral, and exposure pattern may all modify the final erosive effect (Barbour et al., 2011; Lussi et al., 2012).

Effervescent supplements are particularly relevant because acidic components are an intentional part of their formulation. Experimental studies have shown that some preparations can reduce enamel microhardness, increase surface roughness, and, under repeated laboratory exposure, cause measurable enamel surface loss (Wegehaupt et al., 2016; Jeong et al., 2019; Sozen Yanik et al., 2024). However, the magnitude of these effects varies markedly among products, indicating that the complete formulation is more informative than the presence of a particular vitamin or a single pH value.

The potential dental effects are not limited to natural tooth structure. Resin-based restorative materials are exposed to the same oral environment as enamel. Contemporary resin composites consist of an organic polymer matrix, inorganic fillers, and a coupling system connecting both phases. Water sorption and hydrolytic aging can alter the resin network and filler-matrix interface, while acidic conditions may accelerate some degradation processes (Drummond, 2008; Szczesio-Wlodarczyk et al., 2020). Repeated contact with acidic solutions may therefore influence microhardness, surface roughness, and color stability. Direct studies of effervescent vitamin preparations demonstrate that these effects are not uniform: some composites show limited changes, whereas others exhibit more pronounced mechanical, surface, or optical alterations (Gurdogan Guler et al., 2021; Çınar et al., 2023; Ertürk Avunduk & Delikan, 2023; Doğu Kaya et al., 2024; Sozen Yanik et al., 2024; Yazıcıoğlu Pirpir & Harorlı, 2026).

The clinical relevance of these laboratory findings remains uncertain. Most direct evidence comes from *in vitro* immersion models, which cannot fully reproduce salivary dilution, oral clearance, acquired pellicle formation, temperature changes, individual drinking behavior, and repeated remineralization between exposures (Shellis et al., 2011; West et al., 2011). Experimental protocols also vary substantially in substrate, exposure duration and frequency, storage medium, restorative material, and measurement method. These differences complicate direct quantitative comparison and prevent reliable estimation of the amount of enamel loss or restorative-material degradation that might occur during routine daily use.

Despite the widespread availability of effervescent vitamin supplements, the dental evidence remains limited and heterogeneous. Individual studies have examined enamel erosion, microhardness, roughness, color stability, and changes in selected restorative materials, but these outcomes have generally been investigated using different products, substrates, and exposure protocols. To our knowledge, the available evidence has not previously been synthesized in a narrative review focused specifically on both dental enamel and resin-based restorative materials.

The aim of this narrative review is to summarize the available evidence on the effects of effervescent vitamin supplements on dental enamel and resin-based restorative materials. Particular attention is given to erosive potential, enamel surface integrity, and changes in the microhardness, surface roughness, and color stability of resin-based restorations. The review also discusses the chemical factors that may modify these effects, their clinical significance, and the limitations of the current evidence.

2. Literature Search Strategy

A focused narrative literature search was performed to identify studies evaluating the dental effects of effervescent vitamin supplements and publications providing relevant mechanistic or methodological context. PubMed/MEDLINE, Google Scholar, Scopus, and Web of Science Core Collection were searched, and the reference lists of directly relevant articles and reviews were screened for additional publications. The literature search was updated through August 2026.

Search terms were used in different combinations and included “effervescent vitamin,” “effervescent supplement,” “effervescent tablet,” “multivitamin,” “dental enamel,” “dental erosion,” “erosive potential,” “microhardness,” “surface roughness,” “resin composite,” “restorative material,” and “color stability.” Studies directly evaluating effervescent vitamin or multivitamin preparations in relation to enamel or resin-based restorative materials were considered the primary evidence. Supporting studies were included when they provided information on erosive tooth wear, chemical properties of acidic solutions, hydrolytic degradation of resin-based materials, surface-property assessment, or interpretation of dental color differences.

Priority was given to original research articles and relevant consensus or review papers for which the complete text was available for evaluation. Publications available only as abstracts were not used for detailed data extraction. Studies involving acidic beverages, medications, or food-simulating liquids were included only when they provided information directly relevant to the mechanisms or interpretation of the direct evidence on effervescent vitamin preparations. Because the objective was a focused narrative synthesis rather than a systematic review or meta-analysis, no formal risk-of-bias assessment or quantitative pooling of outcomes was performed.

The final evidence base comprised 28 publications: eight experimental studies directly evaluating effervescent vitamin preparations and 20 supporting publications addressing enamel erosion, resin-composite degradation, surface properties, color stability, clinical interpretation, and methodological considerations.

3. Effervescent Vitamin Supplements as an Acidic Challenge

Effervescent vitamin preparations depend on an acid-base reaction that rapidly releases carbon dioxide after the tablet is dissolved in water. Organic acids provide the acidic component, while bicarbonates or carbonates provide the basic component. The final drink contains dissolved vitamins and minerals together with reaction products, residual acids, flavoring agents, sweeteners, and other formulation-specific ingredients. Direct studies demonstrate that the pH of commercially available preparations may vary considerably, with many tested products falling within an acidic range (Wegehaupt et al., 2016; Jeong et al., 2019; Sozen Yanik et al., 2024).

The erosive behavior of such a solution cannot be predicted from pH alone. pH represents an important determinant of the thermodynamic driving force for enamel dissolution and has been identified as one of the strongest individual chemical predictors of initial surface softening (Barbour et al., 2011; Lussi et al., 2012). However, it does not capture the total amount of acid available or how long the solution can resist neutralization. Titratable acidity and buffering capacity are therefore important complementary variables. A highly buffered acidic solution may require a larger amount of salivary base before its pH rises, potentially prolonging the period during which enamel is exposed to an undersaturated environment (Lussi et al., 2012).

The type of acid can also influence mineral dissolution. Citric acid is especially common in effervescent products because it provides a favorable taste and readily participates in the effervescence reaction. In addition to supplying hydrogen ions, citrate can bind calcium, which may influence the saturation state of the solution and the equilibrium between enamel mineral and the surrounding liquid. Nevertheless, the final behavior of a commercial preparation reflects the combined effect of all ingredients rather than the presence of one acid in isolation.

Mineral content is particularly relevant. Calcium and phosphate can increase the degree of saturation of an acidic solution with respect to hydroxyapatite and thereby reduce the tendency for enamel mineral to dissolve. Screening studies of erosive products show that calcium concentration can substantially modify erosive potential even when pH is similar (Barbour et al., 2011; Lussi et al., 2012). This principle is directly illustrated by Wegehaupt et al. (2016): all vitamin-only preparations tested in that study produced measurable enamel loss, whereas vitamin-mineral formulations showed much greater variability. Some calcium-containing formulations produced little or no detectable loss despite remaining acidic, whereas low-calcium products with similar pH values produced considerably more erosion.

This relationship is clinically important because it explains why simple classification of a preparation as “acidic” is insufficient. A product with a pH near 4 may be substantially less erosive than another product with a similar or even slightly higher pH if the first contains sufficient calcium or has lower titratable acidity. Conversely, a preparation with modestly higher pH can remain erosive when its mineral composition and buffering properties favor continued dissolution. The complete chemical formulation should therefore be considered when interpreting experimental findings.

The oral environment further modifies the acid challenge. Saliva dilutes and clears acids, contains bicarbonate and other buffering systems, and supplies calcium and phosphate that support remineralization. The acquired salivary pellicle forms a diffusion barrier on the enamel surface and can reduce the immediate interaction between acids and dental mineral (Magalhães et al., 2009). These protective mechanisms are incompletely reproduced by simple immersion studies and are one reason why *in vitro* effects cannot be directly converted into expected clinical tissue loss.

The same acidic exposure can also influence resin-based materials, but the mechanism differs from enamel dissolution. Composite resins contain a cross-linked polymer matrix and inorganic fillers coupled by silane. Methacrylate-based networks are susceptible to water sorption, plasticization, and hydrolysis. The filler-matrix interface is a particularly vulnerable region because progressive hydrolysis of the coupling layer may promote filler debonding and create pathways for further water penetration (Drummond, 2008; Szczesio-Włodarczyk et al., 2020). Acidic conditions can accelerate hydrolytic processes and may contribute to changes in hardness, roughness, and optical properties.

Consequently, the dental effect of an effervescent preparation results from an interaction between the chemical properties of the dissolved product and the properties of the exposed substrate. For enamel, acidity, buffering, mineral saturation, and exposure pattern are central. For resin-based restorations, susceptibility additionally depends on polymer chemistry, filler composition and loading, coupling stability, and baseline surface characteristics. These mechanisms provide the basis for interpreting the direct experimental evidence discussed below.

4. Effects on Dental Enamel

Available experimental evidence indicates that effervescent vitamin supplements may exert an erosive effect on dental enamel. The magnitude of this effect differs considerably between formulations and appears to depend on the complete chemical composition of the dissolved preparation rather than on acidity alone. The direct evidence currently comes mainly from *in vitro* studies using bovine enamel, although more recent investigations have also included human permanent enamel (Wegehaupt et al., 2016; Jeong et al., 2019; Sozen Yanik et al., 2024).

Wegehaupt et al. (2016) provided one of the most comprehensive assessments of actual enamel surface loss. Bovine enamel specimens were exposed to a range of vitamin-only and vitamin-mineral effervescent formulations for repeated two-minute cycles, and loss was quantified by profilometry. All tested vitamin-only preparations produced measurable enamel loss. After 20 cycles, mean loss ranged from approximately 5.6 to 8.5 μm . In contrast, vitamin-mineral products showed much greater variability. Some produced little or no measurable loss, whereas others caused losses of approximately 5 μm . Higher calcium concentrations were generally associated with lower erosive effects. These findings provide direct evidence that two effervescent formulations with similar pH values may behave very differently when their mineral composition differs.

Jeong et al. (2019) evaluated four commercial effervescent vitamin preparations using bovine enamel and focused on early changes in Vickers microhardness and surface morphology. The tested preparations had acidic pH values, and all significantly reduced enamel microhardness after exposure. Changes were detectable after only one minute and were generally greater after ten minutes. Scanning electron microscopy showed preparation-dependent surface irregularities, cracks, and areas consistent with mineral loss. The results demonstrate that even relatively short laboratory exposure can produce measurable surface softening, although the acute immersion model is more intensive than the brief contact expected during normal drinking.

The distinction between surface softening and actual tissue loss is important when interpreting these results. Surface microhardness is particularly useful for detecting early erosive changes in the superficial mineral layer, whereas profilometry is more appropriate for measuring advanced erosion accompanied by physical surface loss (Schlueter et al., 2011). A reduction in Vickers hardness therefore indicates demineralization and weakening of the superficial enamel but does not demonstrate that a specific thickness of tissue has been irreversibly removed. The findings of Jeong et al. (2019) and the microhardness results of

Sozen Yanik et al. (2024) should therefore be interpreted differently from the profilometric loss reported by Wegehaupt et al. (2016).

Evidence from human permanent enamel was provided by Sozen Yanik et al. (2024), who exposed specimens to four effervescent vitamin solutions for two minutes daily over 30 days. Repeated exposure increased enamel surface roughness and reduced microhardness. After 30 days, enamel roughness was higher in the vitamin groups than in the distilled-water control, and microhardness was lower in the experimental groups. SEM observations showed progressive surface alterations and areas of superficial demineralization. These findings support the biological relevance of changes previously observed in bovine-enamel models, although the study remained an *in vitro* experiment.

In contrast, evidence regarding enamel color is less convincing. In the same human-enamel study, overall color change over the experimental period did not differ significantly between the vitamin solutions and distilled water (Sozen Yanik et al., 2024). This suggests that the most reproducible direct effects of effervescent supplements concern enamel surface integrity rather than visible discoloration.

Overall, the enamel evidence is relatively consistent in direction. Some effervescent vitamin preparations can cause early surface softening, increase roughness, and, under sufficiently intensive repeated exposure, produce measurable enamel loss. At the same time, the magnitude of the effect is highly formulation dependent. pH remains important, but mineral content, acid characteristics, buffering properties, and exposure conditions modify the final response. The laboratory evidence therefore supports the presence of erosive potential without establishing that routine daily use necessarily produces clinically important enamel wear.

5. Effects on Resin-Based Restorative Materials

Resin-based restorative materials are exposed to the same dissolved supplements as enamel, but their response is governed by material chemistry rather than mineral dissolution. Methacrylate-based composites absorb water and undergo progressive hydrolytic aging, while the filler-matrix interface may deteriorate through degradation of the silane coupling layer (Drummond, 2008; Szczesio-Wlodarczyk et al., 2020). Acidic environments may accelerate these processes. Direct evidence nevertheless shows that the response to effervescent vitamin solutions differs markedly among restorative materials (Gurdogan Guler et al., 2021; Ertürk Avunduk & Delikan, 2023; Doğu Kaya et al., 2024; Sozen Yanik et al., 2024).

5.1. Surface Microhardness

Repeated exposure to effervescent multivitamin solutions has been associated with reduced microhardness in selected resin-based materials. Gurdogan Guler et al. (2021) evaluated Beautifil II, a giomer, and a conventional glass-ionomer cement after daily exposure to Supradyne and Sambucol in syrup and effervescent forms. In the giomer, microhardness progressively decreased over 28 days. However, hardness also decreased in the water control, indicating that water sorption and hydrolytic aging contributed to the observed changes. This is consistent with evidence that aqueous storage itself can alter resin matrices and filler-matrix interfaces over time (Drummond, 2008; Szczesio-Wlodarczyk et al., 2020).

A similarly material-dependent response was reported by Sozen Yanik et al. (2024). Filtek Ultimate maintained relatively stable microhardness during exposure to four effervescent formulations, whereas Gradia Direct Anterior and Gradia Direct Posterior showed significant changes in selected solutions. The same chemical challenge therefore did not produce equivalent effects across composite systems. Differences in resin composition, degree of conversion, filler loading, filler chemistry, and coupling stability are plausible explanations.

Supporting studies using food-simulating liquids reinforce this interpretation. Citric acid can reduce hardness in selected composites and ionomers, but the magnitude of softening differs between materials (Kooi et al., 2012; Meena Kumari et al., 2019). Current evidence therefore does not support a universal claim that effervescent vitamin supplements reduce the hardness of all resin composites. They are better regarded as a potential chemical challenge whose effect depends on the material and exposure conditions.

5.2. Surface Roughness

Evidence regarding surface roughness is less consistent. Gurdogan Guler et al. (2021) observed a progressive increase in the roughness of Beautifil II during 28 days of exposure to effervescent multivitamin formulations, with changes greater than those observed in water. This suggests that some acidic formulations may accelerate surface deterioration beyond hydrolytic aging alone.

In contrast, Ertürk Avunduk and Delikan (2023) reported visible surface alterations on SEM after repeated exposure to Redoxon and Ocean Efervit, but within-group changes in profilometric roughness were not statistically significant. This apparent discrepancy is methodologically important. SEM detects localized topographic defects, whereas a profilometer averages height variation across a predefined track. Microscopic pits or filler loss may therefore be visible without producing a large change in mean Ra.

Doğu Kaya et al. (2024) evaluated five microhybrid resin composites exposed to Redoxon Triple Action for two minutes daily over 30 days. Roughness changed over time and differed among materials, but the overall main effect of the vitamin solution was not statistically significant. SEM nevertheless showed localized pits, cracks, filler exposure, and apparent filler loss after experimental exposure. Sozen Yanik et al. (2024) likewise reported significant roughness changes only in selected material-solution combinations.

These findings are consistent with broader evidence that roughness response depends on the restorative material, acidic medium, aging conditions, and measurement method (El-Rashidy et al., 2023; Elmalawany et al., 2023). Statistically detectable changes should not automatically be considered clinically relevant. In some aging studies, surface differences remained below roughness levels commonly discussed as potentially important for plaque retention despite reaching statistical significance. Both the magnitude of change and the measurement context should therefore be considered when interpreting Ra values.

Supporting studies using non-vitamin acidic media help place the direct findings in context, although they should not be treated as equivalent evidence. In aesthetic restorative materials, beverage-induced changes in hardness and color increase with duration and frequency of contact, and the magnitude differs by material (Choi et al., 2019). Acidic beverages have also produced different roughness and color responses in posterior composites with different formulations (Meenakshi & Sirisha, 2020). These studies strengthen the biological plausibility of the direct effervescent-vitamin findings but also emphasize that the exposing liquid and restorative material interact. They do not demonstrate that effects observed with cola, juice, or other beverages can be quantitatively transferred to vitamin supplements.

5.3. Color Stability

Color stability is the most extensively investigated optical outcome in resin composites exposed to effervescent vitamin preparations. The overall pattern is not uniform discoloration but a strong dependence on the specific restorative material and supplement formulation (Çınar et al., 2023; Ertürk Avunduk & Delikan, 2023; Doğu Kaya et al., 2024; Sozen Yanik et al., 2024; Yazıcıoğlu Pirpir & Harorlı, 2026).

Çınar et al. (2023) evaluated three resin composites exposed to Redoxon, Supradyn, another dietary supplement, or water for 28 days. Direct color changes were relatively limited in most groups, although Fill-Up exposed to Supradyn showed a larger response. The authors subsequently exposed specimens to coffee and observed that previous Redoxon exposure increased later staining of Filtek Z550 compared with its control. This isolated finding suggests that acidic supplement exposure may modify later susceptibility to extrinsic staining in selected materials, but confirmation in additional studies is needed.

More pronounced discoloration was reported by Ertürk Avunduk and Delikan (2023). Several combinations of G-aenial Posterior or Solidex with Redoxon or Ocean Efervit exceeded the CIEDE2000 clinical acceptability threshold. Importantly, these optical changes occurred despite the absence of significant within-group profilometric roughness changes. Color alteration therefore does not necessarily require a measurable increase in mean surface roughness.

Doğu Kaya et al. (2024) also found considerable variability between five microhybrid composites exposed to Redoxon Triple Action. Beautifil II showed the largest color change, while several other materials showed smaller alterations. However, the overall main effect of the vitamin solution on color was not statistically significant, indicating that material type explained a substantial part of the response. Likewise, Sozen Yanik et al. (2024) did not find a significant overall difference in color change between the tested effervescent solutions and distilled water for the three evaluated composites.

The strongest evidence of pronounced discoloration comes from the most recent direct study. Yazıcıoğlu Pirpir and Harorlı (2026) exposed five contemporary resin composites twice daily to Sambucol Plus, Supradyn, or Youplus for 28 days. Both composite type and immersion solution significantly affected color stability.

Several combinations exceeded the CIEDE2000 acceptability threshold, with the largest change observed for Filtek One Bulk Fill exposed to Youplus, where ΔE_{00} approached 10. Omnichroma exposed to Supradyn also showed marked discoloration. These results demonstrate that substantial optical changes are possible under repeated experimental exposure, but only in specific material-supplement combinations.

Interpretation of color studies requires attention to the formula used. Paravina et al. (2015) reported 50:50 perceptibility and acceptability thresholds of approximately 1.2 and 2.7 for CIELAB ΔE_{ab} , compared with approximately 0.8 and 1.8 for CIEDE2000 ΔE_{00} . These thresholds are not interchangeable. More recent work also emphasizes that perceptibility and acceptability can vary according to whether the color difference is dominated by lightness, chroma, or hue (Tejada-Casado et al., 2024).

Overall, the evidence on resin-based restorative materials is more heterogeneous than the enamel evidence. Clinically relevant color changes are clearly possible in selected combinations, whereas effects on microhardness and roughness are less consistent. The most defensible synthesis is therefore a material- and formulation-dependent response rather than a uniform degradative effect of all effervescent vitamins on all resin composites.

6. Clinical Relevance and Preventive Considerations

The clinical significance of the available laboratory findings should be interpreted cautiously. Most direct studies were conducted under controlled in vitro conditions and used standardized exposure cycles that cannot fully reproduce normal oral conditions (Shellis et al., 2011; West et al., 2011). Salivary dilution and clearance, buffering, calcium and phosphate availability, formation of the acquired pellicle, drinking speed, swallowing pattern, and the interval between exposures all influence the effective acid challenge. Consequently, the laboratory demonstration of erosive or degradative potential does not establish the incidence or magnitude of clinical damage during ordinary supplement use.

Nevertheless, repeated or prolonged contact with acidic effervescent solutions is avoidable and may reasonably be minimized. Frequency and duration of acid exposure are important determinants of erosive risk, and preventive guidance for erosive tooth wear generally includes reduction of unnecessary contact time with acidic products (Magalhães et al., 2009; Carvalho et al., 2015). Dissolved supplements should therefore be consumed over a relatively short period rather than slowly sipped for a prolonged time. Holding or repeatedly swishing the solution around the mouth would extend contact with enamel and restorations without providing a therapeutic advantage.

Rinsing with water after consumption is a simple measure that may help remove residual solution and support the return toward a neutral oral environment. Saliva subsequently contributes buffering and supplies minerals involved in remineralization of softened enamel. Because an eroded or softened surface is more susceptible to mechanical abrasion, aggressive toothbrushing immediately after a pronounced acid challenge may increase surface loss (Magalhães et al., 2009). The evidence reviewed here does not justify a precise universal waiting time, but it supports avoiding unnecessary brushing abrasion during the period of greatest surface softening.

Additional attention may be appropriate in individuals who already have high background acid exposure or reduced protective capacity. Examples include frequent consumption of acidic beverages, xerostomia or reduced salivary flow, recurrent intrinsic acid exposure, and existing erosive tooth wear. In such situations, an effervescent supplement represents an additional source of acid rather than an isolated exposure. If an equivalent non-effervescent formulation is clinically appropriate, conventional tablets or capsules may reduce direct exposure of dental surfaces to an acidic drink.

Patients with extensive esthetic resin restorations may also be relevant. The direct evidence shows that certain composite-supplement combinations undergo color changes that exceed established acceptability thresholds, whereas other materials remain relatively stable (Ertürk Avunduk & Delikan, 2023; Yazıcıoğlu Pirpir & Harorlı, 2026). However, the evidence is not sufficient to recommend replacement or avoidance of a specific restorative material solely because a patient uses effervescent supplements. Material selection should continue to be based on the full clinical indication, with habitual acidic exposures considered as one component of the oral environment.

Preventive advice should therefore remain proportional to the evidence. The data support minimizing unnecessary duration and frequency of contact with acidic effervescent solutions and recognizing these products as one possible contributor to an individual's total erosive burden. At the same time, there is no evidence that normal once-daily use inevitably causes clinically significant enamel loss or premature failure of resin-based restorations.

7. Discussion

The available literature supports a coherent but nuanced interpretation of the dental effects of effervescent vitamin supplements. These products can create a measurable acidic challenge, and direct laboratory studies consistently demonstrate the potential for enamel demineralization. Evidence for resin-based restorative materials is less uniform, with the most pronounced changes occurring only in selected materials and for selected outcomes. This difference is biologically plausible because the underlying mechanisms are distinct: enamel responds primarily through mineral dissolution and surface softening, whereas resin-based materials are affected by water sorption, hydrolysis, matrix degradation, and disruption of the filler-matrix interface.

For enamel, the consistency across different experimental models is notable. Wegehaupt et al. (2016) quantified actual surface loss after repeated exposure, Jeong et al. (2019) demonstrated rapid reductions in microhardness, and Sozen Yanik et al. (2024) confirmed changes in human permanent enamel. Although the studies differ in substrate and protocol, they point in the same direction: repeated contact with selected effervescent vitamin solutions can alter enamel surface integrity. The strength of this conclusion is greater than would be suggested by any single outcome measure because the studies use complementary methods. Microhardness identifies early softening, profilometry demonstrates tissue loss, and SEM provides morphological confirmation. At the same time, these methods should not be conflated. A large decrease in microhardness cannot be translated directly into a specific amount of enamel lost.

A central finding is the marked variation between commercial formulations. It would be misleading to classify all effervescent vitamins as equally erosive or to use a single pH threshold as a complete predictor of risk. Wegehaupt et al. (2016) showed that the vitamin-mineral formulations tested in their study ranged from little or no measurable erosion to pronounced enamel loss despite broadly similar acidic pH values. This observation is consistent with experimental work showing that pH interacts with calcium concentration, buffering properties, titratable acidity, and degree of mineral saturation (Barbour et al., 2011; Lussi et al., 2012). Product formulation therefore matters: supplements that appear similar to the consumer may produce substantially different effects on enamel under experimental conditions.

The role of calcium is particularly important. When an acidic solution already contains sufficient calcium, the thermodynamic drive for additional mineral dissolution can be reduced. This mechanism offers a plausible explanation for the lower erosive potential of some vitamin-mineral preparations. However, calcium should not be interpreted as an absolute protective factor. Its effect depends on concentration, pH, acid type, phosphate content, and the overall saturation state of the solution. The evidence therefore supports a multivariable model of erosive potential rather than a simple ranking based on pH.

The resin-composite evidence requires even greater caution. Direct studies report changes in microhardness, surface roughness, color, or SEM appearance, but no outcome is affected consistently across all materials. This heterogeneity reflects the diversity of contemporary resin composites. Materials grouped broadly as composites may differ substantially in monomer system, filler size and loading, prepolymerized filler content, silane chemistry, and degree of conversion. These characteristics influence water sorption, hydrolytic stability, polishing behavior, and optical response (Drummond, 2008; Szczesio-Włodarczyk et al., 2020).

Beautifil II illustrates this point. The giomer showed relatively pronounced changes in several direct studies (Gurdogan Guler et al., 2021; Doğu Kaya et al., 2024). This finding is consistent with supporting evidence showing that giomer surface hardness and roughness may be particularly sensitive to citric acid exposure (Kooi et al., 2012). Nevertheless, it would be inappropriate to generalize that all gomers are inherently unsuitable for patients using acidic supplements. The direct literature includes a limited number of representatives from each material category, and manufacturer-specific formulation may be more important than the broad category label.

The distinction between quantitative roughness and qualitative SEM findings also deserves emphasis. Several studies observed clear microscopic defects while profilometric Ra changes were small or statistically non-significant. This does not necessarily represent contradictory evidence. SEM can identify focal pits, cracks, or filler loss, whereas Ra is an averaged numerical descriptor of a scanned surface. Valinoti et al. (2008) demonstrated a similar pattern with acidic medications: SEM evidence of surface degradation was more extensive than the change detected by profilometry. Accordingly, future work should combine complementary surface methods rather than rely on a single roughness parameter.

Color stability appears to be the restorative outcome with the clearest potential clinical relevance. Several direct studies documented changes exceeding accepted perceptibility or acceptability thresholds, but

only in selected material-supplement combinations. The 2026 study is particularly informative because it included contemporary materials such as Omnicroma and Filtek One Bulk Fill and demonstrated very large ΔE_{00} values in certain supplement groups (Yazıcıoğlu Pirpir & Harorlı, 2026). Conversely, Sozen Yanik et al. (2024) found no significant overall difference in color change between vitamin solutions and water for the evaluated composites. These divergent findings reinforce the conclusion that color response depends on the interaction between material and solution rather than on exposure to an effervescent vitamin per se.

The mechanism of discoloration is likely multifactorial. Acidic exposure may alter the resin matrix, increase water sorption, affect filler-matrix integrity, and modify the surface in ways that influence light scattering or pigment uptake. Some supplements also contain colorants or plant-derived ingredients that may contribute directly to optical change. Çınar et al. (2023) observed that prior Redoxon exposure increased subsequent coffee staining in one composite, suggesting that chemical aging may modify later stain susceptibility. Because this effect was not consistent across materials, it should currently be considered hypothesis-generating rather than an established clinical mechanism.

Another important issue is the intensity of laboratory exposure. Protocols ranged from acute one- or ten-minute immersion to repeated two-minute exposures for 28 or 30 days, and one study used twice-daily exposure. Cumulative exposure times therefore differed substantially. In addition, some specimens were stored in distilled water between challenges, whereas others underwent different aging conditions. Such models are useful for comparing materials under standardized conditions but cannot reproduce the dynamic oral environment. Saliva, pellicle, rapid swallowing, intermittent drinking, dietary co-exposures, and remineralization all modify the effective challenge (Shellis et al., 2011; West et al., 2011).

The use of bovine enamel in some direct studies introduces an additional limitation when interpreting magnitude. Bovine enamel provides standardized specimens and is widely used in laboratory erosion research, but its structure and response are not identical to human enamel. The human-enamel findings of Sozen Yanik et al. (2024) therefore strengthen the biological relevance of the overall evidence, although they still arise from an *in vitro* model.

The same principle applies to supporting enamel studies. Human-enamel models using acidic beverages demonstrate that acid exposure can alter surface morphology, hardness, and mineral composition, but the magnitude depends on the solution and experimental model (Jameel et al., 2024). Such evidence is useful for interpreting mechanisms, not for estimating the clinical effect of a particular effervescent supplement. The direct supplement studies should therefore remain the primary basis for conclusions specific to effervescent vitamins.

Clinical interpretation should therefore avoid two extremes. First, the findings should not be dismissed simply because they are laboratory based: the convergence of chemical principles and direct experimental results makes it reasonable to recognize acidic effervescent supplements as a potential contributor to erosive exposure (Wegehaupt et al., 2016; Jeong et al., 2019; Sozen Yanik et al., 2024). Second, the evidence does not support the claim that standard daily use inevitably damages teeth or restorations. No direct clinical study has demonstrated such an outcome, and laboratory models cannot quantify the magnitude of change expected under intraoral conditions (Shellis et al., 2011; West et al., 2011). The most appropriate interpretation is therefore risk-based: exposure duration and frequency, product formulation, salivary protection, baseline erosive risk, and restorative material may all influence whether laboratory potential becomes clinically meaningful.

The evidence also has implications for how future studies should characterize commercial formulations. Reporting only the product name and initial pH provides limited information, because erosive behavior depends on several interacting chemical variables, including titratable acidity, buffering capacity, calcium and phosphate concentrations, and the degree of saturation with respect to dental mineral (Barbour et al., 2011; Lussi et al., 2012). Direct studies of effervescent supplements also demonstrate that products with relatively similar pH values may differ considerably in their effects on enamel (Wegehaupt et al., 2016). Future investigations should therefore provide detailed information on the tested formulation, dissolution volume, pH, titratable acidity, and mineral composition whenever possible.

This interpretation supports simple preventive measures rather than overly broad recommendations. General strategies for preventing erosive tooth wear include reducing the frequency and duration of acidic exposure and supporting salivary neutralization and remineralization (Carvalho et al., 2015; Magalhães et al., 2009). In the context of effervescent supplements, consuming the prepared solution without prolonged sipping or swishing and rinsing with water afterward are reasonable measures to reduce unnecessary contact with dental surfaces. In patients with a high background risk of erosive tooth wear, an equivalent non-effervescent formulation may also be considered when clinically appropriate. More specific recommendations require *in situ* or clinical evidence evaluating realistic patterns of long-term supplement use (Shellis et al., 2011; West et al., 2011).

8. Limitations and Future Research

The current evidence has several important limitations. Most direct studies are *in vitro* investigations, which allow standardized comparison of different formulations and materials but only partially reproduce the oral environment. Salivary buffering, acquired pellicle formation, oral clearance, temperature changes, remineralization, and normal drinking behavior are either absent or incompletely simulated. Consequently, the magnitude of enamel or restorative-material changes observed experimentally cannot be directly extrapolated to routine clinical use (Shellis et al., 2011; West et al., 2011).

Experimental protocols are also highly heterogeneous. Studies differ in exposure duration and frequency, cumulative contact time, enamel substrate, storage conditions, restorative materials, and measurement methods (Wegehaupt et al., 2016; Jeong et al., 2019; Gurdogan Guler et al., 2021; Sozen Yanik et al., 2024). Some enamel studies used bovine specimens, whereas more recent investigations also included human permanent enamel. Restorative studies evaluated different composite types, often with only one or two representatives of each material category. These differences limit direct quantitative comparison and prevent identification of a universally resistant or susceptible class of resin-based restorative material.

Interpretation is further complicated by the use of different outcome measures. Microhardness primarily reflects early surface softening, whereas profilometry measures actual surface loss; SEM provides qualitative information on surface morphology, and color measurements assess optical changes (Schlueter et al., 2011). These methods therefore describe different aspects of degradation and should not be interpreted as interchangeable.

Future studies should use more standardized, clinically relevant exposure protocols and should characterize the tested solutions more completely. Reporting pH alone is insufficient because titratable acidity, buffering capacity, calcium and phosphate concentrations, and mineral saturation can substantially modify erosive potential (Barbour et al., 2011; Lussi et al., 2012). Greater use of human enamel, artificial or natural saliva, and acquired-pellicle models would improve biological relevance. *In situ* studies are particularly needed because they permit controlled exposure while incorporating salivary and pellicle effects (Shellis et al., 2011; West et al., 2011). Ultimately, clinical studies are required to determine whether regular consumption of effervescent vitamin supplements is associated with measurable erosive tooth wear, clinically relevant discoloration, or reduced longevity of resin-based restorations.

9. Conclusions

Available evidence indicates that effervescent vitamin supplements can create an acidic challenge for both dental enamel and resin-based restorative materials. Experimental studies demonstrate that repeated exposure to selected formulations may reduce enamel microhardness, increase surface roughness, and, under sufficiently intensive conditions, cause measurable enamel loss (Wegehaupt et al., 2016; Jeong et al., 2019; Sozen Yanik et al., 2024). The magnitude of these effects differs considerably between products and is influenced by pH, buffering properties, mineral content, acid characteristics, and the overall chemical composition of the dissolved preparation (Barbour et al., 2011; Lussi et al., 2012).

Resin-based restorative materials show a more heterogeneous response. Changes in microhardness and roughness are inconsistent across studies, whereas clinically relevant color changes have been demonstrated in selected material-supplement combinations (Gurdogan Guler et al., 2021; Ertürk Avunduk & Delikan, 2023; Doğu Kaya et al., 2024; Sozen Yanik et al., 2024; Yazıcıoğlu Pirpir & Harorlı, 2026). Differences in resin chemistry, filler characteristics, and filler-matrix stability may contribute to this variability (Drummond, 2008; Szczesio-Włodarczyk et al., 2020).

Because the evidence is predominantly *in vitro*, its clinical significance remains uncertain. Current data support minimizing prolonged or repeated contact of acidic effervescent solutions with dental surfaces, particularly in individuals with additional risk factors for erosive tooth wear (Carvalho et al., 2015; Magalhães et al., 2009). However, the available literature does not justify the conclusion that standard daily use inevitably causes clinically significant enamel damage or deterioration of resin-based restorations. Standardized *in situ* and clinical studies are needed to establish the long-term relevance of the changes observed experimentally (Shellis et al., 2011; West et al., 2011).

Table 1. Characteristics and main findings of direct studies evaluating effervescent vitamin supplements

Study	Substrate/material	Preparation(s)	Exposure	Outcomes	Key findings
Wegehaupt et al. (2016)	Bovine enamel	14 vitamin-only or vitamin-mineral preparations	2 min/cycle; 10 and 20 cycles	Profilometric enamel loss	All vitamin-only products caused enamel loss; vitamin-mineral products varied markedly, with lower erosion generally associated with higher calcium.
Jeong et al. (2019)	Bovine enamel	DM Multivitamin, BeroNew, Berocca, VitaHEIM	Single 1- or 10-min exposure	VHN; SEM	All products reduced VHN; effects were generally greater after 10 min and accompanied by more pronounced SEM changes.
Gurdoğan Guler et al. (2021)	Beautifil II giomer; GIC comparator	Supradyn and Sambucol effervescent formulations	2 min/day for 28 days	VHN; Ra	Giomer VHN decreased and Ra increased; changes in water controls indicate concurrent hydrolytic aging.
Çınar et al. (2023)	Filtek One Bulk Fill, Filtek Z550, Fill-Up	Redoxon, Supradyn	2 min/day for 28 days; then coffee for 7 days	ΔE_{ab}	Discoloration was material dependent; prior Redoxon exposure increased later coffee staining of Filtek Z550.
Ertürk Avunduk & Delikan (2023)	G-aenial Posterior, Solidex	Redoxon, Ocean Efervit	28 days; Methods report 2 min/day	ΔE_{00} ; Ra; SEM	Several combinations exceeded the ΔE_{00} acceptability threshold; SEM changes occurred without significant within-group Ra changes.
Doğu Kaya et al. (2024)	Five microhybrid composites	Redoxon Triple Action	2 min/day for 30 days	ΔE_{ab} ; Ra; SEM	Beautifil II showed the greatest changes; overall solution effects on color and Ra were not significant.
Sozen Yanik et al. (2024)	Human enamel; Filtek Ultimate; Gradia Direct Anterior/Posterior	YOUPLUS, Redoxon, Immuvit, Sambucol	2 min/day for 30 days	Ra; VHN; ΔE_{00} ; SEM	Human enamel showed higher Ra and lower VHN; composite responses were material dependent, with no overall color effect versus water.
Yazıcıoğlu Pirpir & Harorlı (2026)	Five contemporary resin composites	Sambucol Plus, Supradyn, Youplus	2 min twice daily for 28 days	ΔE_{00} ; Whiteness Index	Material and solution affected color; Filtek One Bulk Fill + Youplus showed the largest ΔE_{00} (approximately 9.9).

Abbreviations: ΔE_{ab} , CIELAB color difference; ΔE_{00} , CIEDE2000 color difference; GIC, glass-ionomer cement; Ra, arithmetic mean surface roughness; SEM, scanning electron microscopy; VHN, Vickers hardness number.

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