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Influence of abrasive dentifrices on polymeric reconstructive material properties after simulated toothbrushing

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ABSTRACT

To assess the influence of dentifrices with different abrasiveness levels on the properties of dental reconstructive materials. Forty-eight cylinders were obtained from four polymeric materials, being two CAD/CAM acrylic resins (Ivotion-Dent and Ivotion-Base), one injected acrylic resin (IvoBase-Hydrid) and one light-cured resin composite (Empress Direct). Specimens were allocated to four subgroups for toothbrushing simulation according to the dentifrice relative dentin abrasivity (RDA) and silica content: (i) RDA 0 = 0%; (ii) RDA 50 = 3%; (iii) RDA 100 = 10%; and (iv) RDA 120 = 25%. Specimens were then subjected to toothbrushing. Surface analyses [surface roughness Ra (SR) and scanning electron microscopy (SEM)] along with hardness and optical properties [translucency parameter (TP) and contrast ratio (CR)] were evaluated before and after toothbrushing. Statistical analyses were performed using ANOVA and Tukey test. A significant increase in SR was observed after toothbrushing with higher RDA toothpastes for Ivotion-Dent (100 and 120) and IvoBase-Hybrid (120). Ivotion-Base and Empress Direct presented no significant differences in SR when analyzed as a function of timepoint and RDA levels. Hardness was not influenced by toothbrushing with different RDA dentifrices, except for Empress Direct with RDA 0 toothpaste, where a decrease in the hardness was observed. TP of Ivotion-Dent and Empress Direct significantly decreased after toothbrushing with higher RDA dentifrices and CR of Ivotion-Dent, Empress Direct and IvoBase-Hybrid significantly increased with higher RDA dentifrices. The levels of dentifrice abrasiveness affected differently the SR, hardness and optical properties of polymeric reconstructive materials after toothbrushing.

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Resin composite; acrylic resin; toothbrushing; surface roughness; hardness

1. Introduction

Among polymeric materials, resin composites (RC) and polymethyl methacrylates (PMMA) have been used for a wide range of applications in restorative and prosthetic dentistry [1,2]. Both materials are frequently combined in oral rehabilitation treatments due to its esthetic appearance, relatively easy-handling, repairability and cost-effectiveness [1]. However, polymeric materials are susceptible to changes in their chemical, physical and mechanical properties due to their exposure to the oral environment, which presents humidity, temperature/pH fluctuations and complex interactions with a wide variety of endogenous and exogenous substances [3–5].

Significant changes in material properties including increased surface roughness, pigmentation, volumetric changes and impaired mechanical properties have been reported in previous studies as consequences of the exposition of resins to the oral environment [6–9]. Additionally, the use of dentifrice with different compositions and abrasiveness levels, as well as toothbrushes with different stiffness have been shown to affect the properties of dental materials, and consequently, the stability of prosthodontic treatments in the long-term [10,11].

Toothbrushing is considered a three body abrasive wear process, where the toothpaste slurry acts as an abrasive medium that comes between the toothbrush and the tooth surface [12]. Therefore, toothpaste

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composition and abrasiveness are strictly related with the materials' surface deterioration [10, 13]. Along with dentifrice composition, the wear potential of toothbrushing depends on several factors, such as toothbrush stiffness, brushing techniques and individual brushing habits [14–17].

While resin-based materials present a polymeric matrix that provides favorable stress distribution and mechanical properties [18,19], the polymeric matrix is susceptible to continued abrasive wear and surface alterations [5, 7, 11]. In this context, it is well known that increased surface roughness facilitates bacterial adhesion, biofilm formation and could raise the risk for secondary caries and periodontal disease [20]. Moreover, a rougher surface has been correlated with an esthetically undesirable decrease in surface gloss of resin-based materials, which may compromise the longevity of esthetic treatments [21].

As CAD/CAM (computer-aided design/computer-aided manufacturing) technology has become progressively more accessible, a wide range of polymeric materials have become available for different clinical applications using digital workflows. Although conventionally made and CAD/CAM milled materials may present similar compositions, the differences in processing methods may have a significant impact in their overall properties and behavior in the oral environment [22]. Furthermore, conventional and CAD/CAM PMMA and RCs are frequently combined in oral rehabilitation treatments to replace missing teeth and to reestablish occlusal function. Therefore, it is paramount to assess the stability of these materials when subjected to physical and chemical agents that potentially affect their surface properties, which have a direct relation with their ability to preserve normal function and occlusal stability over time. Due to its polymeric nature, these materials may be subjected to abrasion, which may compromise the anatomy of the restorations and the stability of the occlusal function over the years [5]. Along with novel resin-based materials, there is a growing market of new dental care products with different compositions and clinical indications. Overall, indications have been related to chemical composition and RDA levels. The range of indications include daily care of natural teeth and reconstructive materials, implant-supported prostheses and to reduce inflammation promoting tissue healing [23–25]. Therefore, the effect of novel dental care products with different abrasive potential on reconstructive materials warrants further investigation.

The present study aimed to assess the influence of new dentifrices with different levels of abrasiveness on the surface roughness, mechanical and optical properties of different polymeric materials after toothbrushing simulation. The postulated null hypothesis was that there would be no significant differences in the surface roughness (Ra), mechanical (HV) and optical properties (CR and TP) of polymeric materials before and after toothbrushing simulation regardless of the dentifrice abrasiveness levels.

2. Materials & methods

The materials used in this study, manufacturers, shade and composition are shown in Table 1.

2.1. Specimen preparation

Four dental materials were used in this study, two CAD/CAM acrylic resins (Ivotion-Dent and Ivotion-Base), one injected acrylic resin (IvoBase-Hybrid) and one light-cured resin composite (Empress Direct) from the same manufacturer (Ivoclart, Schaan, Liechtenstein). To prepare the specimens, the CAD/CAM materials (Ivotion-Dent and Ivotion-Base) were milled from their respective pucks into eight cylinders (∅: 3 mm; height: 20 mm). For the injected acrylic resin (IvoBase-Hybrid), eight wax cylinders (∅: 3 mm; height: 20 mm) were fabricated and flasked using injection-mold flasks and boiled out. IvoBase-Hybrid was then injected using the IvoBase Injector system and cured according to the manufacturer's instructions.

Subsequently, the CAD/CAM and injected acrylic resin cylinders were sliced using a slow-speed diamond saw (Extec Corp, Enfield, CT, USA) in a precision water-cooled machine (IsoMet 1000; Buehler, Lake Bluff, IL, USA) to obtain cylinders (∅: 3 mm; thickness: 3 mm) ($n = 48$/group).

For the resin composite material, 48 cylinders were prepared by a single operator using a metallic matrix (∅: 3 mm; thickness: 3 mm). A single increment of resin composite was inserted into the matrix using a stainless-steel spatula (Suprafill #1; Duflex, Juiz de Fora, Brazil) and light-cured for 40 s using a LED device (VALO Corded; Ultradent, Utah, USA; 1000 mW/cm^2), as per manufacturer's instructions. Following light curing, the specimens were stored in distilled water at 37 °C for 24 h to complete the curing process.

One cylinder of each material (∅: 3 mm; thickness: 3 mm) was then grouped and embedded in an acrylic matrix (∅: 3 cm; thickness: 1.2 cm) as shown in Figure 1. The specimens surfaces were polished under water

Table 1. Manufacturers, shade, composition and lot number of the materials tested in the present study.

Product name	Manufacturer	Shade	Composition	Lot number
Ivotion-Base	Ivoclar, Schaan, Liechtenstein	Pink-V	Polymethyl methacrylate (PMMA) >90%; co-polymer, pigments	Z00J71
Ivotion-Dent	Ivoclar, Schaan, Liechtenstein	Multi-A3,5	Double crosslinked polymethyl methacrylate (PMMA)	Z00Y24
Ivobase-Hybrid	Ivoclar, Schaan, Liechtenstein	Pink-V	Powder: polymethyl methacrylate, citrate softener, initiator, pigments; liquid: methyl methacrylate, dimethacrylate, catalyst	NM0188
Empress Direct	Ivoclar, Schaan, Liechtenstein	A1 enamel	Barium glass, mixed oxide, Ba–Al–fluorosilicate glass (78.1%); dimethacrylate (21.5%); catalists and stabilizers (0.4%); pigments (<0.1%)	Z03SFN
Dentifrice RDA 0	N&W Dental Care, São Paulo, Brazil	–	Hyaluronic acid (HA); green tea extract (*Camellia sinensis*); DSBC – dimethylsilyl salicylate; tetrasodium pyrophosphate	–
Dentifrice RDA 50	N&W Dental Care, São Paulo, Brazil	–	Hydrated silica – RDA 50; fluoride – NaF + MFP – 1500 ppm; hyaluronic acid (HA); green tea extract (*Camellia sinensis*); DSBC – dimethylsilyl salicylate; tetrasodium pyrophosphate	L218002
Dentifrice RDA 100	N&W Dental Care, São Paulo, Brazil	–	Hydrated silica – RDA 100; hyaluronic acid (HA); green tea extract (*Camellia sinensis*); DSBC – dimethylsilyl salicylate; tetrasodium pyrophosphate	L218001
Dentifrice RDA 120	N&W Dental Care, São Paulo, Brazil	–	Hydrated silica – RDA 120; hyaluronic acid (HA); green tea extract (*Camellia sinensis*); DSBC – dimethylsilyl salicylate; tetrasodium pyrophosphate	L218003

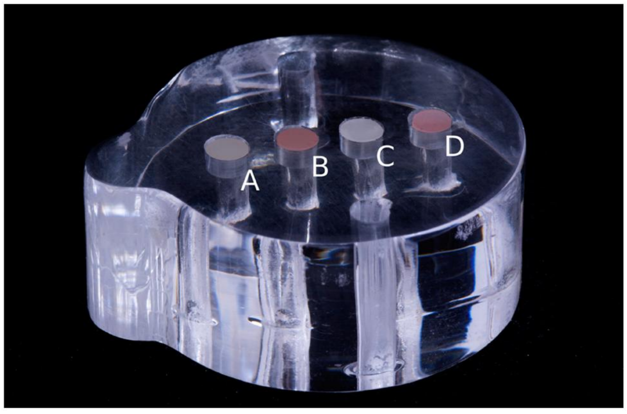

Figure 1. Cylinders (3 × 3 mm) of the experimental materials. (A) Ivotion-Dent, (B) Ivotion-Base, (C) Empress Direct and (D) IvoBase-Hybrid placed in custom-made transparent acrylic resin for toothbrush simulation after surface polishing.

cooling with 1200-, 2500- and 4000-grit abrasive papers and a monocrystalline suspension with a particle size of 1 µm (MetaDi Monocrystalline suspension; Buehler, Lake Bluff, USA) [7]. The specimens were randomly allocated in four subgroups ($n = 12$) for toothbrushing simulation according to the relative dentin abrasivity (RDA) and silica content of the dentifrices as follows: (i) RDA 0 = 0% of silica; (ii) RDA 50 = 3% of silica; (iii) RDA 100 = 10% of silica and (iv) RDA 120 = 25% of silica.

2.2. Simulated toothbrushing

All specimens were subjected to toothbrushing simulation in a brushing machine (Biopdi®; Sao Carlos, Brazil) using soft brushes (N&W Dental Care; Ribeirão Preto, SP, Brazil), and dentifrice slurries (N&W Dental Care) with 0, 50, 100 and 120 RDA (1:3 water, 15 ml/specimen, 37 °C) under standardized velocity (3 linear movements/s) and load (200 g), as described previously [26]. In brief, soft brushes were coupled in separate arms of the brushing machine perpendicular to the material surface and parallel to each other. Each reservoir of the toothbrushing equipment was filled with slurry ($v = 12$ ml) according to the group, and specimens were brushed for 72,000 cycles during 10 h. This duration may correspond with the amount of toothbrushing that is carried out over a period of 6 years, when considering the average brushing frequency of twice daily for 10 s on a pair of premolar or molar teeth [7, 10]. The surface roughness, surface analyses, mechanical and optical properties were assessed at baseline and after completion of toothbrushing simulation.

2.3. Surface roughness

Five equidistant surface scans of each specimen were performed (2.5 mm of reading, 250 µm apart) using a contact profilometer (Mahr Perthometer; Göttingen, Germany) to determine the Ra roughness parameter (arithmetic mean of absolute values of peaks and valleys measured from a median plane) with 0.8 mm cut-off. The mean Ra for each specimen ($n = 12$) was calculated before (immediate) and after (final) toothbrushing simulation on the same specimen.

2.4. Surface analysis

Qualitative analysis of the surface of a representative specimen of each group was performed before and after the simulated toothbrushing through scanning electron microscopy (SEM; VEGA3, Tescan, Brun, Tchequia). The specimens were gold-sputtered in low-pressure atmosphere (Polaron SC 7620 Sputter Coater; Quorum Technologies, Newhaven, UK) and evaluated by a secondary electron detector under high-vacuum mode, at 5 kV accelerating voltage and 10,000× magnification.

2.5. Microhardness

The surface microhardness was measured based on the mean value of three Vickers impressions performed on the central surface of three specimens of each group in a Micro Vickers Hardness Tester (HMV-2; Shimadzu, Kyoto, Japan) with a load of 100 g and dwell time of 15 s. The indentations were performed to achieve a distance between the center of the impressions equal to four times the diagonal of the indentation. The Vickers hardness (HV) was obtained by dividing the load (g) by the indentation area using an optical microscope (40× magnification) and image analyzer software. The test was performed before and after toothbrushing simulation on the same specimen.

2.6. Optical properties

The contrast ratio (CR) and translucency parameter (TP) by color difference (ΔE_{00}) measurements were determined using parameters obtained by reflectance tests performed with a bench top spectrophotometer (CM 3700d Konica Minolta; Tokyo, Japan). Six specimens of each group were placed on black (b) and white (w) backgrounds cards for determining the reflectance values and CIE L*a*b* color coordinates with a wavelength of 400–700 nm.

CR is the property that measures the transparency or opacity of the material by the ratio of reflectance of the specimen on the black background (Yb) to the reflectance of the same specimen on a white background (Yw), which is given by:

$$\mathrm{CR} = \mathrm{Yb}/\mathrm{Yw}$$

TP, which defines the masking ability of the material, was obtained through the calculation of the color difference parameter CIEDE2000 (ΔE_{00}) of the reflectance tests of the specimens over the black and white backgrounds, according to the formula:

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{K_L\ S_L}\right)^2 + \left(\frac{\Delta C'}{K_C\ S_C}\right)^2 + \left(\frac{\Delta H'}{K_H\ S_H}\right)^2 + R_T\left(\frac{\Delta C'}{K_C\ S_C}\right)\left(\frac{\Delta H'}{K_H\ S_H}\right)\right]^{1/2}$$

where, $\Delta L'$, $\Delta C'$ *e* $\Delta H'$, correspond to the difference in lightness, chromaticity and hue for the specimens. R_T is a rotation function that accounts for the interaction between chroma and hue differences in the blue region. Weighting functions S_L, S_C *e* S_H adjust the total color difference for variation in the location of the color difference pair in L', a', b' coordinates, and the parametric factors K_L, K_C *e* $K_{H,}$ are correction terms for deviations from reference experimental conditions [27–29]. The test was performed in the specimens before and after toothbrushing on the same specimen.

2.7. Statistical analyses

Data from surface roughness (Ra), hardness and optical properties (CR and TP) were tabulated and subjected to descriptive analysis, normality and homoscedasticity tests. Data normality and homoscedasticity were confirmed using Shapiro–Wilk ($p > 0.05$) and Levene ($p > 0.25$) tests, respectively. Ra and hardness data were statistically evaluated using repeated measures analysis of variance following *post hoc* comparisons by Tukey test, at a significance level of 5%. CR and TP data were statistically evaluated using analysis of variance following *post hoc* comparisons by Tukey test, at a significance level of 5%. The statistical analyses were performed using SPSS software (IBM SPSS Statistics version 27, Armonk, NY, USA).

3. Results

3.1. Roughness

Mean and 95% confidence interval values of Ra as a function of the RDA level and timepoint are shown in Figure 2. The statistical analysis revealed a significant increase in surface roughness for Ivotion-Dent (100 and 120) and IvoBase-Hybrid (120) after toothbrushing simulation with toothpastes with a higher RDA ($p < 0.020$); however, all other pairwise comparisons were not statistically significant different. Ivotion-Base and Empress Direct presented no significant differences in Ra values when analyzed as a function of timepoint and RDA levels ($p > 0.05$).

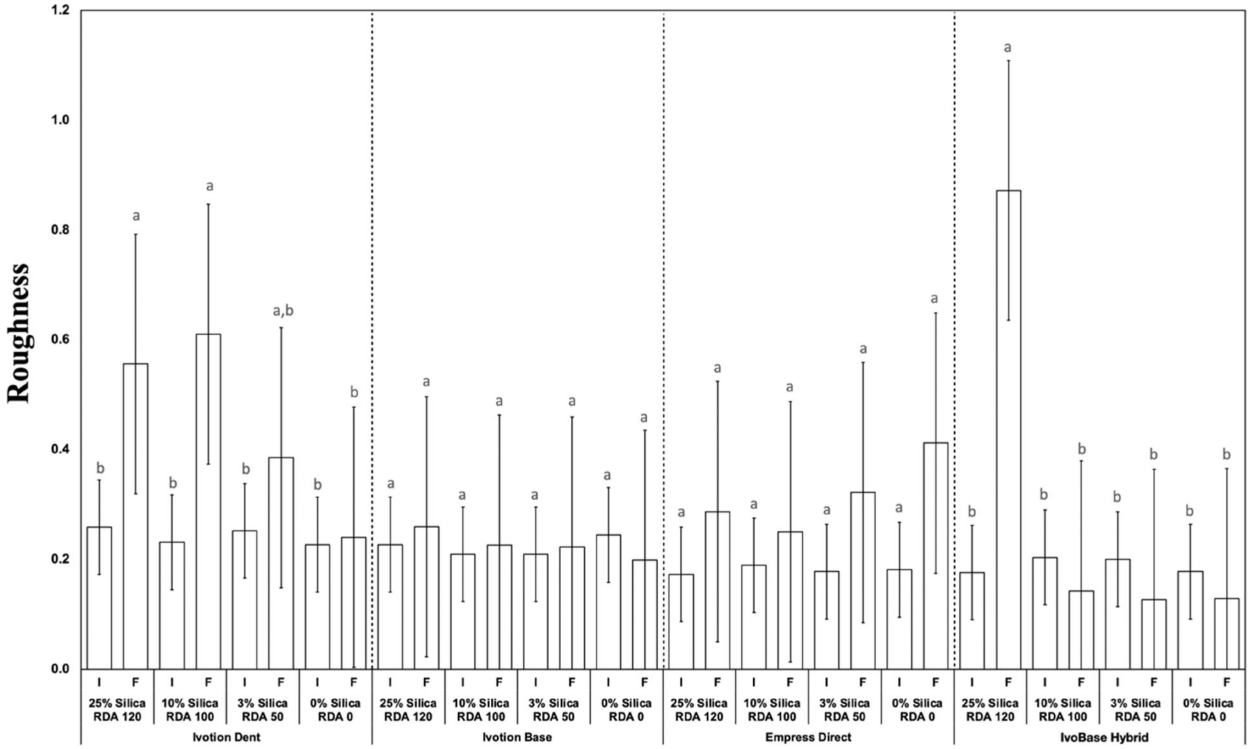

Figure 2. Mean and 95% CI for Ra surface roughness parameter of the tested materials as a function of RDA level and timepoint. *I: immediate; **F: final. ***Different letters represent significant statistical difference.

3.2. Surface analysis

Surface qualitative analyses of representative specimens through SEM imaging are shown in Figure 3. Irregular surfaces were observed in the SEM images of Ivotion-Dent after toothbrushing simulation with higher RDA dentifrices. The irregularities seem to increase proportionally with the RDA level. Images of Ivotion-Base and IvoBase-Hybrid depicted slight scratches and grooves, without notable alterations after testing with different dentifrices compared to the baseline images. Empress Direct presented smooth homogeneous surfaces with no significant modifications after toothbrushing.

3.3. Microhardness

Mean and 95% confidence interval values of microhardness as a function of the RDA level and timepoint are shown in Figure 4. Empress Direct presented the highest hardness, followed by Ivotion-Dent, IvoBase-Hybrid and Ivotion-Base before as well as after toothbrushing simulation, all statistically different from each other ($p < 0.004$). Hardness of the materials was not affected by toothbrushing simulation regardless of the dentifrice RDA except for Empress Direct with RDA 0 toothpaste ($p < 0.001$), where a decrease in the hardness was observed after toothbrushing simulation.

3.4. Optical properties

Mean and 95% confidence interval values of TP and CR as a function of the RDA level and timepoint are shown in Figures 5 and 6. Statistical analysis demonstrated that TP values of the tested materials were not significantly influenced by toothbrushing simulation with different RDA dentifrices, except for Ivotion-Dent and Empress Direct, which presented a decrease in TP values (Ivotion-Dent RDA 100, $p = 0.045$, and Empress Direct RDA 50–120, $p < 0.013$). Similarly, CR significantly increased by toothbrushing simulation with dentifrices with high RDA for Ivotion-Dent (RDA 100–120, $p < 0.028$), Empress Direct (RDA 50–120, $p < 0.002$) and IvoBase-Hybrid (RDA 100–120, $p < 0.046$).

4. Discussion

The current study assessed the effect of toothbrushing using dentifrices with different levels of abrasiveness on the surface roughness, optical and mechanical properties of different polymeric dental materials. Based on data analyses, significant modifications of

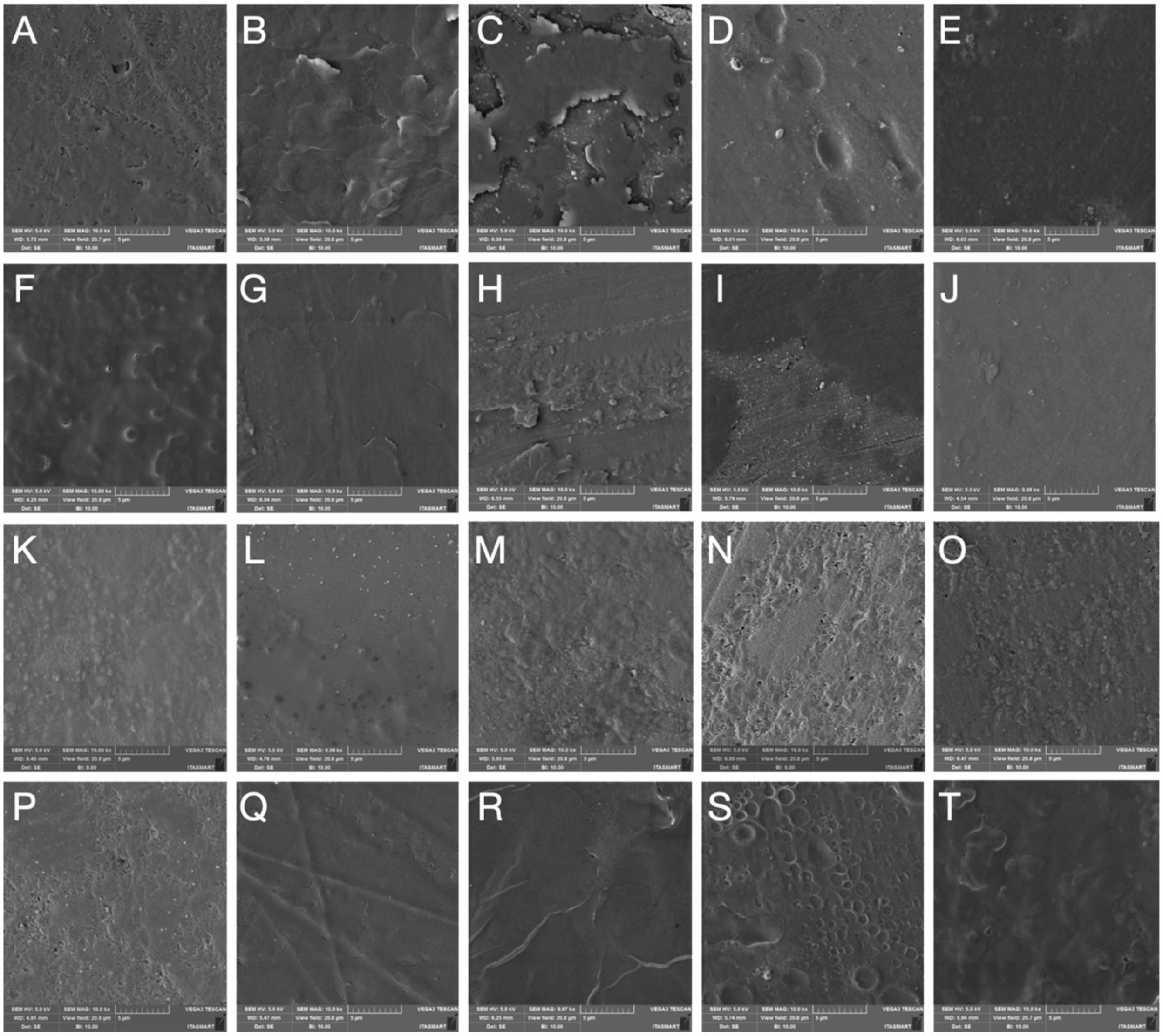

Figure 3. Representative SEM micrographs (10kx) of all tested groups. Ivotion-Base: A–E; Ivotion-Dent: F–J; Empress Direct: K–O; IvoBase-Hybrid: P–T. Different topographical patterns of the materials after toothbrushing for 72,000 cycles were observed as a function of dentifrice RDA. Baseline, RDA 0, RDA 50, RDA 100, RDA 120, from left to right, respectively.

the materials' properties were associated with toothbrushing using dentifrice with different RDA levels. Therefore, the postulated null hypothesis was rejected.

Dentifrice abrasiveness has been frequently related to the type and amount of abrasive agents in the toothpaste composition. Phosphates, carbonates and silicas have been frequently used in commercial dentifrices to enable the removal of soft deposits and extrinsic stains [30]. However, the abrasive capacity of dentifrices is required to be adequate to fulfill their cleaning purposes without damaging the integrity of the tooth structure. The literature reports a classification of toothpastes according to their RDA, into very low (RDA 0–20), low (RDA 20–40), moderate (RDA 40–60), strong (RDA 60–80) and very strong (RDA >80) abrasive toothpastes [31,32]. Considering this classification, the present study evaluated dentifrices from very low (RDA 0), moderate (RDA 50) and very strong (RDA 100 and 120) categories.

Toothpastes with diverse characteristics and compositions have been suggested for different clinical scenarios, such as control of periodontal diseases, post-surgical care, daily oral care or to provide a whitening effect [33,34]. However, information regarding the abrasivity of commercial dentifrices is not always available on the package to allow for an appropriate choice based on professional recommendations. In general, hydrated silica-based whitening toothpastes have been shown to present higher abrasive potential than conventional toothpastes [26]. According to the manufacturer of the dentifrices tested in the present study, the most abrasive

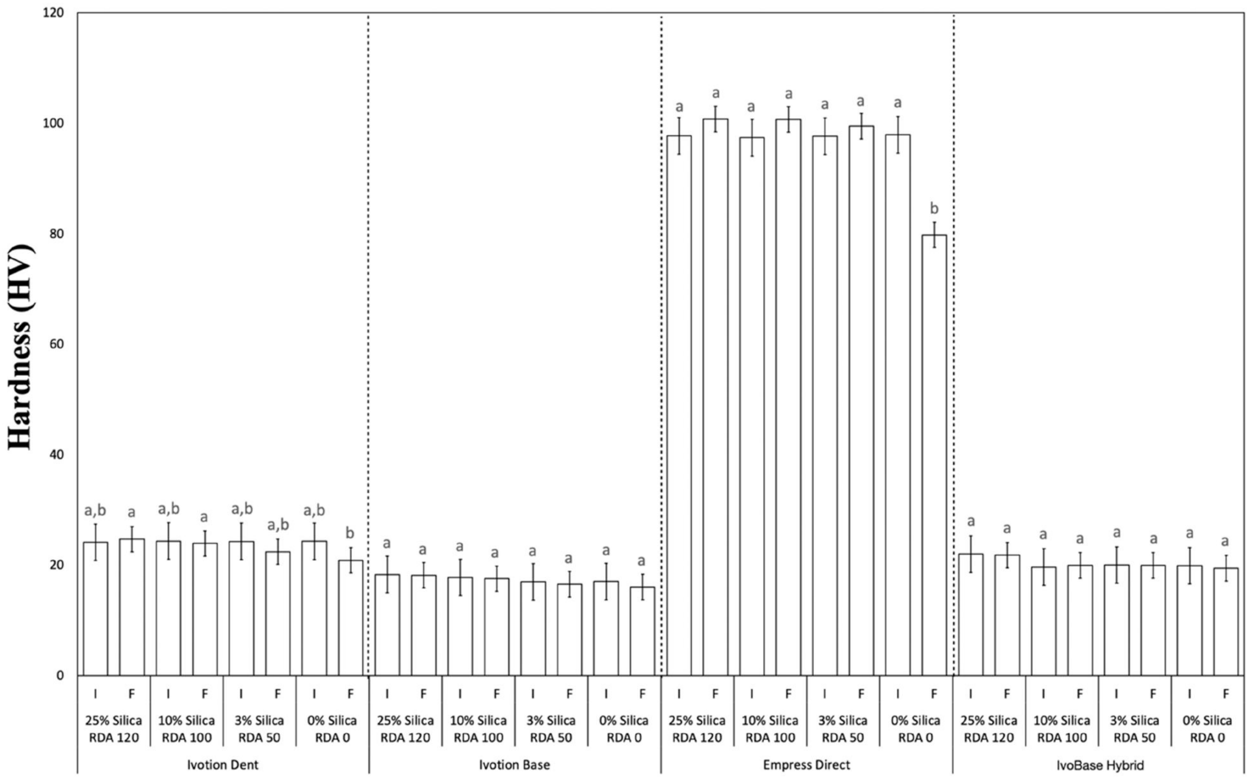

Figure 4. Mean and 95% CI for microhardness parameter of the tested materials as a function of RDA level and timepoint. *Different letters represent significant statistical difference.

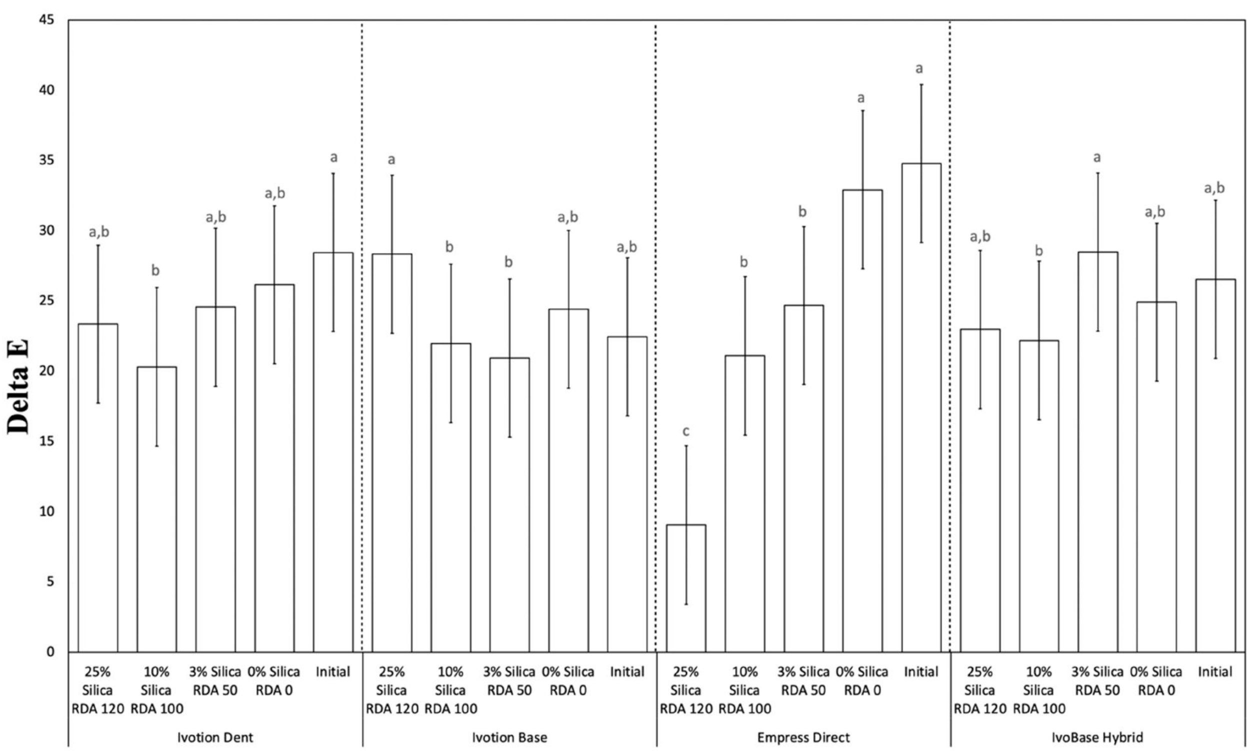

Figure 5. Mean and 95% CI for translucency parameter (TP) of the tested materials as a function of RDA level and timepoint. *Different letters represent significant statistical difference.

toothpaste (RDA 120) is indicated for post-surgical care; the medium abrasive dentifrice (RDA 100) is indicated for brushing natural teeth and implant-supported prostheses; and the lower RDA dentifrice

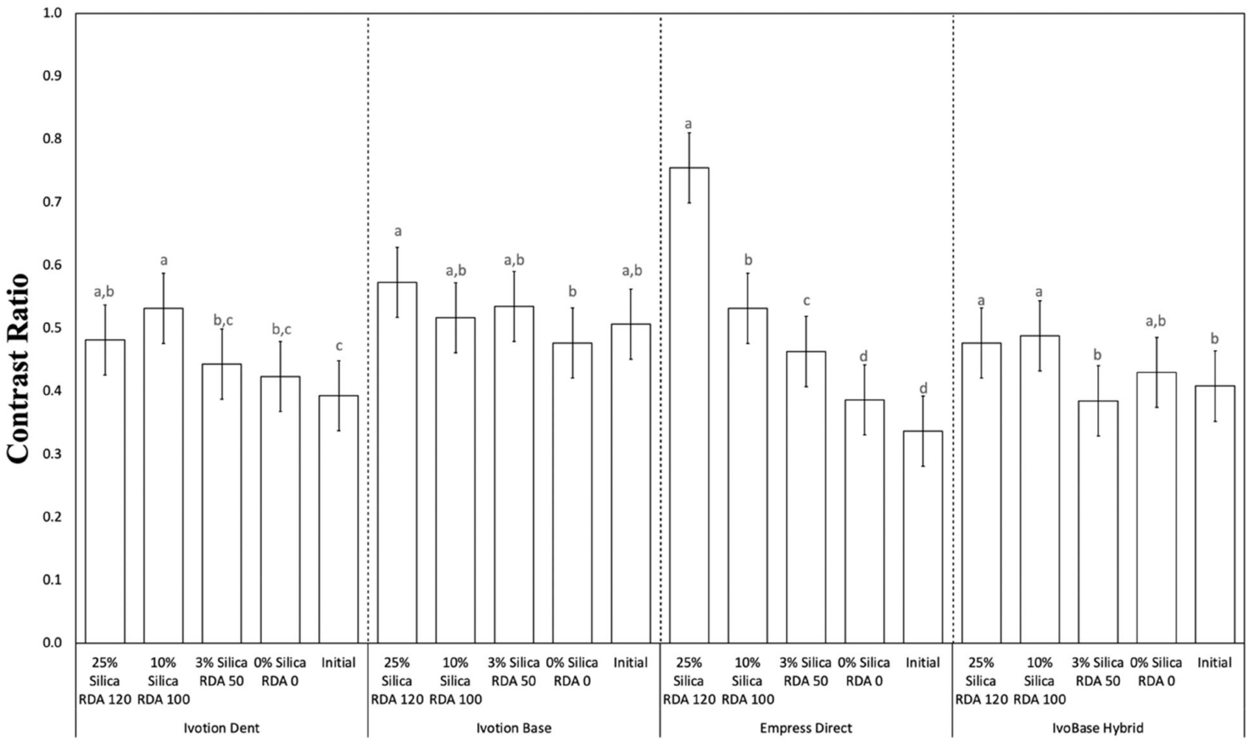

Figure 6. Mean and 95% CI for contrast ratio parameter of the tested materials as a function of RDA level and timepoint. *Different letters represent significant statistical difference.

(RDA 50) is indicated to clean resin composites, ceramics and for patients with severe loss of tooth structure. Nevertheless, the authors could not find strong clinical data that correlate dentifrice RDA with specific clinical recommendations, which warrants further investigations.

Surface roughness plays a significant role in the performance of resin-based dental materials, having a direct relationship with their esthetic [7], biologic [35] and mechanical behavior [6]. A mean roughness of 0.2 µm is considered a critical threshold for bacterial retention [20]. In the present study, Ivotion-Dent immediate presented surface roughness slightly above 0.2 µm (0.22 ± 0.02 µm). Moreover, the surface roughness of Ivotion-Dent, a CAD/CAM PMMA material and IvoBase-Hybrid, an injected acrylic resin, significantly increased in a direct relationship with RDA dentifrice level. Otherwise, the resin composite (Empress Direct) and the PMMA base CAD/CAM material (Ivotion-Base) presented no surface roughness modifications after simulated toothbrushing (final) regardless of the dentifrice RDA. These findings suggest processing method of the polymeric material to be a primary factor for surface roughness modifications after toothbrushing, where higher susceptibility to surface alterations were observed for the CAD/CAM PMMA material when highly abrasive toothpastes (RDA higher than 100) were utilized compared with the base PMMA material and resin composite. In contrast to the findings of this study, previous literature had reported lower surface roughness after toothbrushing for CAD/CAM PMMA in comparison to conventionally heat-polymerized PMMA [36]. Nevertheless, literature comparing these materials is scarce, and the significant differences in materials utilized as well as experimental protocols limit comparisons and warrants further investigations.

It has been suggested that changes in surface roughness of 0.25–0.5 µm can be detected by the tip of the patient's tongue [37]. In the current study, this perception threshold was reached when IvoBase-Hybrid and Ivotion-Dent were brushed with RDA 100 and higher than 100 dentifrices, respectively. However, it is noteworthy that the highly abrasive dentifrice is not recommended by the manufacturer for resin-based restorations.

Hardness is strictly related with the resistance to abrasion forces [38,39]. Lower values increase the material's susceptibility to abrasion and consequently to microcracks, jeopardizing the mechanical behavior and favoring bacterial adhesion [40]. Moreover, it is well known that materials that contain glass fillers are much harder than the ones comprised mostly of polymer matrix [41,42]. As expected, Vickers hardness evaluation demonstrated higher values for the resin composite compared with the PMMA materials. This behavior is explained by the high-volume filler load of Empress Direct (59 vol.%) that enhance its mechanical performance [43]. While a slight decrease in Vickers hardness was observed for almost all materials after toothbrushing simulation, the decreases did not reach statistically significant levels regardless of the dentifrice RDA, except for Empress Direct with RDA 0 toothpaste where decreased hardness was observed after toothbrushing simulation. It has been previously reported that brushing may cause a polishing effect, depending on the interaction among materials and the abrasive particles [44]. In the current study, however, toothbrushing with the dentifrice without abrasiveness resulted in increased surface roughness for Empress Direct. These results might be explained by the degradation of inorganic particles, which could predispose to filler dislodgment and elution [45], followed by the formation of surface and sub-surface microdefects that hampered the material hardness [46]. Overall, the hardness values observed for all tested materials were in agreement with published literature [47–49].

An increase in surface roughness is frequently related to a decrease in surface gloss due to the creation of defects that produce light scattering and facilitate superficial staining [12, 50]. In this study, the optical properties of Ivotion-Dent and Empress Direct presented a significant decrease in TP after toothbrushing simulation, while CR values significantly increased with high RDA toothpastes for Ivotion-Dent, Empress Direct and IvoBase-Hybrid. No difference was observed for Ivotion-Base compared to its baseline. Although no difference was observed for Empress Direct regarding surface roughness after toothbrushing, it seems that the brushing process had an abrasive effect, wearing the polymeric matrix and fillers, instead of removing them [51], thus promoting a polishing effect. Nevertheless, the interface between the matrix and fillers are susceptible to water sorption [52], and the hydrolytic degradation may have modified light scattering. These findings are in line with previous literature that showed optical property modifications in resin composites after simulated toothbrush with abrasive dentifrices [53–55]. Moreover, the roughness alteration of the acrylic resins, except for Ivotion-Base, may have affected the light dispersion, since abrasive toothbrushing can pluck out the filler particles, leaving voids that negatively affected the optical properties of the material [50, 56]. Therefore, it is recommended to follow the manufacturer recommendations and avoid the use of high RDA dentifrices on the surface of polymeric restorations. However, most toothpaste manufacturers do not refer to the RDA values [57], thus dental professional appointments and company RDA data are important for information and recommendations to patients.

Cleaning prosthetic materials is pivotal to prevent microorganisms proliferation and oral diseases [58]. Two methods are conventionally recommended, mechanical and chemical [59]. Mechanical techniques, including brushing with water, soap, toothpaste or abrasives and, chemical techniques are categorized based on their composition and mechanism of action, being hypochlorites, peroxides, enzymes, acids and mouth washes some examples [60]. A Cochrane systematic review concluded that there is a lack of suitable evidence to determine the efficacy of one cleaning method over another [61]; nevertheless toothbrushing is the most applied method by patients [62]. Toothpaste is a relatively inexpensive cleaning agent and is widely used. However, abrasive dentifrices are available on the market for different indications and, consumers should be careful when selecting these, as high abrasive toothpastes can scratch prosthetic materials, which can influence esthetics and the colonization of microorganisms [63]. The influence of chemical cleaning methods on the properties of the materials investigated in this study warrant further investigation.

It has been suggested that the total of 72,000 brushing strokes correspond to a period of 6 years of toothbrushing [7]. This correlation suggests that the tested materials will have high medium- and long-term clinical longevity if low abrasive dentifrices are used. In contrast, higher RDA toothpastes may produce significant alterations in the optical properties of resin composites and increased surface roughness in dental CAD/CAM PMMA materials in the mid-term. Therefore, periodical clinical follow-ups to assess the stability of the treatment, and polishing can be easily performed chairside to reestablish gloss and surface quality either for direct [64] or for prosthodontic treatments [65,66].

While toothbrushing simulation provides relevant insights on material behavior, the main limitations of the present study include the *in vitro* design that lacked complete oral simulation, such as pH fluctuations, temperature variations, occlusal loads and variations of force and bristles stiffness. Furthermore, in the oral environment, saliva and its buffering activity are present during abrasive challenges, which were not simulated in the present study. These factors may have a significant impact on material behavior and should therefore be considered in future investigations, as should the wear potential of the abrasive toothpastes.

5. Conclusion

Based on the findings of this *in vitro* study, the following conclusions were drawn:

- The CAD/CAM PMMA Ivotion-Base presented no significant alterations in SR, hardness and optical properties after toothbrushing with high RDA dentifrices.
- The surface, optical and mechanical properties of Ivotion-Dent, IvoBase-Hybrid and Empress Direct were affected differently after toothbrush simulation.
- Toothbrushing simulation with high RDA dentifrices decreased the translucency of Ivotion-Dent and Empress Direct.
- Toothbrushing simulation with high RDA dentifrices increased the contrast ratio of Ivotion-Dent and Empress Direct and IvoBase-Hybrid.

Author's contribution

L. F.de Carvalho: Conceptualization, Methodology, Investigation, Software, Formal analysis, Writing – original draft. L. M. M. Alves: Conceptualization, Methodology, Formal analysis, Resources, Writing – review & editing. E. T. P. Bergamo: Conceptualization, Methodology, Formal analysis, Resources, Supervision, Writing – review & editing. E. B. Benalcazar Jalkh: Conceptualization, Methodology, Formal analysis, Resources, Writing – review & editing. T. M. B. Campos: Methodology, Visualization, Resources, Formal analysis, Writing – review & editing. A. Zahoui: Methodology, Investigation, Data curation, Validation, Writing – review & editing. E. de S. Fermino: Methodology, Investigation, Data curation, Validation, Writing – review & editing. A. C. Magalhães: Conceptualization, Methodology, Validation, Supervision, Resources, Formal analysis, Writing – review & editing. T. L. Silva: Methodology, Visualization, Resources, Formal analysis, Writing – review & editing. P. G. Coelho: Conceptualization, Formal analysis, Methodology, Resources, Supervision, Writing – review & editing. E.A. Bonfante: Conceptualization, Formal analysis, Funding acquisition, Methodology, Investigation, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing.

Disclosure statement

The authors declare no conflict of interest.

Key message

This study highlights the importance of using an adequate dentifrice for each clinical situation to preserve the materials properties.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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