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Surface roughness analysis of acrylic and bis-acrylic resins used in provisional crowns after exposure to acidic beverages: in *vitro study*

Análise de rugosidade superficial de resinas acrílicas e bisacrílicas utilizadas em coroas provisórias submetidas à ação de bebidas ácidas: estudo *in vitro*

Análisis de la rugosidad superficial de resinas acrílicas y bisacrílicas utilizadas en coronas provisionales sometidas a la acción de bebidas ácidas: un estudio *in vitro*

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ABSTRACT

Objective: To evaluate the effect of contact with coffee and cola-type soft drinks on the surface roughness (Ra) of self-curing acrylic and bisacrylic temporary resins. **Methods:** In vitro study with four materials (acrylics: Duralay, Dencor; bisacrylics: Protemp, Primma Art). 180 specimens were made in a standardized metal matrix. After inspection, sequential finishing, and hydration for 24 hours at 37 °C, the baseline reading was obtained. The specimens were then immersed for 7 days at 37 °C in glue, coffee, or a control. Ra (µm) was measured with a profilometer. Statistical analysis was performed using two-way ANOVA followed by Tukey's test (α=0.05). **Results:** A significant interaction was observed between resin and medium. Primma Art showed an increase in Ra after glue application (7 days), representing the highest value in the study, while saliva promoted a reduction in Ra in this bisacrylic resin. Acrylic (Duralay, Dencor) and Protemp materials remained stable across conditions, with only slight numerical variations. Coffee did not generate statistically significant differences for any material. **Conclusion:** The findings suggest that material selection and exposure to cola-type soft drinks influence the surface integrity of temporary restorations, recommending a preference for more stable formulations and dietary guidance during clinical use.

Keywords: Surface properties, Acrylic resins, Temporary dental restoration.

RESUMO

Objetivo: Avaliar o efeito do contato com café e refrigerante tipo cola na rugosidade superficial (Ra) de resinas provisórias acrílicas autopolimerizáveis e bisacrílicas. **Métodos:** Estudo *in vitro* com quatro materiais (acrílicas: Duralay, Dencor; bisacrílicas: Protemp, Primma Art). Foram confeccionados 180 espécimes em matriz metálica padronizada. Após inspeção, acabamento sequencial e hidratação por 24h a 37 °C, obteve-se a leitura baseline. Os espécimes foram então imersos por 7 dias a 37 °C em cola, café ou controle. A Ra (µm) foi medida com rugosímetro. A análise estatística foi feita por ANOVA two-way seguida de Tukey

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(α=0,05). **Resultados:** Observou-se interação significativa entre resina × meio. A Primma Art apresentou aumento de Ra após cola (7 dias), configurando o maior valor do estudo, enquanto saliva promoveu redução de Ra nessa bisacrílica. As acrílicas (Duralay, Dencor) e a Protemp mantiveram-se estáveis entre as condições, com variações numéricas discretas. Café não gerou diferenças estatisticamente significativas para nenhum material. **Conclusão:** Os achados sugerem que a seleção do material e a exposição a refrigerantes tipo cola influenciam a integridade superficial de provisórios, recomendando-se preferência por formulações mais estáveis e orientação dietética durante o uso clínico.

Palavras-chave: Propriedades de superfície, Resinas acrílicas, Restauração dentária temporária.

RESUMEN

Objetivo: Evaluar el efecto del contacto con café y refrescos tipo cola sobre la rugosidad superficial (Ra) de resinas temporales autopolimerizables acrílicas y bisacrílicas. **Métodos:** Estudio in vitro con cuatro materiales (acrílicos: Duralay, Dencor; bisacrílicos: Protemp, Primma Art). Se realizaron 180 especímenes en una matriz metálica estandarizada. Después de la inspección, el acabado secuencial y la hidratación durante 24 horas a 37 °C, se obtuvo la lectura base. Luego, los especímenes se sumergieron durante 7 días a 37 °C en pegamento, café o un control. La Ra (µm) se midió con un perfilómetro. El análisis estadístico se realizó mediante ANOVA de dos vías seguido de la prueba de Tukey (α=0,05). **Resultados:** Se observó una interacción significativa entre la resina y el medio. Primma Art mostró un aumento en la Ra después de la aplicación del pegamento (7 días), lo que representa el valor más alto en el estudio, mientras que la saliva promovió una reducción de la Ra en esta resina bisacrílica. Los materiales acrílicos (Duralay, Dencor) y Protemp se mantuvieron estables en diversas condiciones, con solo ligeras variaciones numéricas. El café no generó diferencias estadísticamente significativas en ningún material. **Conclusión:** Los hallazgos sugieren que la selección del material y la exposición a refrescos de cola influyen en la integridad superficial de las restauraciones provisionales, lo que recomienda la preferencia por formulaciones más estables y la aplicación de pautas dietéticas durante el uso clínico.

Palabras clave: Propiedades superficiales, resinas acrílicas, restauración dental temporal.

INTRODUCTION

Temporary prosthetic crowns constitute a fundamental stage of the rehabilitative treatment and must maintain their integrity throughout the provisional period, which is often prolonged (ALNASSAR T, et al., 2018). Specific materials are used for their fabrication, such as acrylic resins, which are recognized for their biocompatibility, ease of handling, low cost, satisfactory esthetics, and chemical stability in the oral environment. Bis-acrylic resins exhibit similar properties, fulfilling esthetic requirements and allowing adequate finishing and polishing, in addition to enabling adjustments at any time. In daily clinical practice, temporary restorations may be maintained for extended periods, especially in complex rehabilitation treatments such as implant-supported prostheses. During this phase, the integrity of the temporary material plays a crucial role in preserving periodontal health, patient comfort, and treatment success. Degradation of the surface of temporary crowns can promote the accumulation of bacterial plaque, gingival inflammation, and discoloration, compromising both biological and aesthetic results (RIBEIRO AKC, et al., 2023).

Surface characteristics, particularly roughness, are essential parameters in the evaluation of restorative materials, as they directly influence the durability of provisional restorations (ANUSAVICE KJ, et al., 2013). Roughness corresponds to the elevations and depressions present on the surface of the tooth or restorative material and, clinically, may promote tissue irritation and inflammation, as well as contribute to biofilm accumulation (GITI R, et al., 2021). Surface alterations in restorations fabricated with acrylic and bis-acrylic resins may be associated with the type of material used, the finishing and polishing technique, and exposure to acidic beverages (KAVUT İ, et al., 2022).

Coffee is among the most widely consumed beverages worldwide, representing a particularly ingrained habit. Beyond its physiological effects, its consumption encompasses psychological and sociocultural dimensions, such as family, friendship, and work connections (ARRUDA CN, et al., 2015). Similarly, cola-type soft drinks have become widely prevalent in recent decades, driven by factors such as availability in low-cost "super-size" portions, high palatability, long shelf life, ease of transport and storage, and aggressive marketing strategies. Despite previous studies, findings regarding the impact of acidic beverages on the roughness of provisional materials remain heterogeneous, varying according to polymer composition, pH, and exposure regimen, thereby reinforcing the need for standardized investigations (BITENCOURT SB, et al., 2020; DAS K, et al., 2025). From a mechanistic standpoint, acidic and chromogenic solutions may promote water sorption and plasticization of the organic matrix, as well as hydrolysis and surface wear, resulting in increased roughness (RIZZANTE F, et al., 2023). Epidemiological data indicate that the consumption of acidic beverages such as coffee and cola-type soft drinks is highly prevalent worldwide, with frequent daily intake across different age groups. These beverages are commonly consumed multiple times per day, resulting in repeated acidic challenges to restorative materials during routine oral function. Although in vitro immersion protocols represent an accelerated model, they are widely accepted to simulate cumulative chemical exposure that may occur during prolonged clinical use of provisional restorations (CARVALHO TS; LUSSI A, 2020).

Despite the growing number of studies investigating the effect of acidic beverages on temporary restorative materials, the available evidence focuses on a single class of material or evaluates isolated products using heterogeneous experimental protocols, which limits direct comparison between chemically distinct temporary systems. In this sense, comparative analyses between self-curing acrylic resins and bis-acrylic resins under identical exposure conditions are still scarce. This gap highlights the need for controlled studies that directly compare these classes of materials under standardized conditions (MÂRȚU I, et al., 2022).

Due to their acidic nature and variable composition, these beverages can alter the pH of the oral environment and interact with polymeric surfaces, potentially modifying the topography and roughness of provisional restorative materials (KAVUT İ, et al., 2022). In this context, it becomes relevant to investigate their effects on different classes of resins used in provisional restorations. The aim of this study was to evaluate the effect of exposure to coffee and cola soft drinks on the surface roughness of self-curing acrylic and bis-acrylic resins. The tested hypothesis was that contact with cola soft drink and coffee increases surface roughness, with the effect of the cola soft drink being greater than that of coffee.

METHODS

Study design

This was an in vitro laboratory study with a quantitative and experimental design. The response variable was surface roughness (Ra, µm). The experimental factors were the type of material (self-curing acrylic resins and bis-acrylic resins; four brands) and the immersion medium (distilled water, coffee, and cola soft drink). The self-curing acrylic resins used were Dencor (Clássico Artigos Odontológicos Ltda., Atibaia–SP, Brazil) and Duralay (Reliance Dental, São Paulo–SP, Brazil), while the bis-acrylic resins were Protemp (3M Produtos Odontológicos – 3M Dental, Sumaré–SP, Brazil) and Primma Art (FGM Dental Produtos, Santa Maria–RS, Brazil).

A total of 180 specimens were fabricated (n = 15 per group), distributed into 12 groups (4 materials × 3 solutions). Surface roughness measurements were performed at two time points: baseline (after finishing/polishing and hydration) and post-exposure (after the immersion period). Specimen allocation to groups was randomized (**Table 1**).

Table 1 - Study groups.

Group	Resin	Immersion Protocol
G1	Acrylic Resin - Dencor	Control (n = 15) Saliva (n = 15) Cola soft drink (n = 15) Coffee (n = 15)
G2	Acrylic Resin - Duralay	Control (n = 15) Saliva (n = 15) Cola soft drink (n = 15) Coffee (n = 15)
G3	Bis-acrylic Resin - Protemp	Control (n = 15) Saliva (n = 15) Cola soft drink (n = 15) Coffee (n = 15)
G4	Bis-acrylic Resin - Primma Art	Control (n = 15) Saliva (n = 15) Cola soft drink (n = 15) Coffee (n = 15)

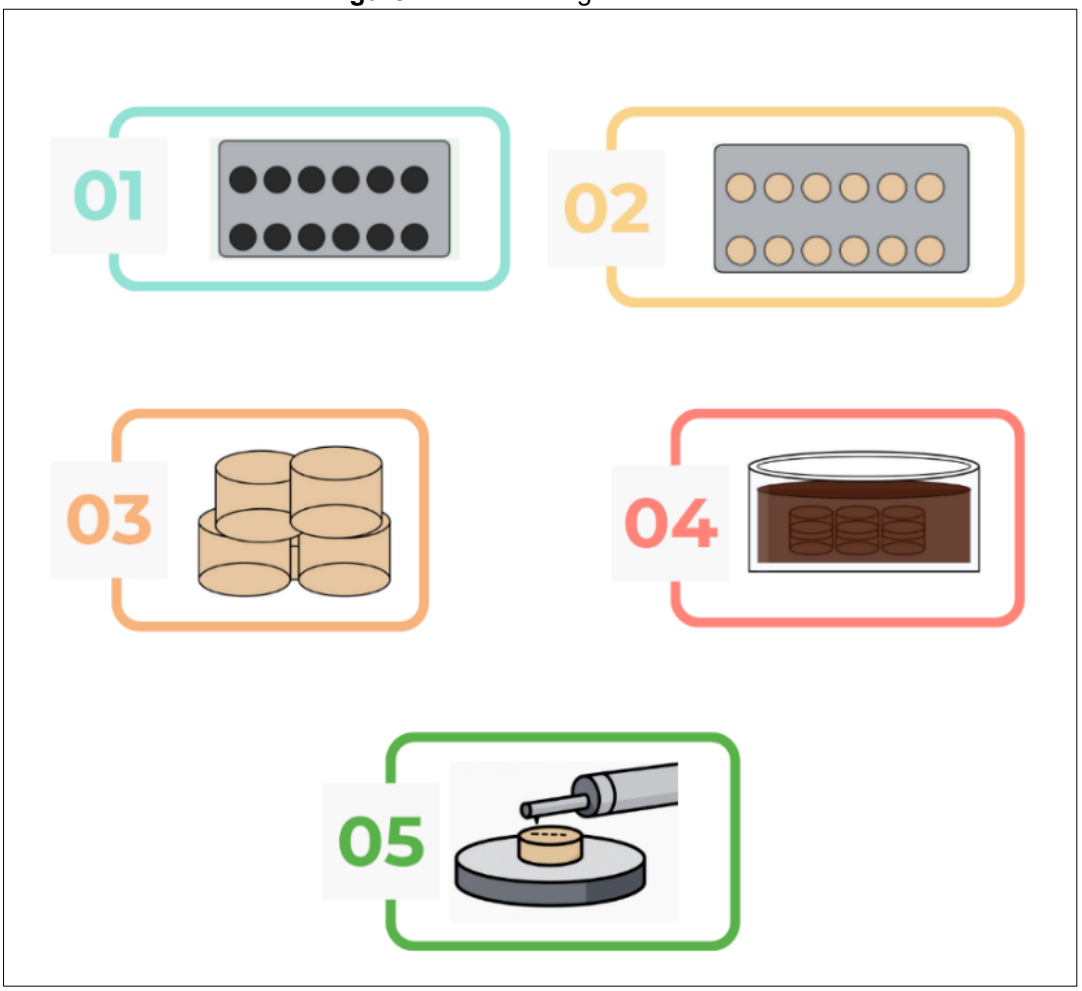
Source: Silva FCS, et al., 2026.

Sample preparation

The resins were handled according to the manufacturers' instructions and poured into a metallic mold containing 12 circular compartments, each measuring 10 mm in diameter and 3 mm in thickness (Figure 01). The mold was placed on a glass slide (80 × 35 × 3 mm), and the assembly was held in position with an elastic band until polymerization was complete. After removal, the specimens were numbered for paired measurements.

The specimens were inspected under a 4× stereomicroscope (BioArt, São Carlos–SP, Brazil) and excluded if they exhibited inadequate morphology, thickness outside the 3 mm standard, porosities, bubbles, or cracks. The upper and lower surfaces were leveled, and the smoother surface was subjected to sequential finishing using abrasive papers of decreasing grit size [specify grit size/RPM/time]. Subsequently, the specimens were rinsed under running water for 1 minute and, to standardize the initial condition, immersed in distilled water at 37 °C for 24 hours, simulating the rehydration that occurs during the first day of clinical use of provisional restorations.

Figure 1 - Methodological flowchart.



Note: (01) Metallic mold with 12 circular cavities (Ø 10 mm; thickness 3 mm). (02) Filling of the cavities with provisional resins: self-curing acrylic (Duralay, Dencor) and bis-acrylic (Protemp, Primma Art). (03) Cylindrical specimens after polymerization and initial surface leveling. (04) Immersion of the specimens in the test solutions (cola soft drink and coffee) and in artificial saliva, according to the experimental times described in the text. (05) Surface roughness (Ra) measurement using a profilometer, with scanning performed on the polished surface of each specimen.
Source: Silva FCS, et al., 2026.

Experimental protocol and measurements

Three immersion media were evaluated: distilled water (control), coffee (prepared at a concentration of 100 g/L), and cola soft drink (commercial product, 350 mL can). The solutions were maintained at 37 °C throughout the experiment. After the initial hydration, the specimens were stored in an incubator at 37 °C and randomly immersed in the coffee and cola soft drink solutions for 7 days; the control group remained in distilled water for the same period.

Surface roughness

The average surface roughness (Ra, µm) was measured using a profilometer, on the Ra scale. For each specimen, orthogonal readings were taken along the x and y axes, and the final value for each time point was obtained by averaging the readings. Measurements were performed at two time points: baseline (immediately after polishing and hydration) and post-exposure, at the end of the 7-day period.

Statistical analysis

Data were subjected to two-way ANOVA, followed by Tukey's post hoc test for multiple comparisons, with a significance level set at $p<0.05$. The analyses were performed using Jamovi software (version 2.6). The estimated marginal means indicated a significant interaction between resin type and immersion medium ($p<0.001$).

RESULTS

According to the data, in the cola medium, the Primma Art resin exhibited significantly higher surface roughness compared with the other resins, while Dencor and Protemp showed intermediate values (Table 2). In contrast, in the artificial saliva, coffee, and dry conditions, no statistically significant differences were observed among the resins, indicating a more homogeneous behavior in these environments. These findings suggest that the immersion medium influences the surface performance of the resins, particularly in acidic solutions such as cola soft drinks, which tend to increase roughness in certain formulations. This interaction indicates that the effect of the immersion medium on surface roughness was dependent on the type of provisional resin evaluated, rather than being uniform across materials.

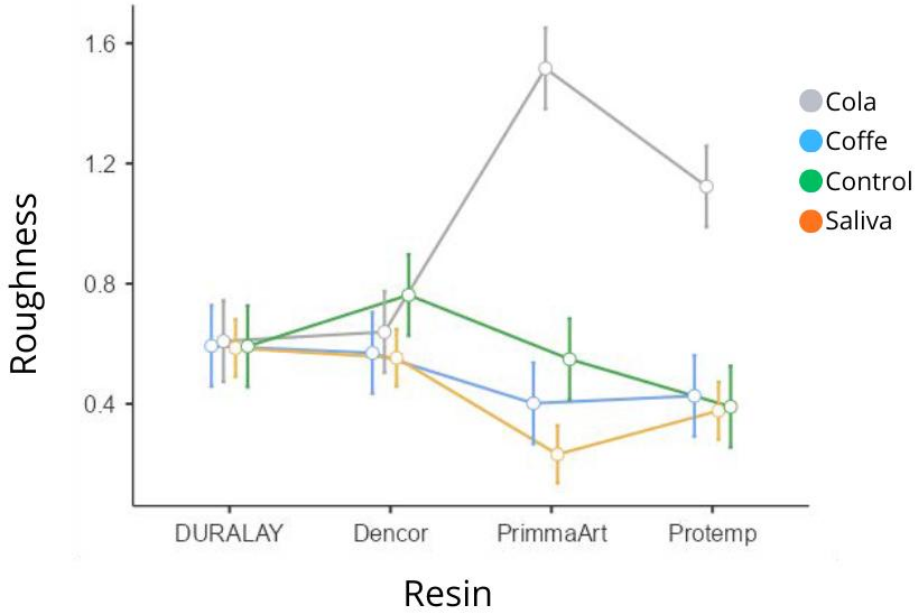
Table 2 - Means and statistical groupings (Tukey, p<0,05).

Medium	Resin	Mean	Comparison among groups
Coffee	Duralay	0.593	a
Coffee	Dencor	0.570	a
Coffee	PrimmaArt	0.402	a
Coffee	Protemp	0.426	a
Cola soft drink	Duralay	0.609	b
Cola soft drink	Dencor	0.639	b
Cola soft drink	PrimmaArt	1.516	c
Cola soft drink	Protemp	1.124	b
Saliva	Duralay	0.586	a
Saliva	Dencor	0.553	a
Saliva	PrimmaArt	0.232	b
Saliva	Protemp	0.377	ab
Control	Duralay	0.592	a
Control	Dencor	0.762	a
Control	PrimmaArt	0.549	a
Control	Protemp	0.391	a

Note: Different letters in the same row indicate statistically significant differences ($p < 0.05$) according to Tukey's test.
Source: Silva FCS, et al., 2026.

The graph of the estimated marginal (**Graph 1**) means illustrates the interaction between the factors "resin" and "immersion medium" on surface roughness. In general, roughness values remained similar among the resins in the coffee, artificial saliva, and dry (control) media, indicating stability under these conditions. This pattern indicates that, under non-aggressive or mildly acidic conditions, the evaluated provisional resins exhibited comparable surface behavior, regardless of material class. However, in the cola medium, a marked increase in roughness was observed for the Primma Art resin, followed by intermediate values for Protemp and Dencor, and lower values for Duralay. This behavior confirms the aggressive effect of the acidic cola medium on the resin surface, as evidenced by the deviation of the curve relative to the other conditions. When materials were compared by class, the bis-acrylic resin Primma Art showed a more pronounced roughness increase than the self-curing acrylic resins, whereas Protemp presented an intermediate response.

Graph 1 - Estimated marginal means.



Note: Comparisons based on estimated marginal means.
Source: Silva FCS, et al., 2026.

DISCUSSION

In clinical practice, it is widely recognized that provisional crowns play a fundamental role in rehabilitative treatment, as they contribute to the maintenance of function, aesthetics, and periodontal health, in addition to directly influencing the predictability and success of the definitive restoration.

Erosive tooth wear has significant impacts on oral and general health (SCHMIDT; HUANG 2022) Considering that oral rehabilitations commonly involve the use of provisional crowns fabricated from different acrylic and bis-acrylic resins, the present study was conducted in view of the need for materials that are resistant to acidic environments.

The hypothesis that acidic beverages would increase the surface roughness of provisional resins, with a more pronounced effect for cola soft drink compared with coffee, was partially confirmed. Among the materials tested, a significant increase in Ra was observed only for the bis-acrylic resin Primma Art after 7 days of exposure to cola, whereas coffee did not produce statistically significant differences. The data in **Graph 1** demonstrate a material-dependent interaction: Primma Art exhibited the greatest roughness increase in the cola medium, while saliva led to a reduction, particularly in bis-acrylic resin. The acrylic resins and Protemp showed only slight variation among the media, with coffee and control conditions remaining close to baseline values. Therefore, the answer to the guiding question is that the effect of the acidic medium is material-dependent, and susceptibility is not universal among provisional materials.

Among the acrylic resins (Duralay and Dencor), intragroup comparisons maintained the same level of significance across all conditions, indicating the absence of statistical differences. This behavior is consistent with studies showing that more effective polishing protocols (e.g., goat-hair brushes combined with diamond paste) tend to reduce roughness values (≈0.22–0.90 µm), whereas silicone points often maintain higher values (≈1.17–1.44 µm) (TUPINAMBÁ ÍVM, et al., 2018; MÂRȚU I, et al., 2022). Even though they remained stable, the evaluated acrylic resins exhibited Ra values > 0.2 µm, exceeding the threshold associated with increased biofilm retention, reinforcing the need for optimized and meticulous polishing procedures (BOLLEN CML, et al., 1997).

Among the bis-acrylic resins, divergent behaviors were observed. Primma Art showed a marked increase in Ra in the cola medium, suggesting a critically roughened surface, whereas Protemp exhibited no statistically

significant differences among conditions. These findings reinforce that specific formulations and polymer network structures may modulate the response to acidic environments even within the same class of materials (BARSZCZEWSKA-RYBAREK IM, 2019; MÂRȚU I, et al., 2022). Differences in cross-linking density and filler content/particle characteristics between bis-acrylics may explain Primma Art's greater susceptibility to acid-induced degradation or softening, while Protemp remained stable. This pattern aligns with previous findings showing that cola beverages tend to increase Ra in certain bis-acrylic and acrylic resins, whereas Protemp demonstrates smaller surface alterations, likely due to its higher filler content and lower water sorption (WAYAKANON P, et al., 2024; RIZZANTE FA, et al., 2025). The literature also reports softening of dimethacrylate-based matrices when exposed to acidic beverages, particularly those containing phosphoric acid, which helps explain the increased Ra observed in specific bis-acrylic formulations (XAVIER AM, et al., 2016).

The reduction in Ra observed in saliva may be attributed to two complementary mechanisms. First, aqueous plasticization of the dimethacrylate matrix occurs as water diffuses through the polymer network, increasing the distance between polymer chains, reducing modulus and stiffness, and facilitating surface rearrangement. This process may promote the smoothing of microasperities produced by finishing procedures or initial chemical attack, an effect well documented for resin-based materials exposed to water or artificial saliva due to sorption and solubility phenomena, even under prolonged immersion conditions (SIDERIDOU I, et al., 2003; FISCHER NG and APARICIO C, 2021). In addition, the formation of an acquired salivary pellicle on dental materials acts as a conditioning layer that alters surface energy and may partially mask microdefects, while also functioning as a diffusion barrier that reduces direct chemical interactions with the substrate. From a metrological standpoint, these effects may result in lower apparent Ra values after immersion in saliva (ALSHALI RZ, et al., 2015).

Cola soft drink solutions, in addition to their low pH, exhibit high titratable acidity and contain acidic components such as phosphoric and citric acids, which promote polymer solubilization and surface topographic alterations, often to a greater extent than coffee (BARBOSA et al., 2013; BITENCOURT SB, et al., 2020). In contrast, the surface stability observed for Duralay, Dencor, and Protemp differs from reports describing increased Ra values after prolonged acidic immersion. Such discrepancies may be attributed to differences in material formulation, degree of conversion, and finishing and polishing protocols, factors widely recognized as critical determinants of surface roughness (TUPINAMBÁ ÍVM, et al., 2018). From a biological standpoint, the maintenance of smoother surfaces is clinically desirable, as surface irregularities favor biofilm accumulation and may contribute to soft tissue inflammation (ANUSAVICE KJ, et al., 2013; HARALUR SB, et al., 2024), underscoring the clinical relevance of controlling surface roughness in provisional restorations.

Clinically, when the longevity of the provisional restoration is critical and there is a high consumption of acidic soft drinks, material selection should prioritize formulations with demonstrated surface stability, such as the tested acrylic resins and the bis-acrylic Protemp, which tend to exhibit smaller roughness changes under acidic conditions compared with other provisional materials, depending on the polishing protocol and composition (filler content/cross-linking) (CARVALHO TS and LUSSI A, 2020; WAYAKANON P, et al., 2024; RIZZANTE FA, et al., 2025). In parallel, dietary counseling is essential, reducing exposure frequency, favoring rapid ingestion, and limiting the intake of soft drinks and other low-pH beverages, as these are consistently associated with increased wear and surface alterations in both dental materials and hard tissues (BITENCOURT SB, et al., 2020).

As limitations, this study employed an in vitro model without reproducing salivary flow, acquired pellicle formation, thermal cycling, or abrasion from brushing/chewing, and the exposure was continuous (7 days), differing from intermittent consumption patterns. Furthermore, the evaluation included specific commercial brands, and the findings cannot be directly extended to all acrylic and bis-acrylic formulations available on the market. These aspects may explain discrepancies with previous studies and limit immediate clinical extrapolation. Future research should employ cyclic erosive–abrasive models, quantify titratable acidity, and assess the impact of different finishing/polishing protocols (and the use of surface sealants) across brands, in addition to integrating multiple outcome measures (Ra, microhardness, color/gloss, SEM/AFM) and short-term clinical validation.

CONCLUSION

Within the limitations of an in vitro model, this study demonstrated that the effect of acidic beverages on the surface roughness of provisional resins is material-dependent, thereby fulfilling the proposed objective of comparatively evaluating self-curing acrylic and bis-acrylic materials. Only the bis-acrylic resin Primma Art exhibited a significant increase in roughness after 7 days of exposure to a cola soft drink, whereas coffee did not promote statistically significant changes for any material, and the acrylic resins maintained surface stability under the tested conditions. These findings contribute to a better understanding of the differential behavior of provisional resin classes under acidic challenges and reinforce the clinical relevance of material selection and dietary guidance during the provisional phase. Nevertheless, the results should be interpreted considering the limitations inherent to an in vitro design, including continuous exposure conditions and the absence of mechanical and thermal challenges. Future studies should investigate cyclic erosive–abrasive models, additional surface properties, and clinical validation to further elucidate the long-term performance of provisional restorative materials.

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