INTRODUCTION

Restoring the anterior dentition proves to be one of the greatest challenges in terms of esthetics in daily dental practice. The quest for esthetics by both patients and dentists has led to the continuous improvement of dentistry in terms of innovations, techniques in restorative, and rehabilitating materials to achieve restorations with an appearance closer to natural teeth. The characteristics of simulating dental structure, translucence, color, and surface smoothness have made resin composite as the first choice among the restorative materials used in dentistry. A constant search for improvements in the physical-mechanical and chemical properties as well as esthetics has been observed aiming resin composite development. Increasingly, composite are being placed in preference due to patient demands for esthetics as well as the clinical desire to do minimal preparation where possible and provide patients with bonded esthetic restorations. As a consequence, these resin composites are increasingly used as an alternative to porcelain-fused-to-metal crowns and ceramic veneers for the restoration of severely compromised anterior teeth. In this indication, not only color match, translucency and opalescence, surface gloss is also of paramount importance. Surface quality and wear resistance are important factors that determine their clinical success. A smooth surface can improve longevity and esthetics of restorations by reducing plaque accumulation and surface staining, allowing successful mimicking of the tooth’s natural appearance. Differences in gloss between a restoration and surrounding enamel are clinically relevant as the human eye can easily detect differences in gloss even if their colors are matched. Modern-resin composites can achieve a high luster if appropriate polishing procedures are used. Gloss is an attribute of visual appearance that originates from the geometrical distribution of light reflected by the surface and is directly influenced by the surface roughness. Previous studies that investigated the influence of toothbrushing on surface gloss and
surface roughness of resin composites showed a decrease in gloss and increase in roughness of various resin composites, as well as differences between the observed materials. Nevertheless, color stability, abrasive wear, and surface roughness remained to be of concern inherent to the material and researchers are unanimous to recognize that direct restorations performed with conventional composites undergo changes in color, wear, and surface roughness with time. The surface degradation due to mechanical and/or chemical interaction with the oral environment occurs because of several factors: Wear of fillers, degradation of the resin matrix, or weakening of resin-filler bonding. These three factors lead to a roughening of the surface which is the main cause of a gloss decrease. Clinically, this kind of superficial degradation can cause esthetic problems, especially in patients who present a high lip line.

EFFECTS ON WEAR OF COMPOSITE RESINS

A desirable property for a restorative material is the high resistance to wear that may clinically result from the centric and functional contacts, attrition of food bolus, interproximal contact areas and tooth brushing by the action of toothbrush and dentifrice. Wear is a complex process, since it involves abrasion, adhesion, fatigue, erosion and friction, which interact among themselves. Wear by tooth brushing occurs more commonly on the buccal surfaces of the teeth (Class V restorations), since these sites tend to receive a more intense action of tooth brushing. The abrasion resistance of a material can be evaluated through its mass loss and superficial smoothness, after a certain period of tooth brushing. Rough surfaces can lead to the increase of plaque retention and staining. The superficial texture can also influence the esthetical properties of composite resins, since it affects the light reflectance and the apparent shade of a translucent material. Due to the reduced filler content of flowable composites, it is assumed that they could present a lower resistance to toothbrush abrasion than the composites with a larger amount of fillers. According to Bayne et al., wear resistance is related to the interparticle space, as well as to the size and density of fillers. In the flowable composites, the interparticle space is reduced by the presence of small and joined fillers which protect the matrix, in spite of their volume percentage being of just 30–50% on average. Such fact could lead the flowable composites to present good results of wear. In his study, Bayne et al. did not observe statistically significant difference between flowable and traditional resins, all presenting a relatively low wear rate. Condon and Ferracane, Sulong and Aziz, and Suzuki et al. also suggested that small particles could provide some protection to the matrix against abrasion. This would happen because filler particles have a high modulus of elasticity and are abrasion-resistant, and when small enough, they can effectively reduce the spacing among them, which would protect the matrix. According to Aker, the size of filler particles can affect the resistance to abrasion and suggests that volume loss is caused by the combination of the removal of the matrix and the eventual dislodgment of some particles due to it and the big particles seem to hinder that removal. Mandikos et al. and Tanoue et al. observed that wear resistance of composite resins, could be influenced not only by filler content and size, but also by other factors such as matrix-filler interaction. Xie et al. assessed the wear resistance of glass-ionomer cements and observed that bigger glass fillers and a better-integrated microstructure contributed to a greater wear resistance. In a study about few chemically-cured resins with different types of filler, it was observed that a microfilled resin showed the greatest resistance to abrasion and presented the flattest surfaces after simulated toothbrushing. Gladys et al. found in their study a roughness value of 0.11 μm for Silux Plus after abrasion, which was statistically similar to the hybrid composite (Z100). Bayn et al. proposed that the protection supplied by the micro fillers to the matrix can be endangered if they are agglomerated, increasing the real inter particle spaces, and decreasing the effective resistance of the material. Similar to the study, Manhart et al. observed a significant correlation between depth of wear and mean of surface roughness of some indirect composite resins after toothbrushing. These studies also suggested that the differences in wear, hardness, and surface roughness could occur due to differences in the chemistry or in the light-curing method.

EFFECTS ON SURFACE ROUGHNESS OF COMPOSITE RESINS

In the oral cavity, surfaces of restorative materials are subjected to a multiple factors that alter the quality of the restorations with oral hygiene procedures playing a significant role. While toothbrushing with fluoridated toothpaste helps decrease the incidence of caries, the frequent use of prophylactic home procedures may have side effects of rough surface of restorative materials and dental hard tissues, thereby enhancing bacterial growth. Direct restorations especially those which cover the labial/buccal aspects of the tooth, such as Class IV/Class V fillings are more affected by toothbrushing in comparison to Class II fillings. The occlusal parts are more influenced by the interaction with the antagonist and food items during chewing than by toothbrushing. In indirect restorations such as
crows and bridges, the whole buccal or oral part is subjected to toothbrush/toothpaste interaction. During toothbrushing, the toothpaste is quickly diluted by saliva; in experiments in vitro, this effect is simulated by diluting the toothpaste with distilled water. However, the special properties of saliva, which contains specific proteins and ions that may diminish the roughening effect of the toothbrush, cannot be simulated. Besides brushing, other interventional procedures, such as finishing and polishing of dental restorations, pressing of materials against metal or acrylic matrices and professional tooth cleaning devices, influence the surface roughness, which is dependent on the material and kind of intervention. Increasing roughness is correlated with increased deposition of plaque and roughness is a determining factor for staining. The clinical significance of the surface roughness of restorative materials can be understood by their influence on perceived esthetic appearance of the restoration (discoloration and wear), recognized by both the dentist and patient and also the biological consequences regarding periodontal health, especially the occurrence of gingivitis, and the development of secondary caries that requires examination.

In vivo studies on the threshold surface roughness for bacterial plaque retention showed that a mean roughness above 0.2 µm was related to a substantial increase in bacterial retention. On the other hand, increased surface roughness accelerates the wear of dental materials. For enamel-enamel contact areas, a mean roughness of 0.64 µm has been found on replicas from longitudinal clinical studies. With regard to the effect of toothbrushing procedures on dental materials and dental hard tissues, most studies investigate wear after toothbrushing. The roughness of dental materials is mostly evaluated in combination with prophylactic pastes and different polishing agents. In 1991, Willems et al. reported on surface roughness after toothbrush simulation of 70 composite materials that were available at that time; more than 70% of those materials had a mean roughness after tooth brushing of more than 0.2 µm and 40% of them had a mean roughness of more than 0.64 µm. However, from these 70 composites, only seven are still on the market today. Unfortunately, this study did not include an evaluation of roughness before simulated toothbrushing, therefore making it impossible to assess the difference in roughness caused by simulated tooth brushing.

According to Gusmão et al., the main cause factor of abrasion is not limited to the type nor quantity present in the dentifrice, however, the physical characteristics of the mineral as the size and the shape of the particles. Silica, for example, when used in fine particles with regular shapes, preserves its mild abrasivity mineral characteristic, but is highly abrasive when coarse and irregular particles are incorporated. Thus, only the gel or cream formula or type of abrasive agent present in the dentifrice is not sufficient to characterize its abrasivity to the tooth structures and composite resins.

Clinically proven relevant parameters for simulated toothbrushing were chosen for this study, a force of 170 g, 36,000 strokes of circular movements and an optimal polishing procedure were defined. With regard to the force applied by human beings during toothbrushing, a clinical study of 94 subjects revealed a mean toothbrushing force of 330 g, with a range from 140 g to 720 g; plaque removal, however, was not influenced by these forces coinciding with other studies.

Few studies used 350 g and 20,000 strokes, 200 g and 60,000 strokes, 500 g and 20,000 strokes or 200 g and 30,000 cycles. A comprehensive study evaluating 70 composites applied a force of 150 g, and the test ran for 3 h without counting the number of strokes. It may be assumed that higher forces result in a higher absolute roughness.

In a study by Tellefsen et al., the R₄ values for most of the composite materials increased between 1 and 6 h of brushing, indicating that the surface became rougher. This might be explained by the fact that when brushing on composite resin materials, it wears away leaving the large filler particles sticking up from the surface, coinciding with results from van Dijken and Ruiter. For Dyract, however, a lower R₄ value after 6 h of brushing than after 1 h brushing was found, indicating that the surface had become smoother. This was the case for brushing with two dentifrices (Pepsodent and Colgate) used in the study. An explanation for this can be that the micro filler particle content is such that no or very few filler particles have emerged.

The simulated toothbrushing abrasion is considered an established model in the literature, because it is an important in-vitro wear factor, able to simulate a clinical condition. According Sessons and Phillips, for each session of brushing, a patient performs approximately 15 cycles. Thus, maintaining an oral hygiene based on two daily sessions of brushing, 10,000 cycles are performed by the end of 1 year. In a study by Monteiro and Spohr, the brushing time was statistically significant. The highest surface roughness mean was obtained after 20,000 cycles, the equivalent of 24 months of brushing (0.584 µm), differing statistically from 5000 cycles, equivalent to 6 months of brushing (0.297 µm) and 10,000 cycles, equivalent to 12 months of brushing (0.354 µm). This finding concurs with other studies.

In this study, a nanohybrid composite resin (Empress Direct) and a nanocomposite resin (Z350...
can remove the stains demonstrated no correlation between this wear and chemical degradation also affects gloss, consequently increasing the extrinsic staining. In addition, the water sorption may cause softening of the resin matrix, degradation of resin, reduction of stain resistance, and changes in translucency. Moreover, external discoloration can be the result of dietary and smoking habits, bad oral hygiene, and adsorption or absorption of water-soluble stains throughout the resin matrix. Biofilm-covered resin restorations are susceptible softening caused by organic acids produced in biofilm, producing surface texture alteration and, consequently, may be liable to pronounced surface staining. Previous studies concerning color stability have shown that drinks and mouth rinses have varied degrees of staining effect on auto- and light-cured composite resin according to their composition and properties. Once staining has occurred, brushing with toothpaste, repolishing, and bleaching procedures can remove the stains partially or even totally. Polishing procedures, although remove material from the composite surface, can remedy highly stained composites. Finishing the composite surface with a celluloid strip can produce the smoothest composite surface, but this discolors composite surface more than a polished one. Therefore, it is recommended that composite resins should be finished and polished in the appropriate time because early finishing and polishing results in greater staining susceptibility. While studies have shown that the surface roughness of composite resins have a direct influence on susceptibility to staining, other studies have reported no correlation between surface roughness and staining susceptibility. The surface roughness of the composite is usually dictated by size, hardness, and quantity of load particles, which influence the mechanical properties of composites, the flexibility of organic matrix, hardness, and size of the abrasive. However, there is lack of studies to assess the influence of beverages in the color stability of composite resins associated to brushing.

Certain studies had similar conclusive findings. In terms of brushing, the resin’s affinity for stains is modulated by its conversion rate and physic chemical characteristics with water sorption rate being of particular importance. Other important factors affecting color stability are the surface roughness, surface integrity, finishing, and polishing techniques. In a study by Cesar and Regina, there was no difference in color stability between brushed and not brushed specimens, regardless of toothpaste used, showing that despite the greater roughness of the brushed specimens, did not result in color change. This fact can be justified because, although rough surfaces are discolored by adsorption of pigments, some studies demonstrated no correlation between surface roughness and staining.

**EFFECTS ON COLOR STABILITY OF COMPOSITE RESINS**

Color stability is the ability of any dental material to retain its original color. The oral cavity has a dynamic environment. With the continuous presence of microflora, saliva, and frequent intake of colored food (chromatogens), the color stability of an esthetic material may become compromised. The color stability of a resin composite is related to the resin matrix, dimensions of filler particles, depth of polymerization, coloring agents, and certain extrinsic and intrinsic factors. Intrinsic factors, such as the resin matrix of composites and incomplete polymerization, have a considerable influence on color stability. This is usually attributed to chemical degeneration of the filler-resin bond and solubility of the resin matrix. Besides the materials composition, the finishing and polishing procedures may also influence the composite surface quality and can, therefore, be related to the early discoloration of this material. The roughening of the surface caused by wear and chemical degradation also affects gloss, consequently increasing the extrinsic staining. In addition, the water sorption may cause softening of the resin matrix, degradation of resin, reduction of stain resistance, and changes in translucency. Moreover, external discoloration can be the result of dietary and smoking habits, bad oral hygiene, and adsorption or absorption of water-soluble stains throughout the resin matrix. Biofilm-covered resin restorations are susceptible softening caused by organic acids produced in biofilm, producing surface texture alteration and, consequently, may be liable to pronounced surface staining. Previous studies concerning color stability have shown that drinks and mouth rinses have varied degrees of staining effect on auto- and light-cured composite resin according to their composition and properties. Once staining has occurred, brushing with toothpaste, repolishing, and bleaching procedures can remove the stains partially or even totally. Polishing procedures, although remove material from the composite surface, can remedy highly stained composites. Finishing the composite surface with a celluloid strip can produce the smoothest composite surface, but this discolors composite surface more than a polished one.

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As a result of abrasion by brushing, as well as by the corrosive process (erosion), restorative materials can become rough and wear out. The presence of irregularities can influence the appearance, lead to surface discoloration, bacterial biofilm retention and gingival irritation, increasing the risk of caries and periodontal inflammation. As regards, the influence of brushing time on color stability, ΔE value did not change, except for the nano-filled resin composite, which exhibited higher ΔE values up to the third cycle of brushing for both dentifrices. It is known that the surface of the resin composite presents a higher resin content when photo polymerized under a certain pressure against smooth surface, such as the placement of a glass slide. With the increase in the number of brushing cycles, it is reasonable to believe that there was a gradual removal of this matrix-rich layer. This may have contributed to the color change of the nanofilled resin composite after the third cycle, in which the superficial staining may have been removed by wear. Some studies have shown that the type of monomer interferes in the level of water sorption of the resin composite leading to color change. Due to the low conversion levels of the TEGDMA monomer, it is predisposed to water sorption, increasing the solubility of the polymer formed between the polymer matrix bonds, causing deterioration of this structure and of the matrix/filler particle interface, resulting in greater color change. The higher the degree of water sorption of the resin composite, the lower the color stability, due to the increase in the free volume of formed polymer. Consequently, more space is available for diffusion of water molecules into the polymeric structure. This phenomenon is called composite plasticization and it causes softening of the polymer matrix, promoting a greater color change of the resin composite.

As regards the filler particles, resin composites with larger particles are more susceptible to water sorption and color change, a phenomenon explained by the weak bond in the matrix/filler interface, which is broken by water sorption, changing the manner in which light is dispersed by the particles. In addition, composites with low concentration of filler particles present higher ΔE values. Abrasion gradually removes the resin matrix from the filler particles of composites; the unsupported filler particles are easily eliminated, leaving a particle-free resin layer that is rapidly abraded and the process becomes continuous. However, the influence of the polymer degree of conversion and the volume ratio of filler in the matrix on the resistance to abrasion of resin composites. Since particle sizes of the agglomerated nanoparticle resin composites are smaller than 2 μM, the abrasion process is comparatively slower than for hybrid resin composite.

**EFFECTS OF TOOTHBRUSHING ON COMPOSITE RESTORATIONS MADE FROM COMPUTER-AIDED DESIGN/COMPUTER-AIDED MANUFACTURING (CAD/CAM) BLOCKS**

Toothbrushing is a primary factor affecting the surface roughness and gloss of restorations and is an example of three body wear. The bristles of the toothbrush act as an antagonist while the toothpaste slurry is used as the medium. Many studies have observed the effects of toothbrushing on the surface roughness and gloss of composite resins. However, there is scant information regarding the effect of toothbrushing on composite resin CAD/CAM blocks.

In dentistry, many different CAD/CAM blocks used in preparing restorations are available commercially, and their use has gained in popularity. Restorations prepared from CAD/CAM blocks offer uniform material quality, reproducibility, and low fabrication cost. There are numerous types of CAD/CAM blocks available including lithium disilicate glass ceramics, leucite-reinforced glass ceramics, feldspathic glass ceramics, aluminum-oxide and yttrium tetragonal zirconia polycrystals, composite resin, titanium, and titanium alloy. Currently, the demands for esthetics, shorter treatment time, and nonmetallic restorations from both dentists and patients are critical challenges for researchers trying to develop the best restorative material. The advantages of a composite resin block are that it is easy to polish and to mill, does not require sintering or crystallization firing, and is repairable in the mouth. Newly available CAD/CAM composite resin blocks are fabricated by high-pressure/high-temperature polymerization resulting in improved mechanical properties.

A study evaluating two-body wear, gloss retention, and surface roughness of CAD/CAM blocks found that all ceramic based, one nanocomposite, and two polymethyl methacrylate CAD/CAM blocks behaved similarly or better in terms of two-body and toothbrushing wear than natural enamel. Recently, the two-body and three-body wear characteristics of composite resin CAD/CAM blocks were evaluated using water and poppy seeds in vitro, and it was reported that all CAD/CAM block materials tested exhibited low wear compared to direct posterior composite resins.

The results of the present study by Krid et al. indicated that most of the composite resin CAD/CAM blocks were comparable or better to ceramic blocks in...
terms of Ra and gloss retention. The Ra values of the ceramic blocks and composite resin were <0.2 µm, at each measuring stage resembling the threshold limit of plaque accumulation proposed by Bollen et al.,[32] and also below 0.64 µm, which is the average roughness value of enamel.[33] This suggests that the surface roughness of all the CAD/CAD blocks evaluated after toothbrushing would not be susceptible to plaque accumulation and staining. Furthermore, differences in Ra can only be discriminated by patients when the difference is over 0.5 µm.[84] Restorations visually appear to be smooth when a surface has a roughness of <1 µm Ra.[85]

CONCLUSION

Toothbrushing also brings negative effects over a period of time whether done or not done appropriately to maintain oral hygiene on the surface of composite restorations. Various studies evaluating the effects of toothbrushing observed increased wear and surface roughness with increased brushing time and forces. In addition, the filler particle size and matrix-filler interaction along with dentifrice used and polishing methods post restoring and light-curing methods influence the properties of the composite resins compromising on surface roughness and gloss of the restorations over a period of time. The need to assess further on the methodologies to reduce the burden of external, internal factors including the oral environment and incorporating certain advantageous features in the composite resins is required for improving the quality and increasing the life span of composite resin restorations.

REFERENCES

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