ANA CAROLINA BOTTA MARTINS DE OLIVEIRA

Rugosidade superficial do esmalte e de resinas compostas: avaliação de instrumentos de acabamento e técnicas de polimento pelo Microscópio de Força Atômica

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Orientador: Prof. Dr. Sillas Luiz Lordelo Duarte Júnior

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SUMÁRIO

RESUMO

Oliveira ACBM. Rugosidade superficial do esmalte e de resinas compostas: avaliação de instrumentos de acabamento e técnicas de polimento pelo Microscópio de Força Atômica [Dissertação de Mestrado]. Araraquara: Faculdade de Odontologia da UNESP; 2007.

Resumo

O objetivo deste estudo foi avaliar o efeito de instrumentos de acabamento e técnicas de polimento sobre a rugosidade superficial de resinas compostas e comparar ao esmalte humano íntegro, através do Microscópio de Força Atômica (MFA). Superfícies planas da face vestibular de quatro incisivos centrais superiores humanos hígidos foram usadas para análise da rugosidade superficial do esmalte. Resinas compostas nanoparticulada (Filtek Supreme XT, 3M ESPE), microhíbrida (Point 4, Kerr Corp.), híbrida (Tetric Ceram, Ivoclar Vivadent) e microparticulada (Durafill VS, Heraeus Külzer) foram avaliadas. Todas as amostras de resinas compostas foram confeccionadas sob uma tira de poliéster. Os procedimentos de acabamento superficial foram realizados com uma fresa carbide de 30 lâminas e uma ponta diamantada de 30 µm nas amostras de resinas compostas nanoparticulada e microhíbrida. Quatro técnicas de polimento (T0: Matriz de poliéster – controle; T1: discos de óxido de alumínio; T2: disco de feltro + pasta diamantada; T3: discos de óxido de alumínio + disco de feltro + pasta diamantada) foram testadas em todas as amostras de resinas compostas. A rugosidade média superficial (Ra) foi avaliada pelo MFA no modo contato. Os dados obtidos foram submetidos ao Teste t de Student, à análise de variância e ao Teste de Tukey, ao nível de 5% de significância. A maior lisura superficial foi obtida com a matriz de poliéster para a Filtek Supreme XT (Ra=23,63nm), Point 4 (Ra=12,84nm) e Tetric Ceram (Ra=15,20nm). A resina Durafill VS foi menos rugosa com os discos de óxido de alumínio (Ra=43,05nm). A maior rugosidade superficial foi obtida com a ponta diamantada para Filtek Supreme XT (Ra=510,55nm) e Point 4 (Ra=531,64nm), sem diferença estatisticamente significante entre elas. A rugosidade superficial do esmalte foi de 46,55 nm. Com base nestes resultados pôde-se concluir que a rugosidade superficial aumentou significantemente depois dos procedimentos de acabamento. A fresa carbide produziu menor rugosidade que a ponta diamantada extra-fina. A pasta diamantada também aumentou a rugosidade das resinas compostas. Os discos de óxido de alumínio podem ser utilizados como técnica de polimento padrão para todas as resinas compostas, exceto para a resina híbrida. Para Tetric Ceram nenhuma das técnicas de polimento promoveu uma rugosidade superficial menor ou semelhante ao esmalte dental, exceto a matriz de poliéster.

Palavras-chave: Polimento dentário; microscopia de força atômica; esmalte dentário; resinas compostas.

ABSTRACT

Oliveira ACBM. Surface roughness of enamel and composite resins: evaluation of finishing instruments and polishing techniques by Atomic Force Microscopy [Dissertação de Mestrado]. Araraquara: Faculdade de Odontologia da UNESP; 2007.

Abstract

The aim of this study was to assess the effect of finishing instruments and of polishing techniques on surface roughness of composite resins and to compare to intact human enamel through Atomic Force Microscope (AFM). Flat buccal surface of four caries-free human maxillary central incisors were used for the roughness analysis of enamel. Nanofiller (Filtek Supreme XT, 3M ESPE), microhybrid (Point 4, Kerr Corp.), hybrid (Tetric Ceram, Ivoclar Vivadent) and, microfilled (Durafill VS, Heraeus Külzer) composite resins were evaluated. Mylar matrix strip was used as control group for both analyses. Finishing procedures were done with a 30-blade carbide bur and 30µm finishing diamond bur for nanofiller and microhybrid resins. Four polishing techniques were tested (T0: Mylar matrix – control; T1: aluminum oxide discs; T2: felt disc + diamond paste; T3: aluminum oxide discs + felt disc + diamond paste) in all composite resins. The mean roughness (Ra) was evaluated under AFM on the contact mode. The obtained data was submitted to Student´s t test, variance analysis (ANOVA) and, Tukey´s Test, at 5% level of significance. The smoothest surface was obtained with Mylar matrix associated with Filtek Supreme XT (Ra=23.63nm), Point 4 (Ra=12.84nm) and Tetric Ceram (Ra=15.20nm). Durafill VS showed the lowest roughness with aluminum oxide discs (Ra=43.05nm). The highest surface roughness was obtained with diamond bur for Filtek Supreme XT (Ra=510.55nm) and Point 4 (Ra=531.64nm), without significant difference between them. Surface roughness of enamel was of 46.55nm. Roughness increased significantly after finishing procedures. 30-blade carbide bur produced less roughness compared to extra fine diamond bur. Diamond paste also increased the roughness of composites. Aluminum oxide discs may be used as standard polishing technique for all composite resins, except for hybrid resin. For Tetric Ceram none of the tested polishing techniques promoted a similar or lower roughness to the dental enamel, except the Mylar matrix.

Keywords: Dental polishing; microscopy, atomic force; dental enamel; composite resins.

INTRODUÇÃO

Introdução

A valorização da estética na sociedade e o desenvolvimento de novas resinas compostas têm proporcionado o aumento da utilização deste material restaurador na prática clínica. Entretanto, a qualidade e a integridade da restauração podem ser comprometidas pela rugosidade superficial[1].

Superfícies rugosas contribuem para o acúmulo de placa bacteriana, detritos e corantes[11,15,18,21,22,35,37,38], que além de causarem irritação gengival[15,18,21,35,37,38] e risco de cárie secundária[15,21,37,38], diminuem o brilho da restauração[20] e tornam possíveis as descolorações e/ou degradações superficiais[11,15,18,21,22,35,37,38]. Além disso, a rugosidade superficial também afeta as propriedades mecânicas das resinas compostas, diminuindo a sua resistência e acelerando o seu desgaste[22,27].

A rugosidade superficial está relacionada à própria composição do material restaurador e aos procedimentos de acabamento e polimento executados pelo cirurgião-dentista. Quanto às características intrínsecas das resinas compostas, a rugosidade superficial é dependente da composição da matriz orgânica[19,22,25], tamanho[12,18,20,22,29,31,32], forma[12,20], dureza[22,32] e distribuição das partículas de carga[12,18,22,29,31,32]. O aumento da porcentagem de carga, modificação e redução do tamanho das partículas[12,18,20,22,29,31,32] e sua melhor distribuição na matriz resinosa[12,18,22,29,31,32] contribuem para melhorar a lisura superficial dos materiais restauradores e, conseqüentemente o resultado estético[22].

Os procedimentos de acabamento e polimento contribuem significantemente com a estética e a longevidade de restaurações diretas de resina composta[22,35,37]. Uma superfície altamente polida promove melhor conforto ao paciente[10], reduz o acúmulo de placa bacteriana[4,11,18,21] e alteração de cor da restauração[4,11,18,21]. Dessa forma, obter uma lisura superficial apropriada é um dos passos mais importantes para o sucesso de uma restauração[13,18].

Muitos estudos[3,11,13,16,18,19,23,25] têm demonstrado que a maior lisura de superfície é obtida com o uso da matriz de poliéster. Porém, nem sempre são possíveis clinicamente sua instalação e adaptação, principalmente em áreas de difícil acesso. Dessa forma, os instrumentos de acabamento e polimento tornam-se imprescindíveis para ajuste da restauração. O procedimento de acabamento tem como finalidade remover os excessos mais grosseiros[16,25,29,38], devolvendo a forma anatômica do dente[38], promover o contorno adequado e a adaptação marginal da resina composta[16,29], evitando a infiltração marginal e recidiva de cárie. O polimento é essencial para redução da rugosidade superficial e de fendas provenientes dos procedimentos de acabamento[22,25,29,38] e para obtenção de uma textura superficial semelhante ao esmalte do dente adjacente[14,16,19,29,31,38].

Diferentes instrumentos podem ser utilizados para acabamento e polimento de restaurações de resina composta como: fresas carbides[4,5,7,11,13,14,16,22], pontas diamantadas[4,5,7,13-16,18,22], borrachas[13,31,36], pedras[2,16], pastas[31,36] e, discos abrasivos[4,11,13,15,16,18,22,23,31,36].

Instrumentos de acabamento e polimento variam de acordo com a sua forma, flexibilidade do material de reforço, dureza do abrasivo e sua granulação[18]. Estes fatores além de serem determinantes na escolha do instrumento, influenciam a rugosidade superficial de uma restauração[18]. Diferentes instrumentos de acabamento e/ou polimento podem ser associados para produzir uma restauração com uma textura superficial ideal, lisa e brilhante semelhante ao esmalte dental[29].

A rugosidade superficial pode ser avaliada por diversos equipamentos como o Microscópio Eletrônico de Varredura (MEV)[13,14,16,21-23], rugosímetro[4,11,13,14,21-23,31] e o Microscópio de Força Atômica (MFA)[27,30,34,35]. Diferentemente dos demais, o Microscópio de Força Atômica fornece tanto dados quantitativos, como valores de rugosidade superficial, quanto dados qualitativos, como a imagem da superfície em duas e três dimensões, numa resolução nanométrica com detalhes precisos[28]. Entretanto, ainda poucos são os trabalhos que utilizam em sua metodologia este microscópio para análise da rugosidade superficial de materiais restauradores[27,30,35] e do esmalte dental[34].

Nesse contexto, torna-se importante avaliar o efeito de instrumentos de acabamento e técnicas de polimento sobre a rugosidade superficial de diferentes resinas compostas pelo Microscópio de Força Atômica. Além disso, se faz necessária a comparação das técnicas de polimento de diferentes resinas com a rugosidade superficial do esmalte íntegro.

PROPOSIÇÃO

Proposição

Esta dissertação de mestrado é composta por dois artigos científicos, descritos como capítulos, com os seguintes objetivos específicos:

1. Avaliar o efeito dos instrumentos de acabamento sobre a rugosidade superficial de resinas compostas através do Microscópio de Força Atômica. A hipótese nula testada é que não há diferença na rugosidade superficial de restaurações de resinas compostas submetidas a diferentes instrumentos de acabamento.

2. Avaliar a rugosidade superficial de resinas compostas submetidas a diferentes técnicas de polimento e comparar com esmalte dental humano íntegro, através do Microscópio de Força Atômica. Duas hipóteses nulas foram testadas: 1) Não há diferença na rugosidade superficial de resinas compostas nanoparticulada, microhíbrida, híbrida e microparticulada submetidas a diferentes técnicas de polimento; 2) Não há diferença na rugosidade superficial das resinas compostas submetidas a procedimentos de polimento em relação ao esmalte humano íntegro.

CAPÍTULO 1

Effect of finishing instruments on surface roughness of nanofiller and microhybrid composite resins

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Abstract

The aim of this study was to assess the effect of finishing instruments on surface roughness of composite resins by Atomic Force Microscope (AFM). A nanofiller composite resin (Filtek Supreme, 3M ESPE - F) and a microhybrid composite resin (Point 4, Kerr Corp - P) were selected. The finishing procedures were done with a 30-blade carbide bur (C) and 30µm finishing diamond bur (D). Standardized specimens were produced and assorted in six experimental groups (n=4) according to: (i) composite resin, (ii) absence of finishing (Mylar matrix - M), and (iii) finishing instrument (FM, PM, FC, FD, PC, PD). The mean surface roughness was evaluated by AFM and the obtained data was submitted to statistical analysis. FM and PM groups were assessed by the Student's T test, and FC, FD, PC, PD groups were submitted to variance analysis (ANOVA), both at 5% significance. The mean surface roughness values, in nanometers, were FM: 23.63 (b); FC: 283.88 (c); FD: 510.55 (d); PM: 12.52 (a); PC: 343.98 (c); PD: 531.64 (d). Roughness increased significantly after finishing procedures. 30-blade carbide bur produced less roughness compared to extra fine diamond bur. Microhybrid composite displayed less roughness than nanofiller composite in absence of finishing procedures.

Keywords: Surface roughness, nanofiller composite resin, microhybrid composite resin, finishing, Atomic Force Microscopy.

Running Heads: Effect of finishing instruments on roughness of composites.

Introduction

Polishing and finishing procedures improve esthetic and longevity of direct restorations of composite resin.[1,2,3] Rough surfaces contribute to bacterial plaque, debris and, staining accumulation.[1-8] Beyond the discomfort that affects the patient,[4] these factors may cause gingival inflammation,[2,3,5,6,7,8] secondary caries,[3,5,7,8] superficial staining[1-9] and, reduction of the restoration gloss[10]. Therefore, the superficial smoothness is one of the most important steps for the success of a restoration.[6,11]

Many studies[4,6,12,13] have demonstrated that polyester matrix deliveries a smoother surface than finishing and polishing instruments. However, the polyester matrix insertion and adaptation are not always clinically possible, mainly in areas of difficult access. Thus, finishing instruments becomes indispensable to improve the restoration margins, removing overhangs and producing appropriated countour.[3,12,14-17] Carbide burs,[1,4,11,12,14,18-20] diamond burs,[1,5,6,11,12,14,18-20] abrasive impregnated rubber cups and points,[3,11,15] abrasive strips, stones,[12,21] polishing pastes[15,22] and, abrasive discs[1,4,5,6,11,12,13,15,18,22] have been used for finishing and polishing of composite resin restorations.

Good results have been obtained with flexible discs of aluminum oxide, but its application is limited due to the complexity of the dental anatomy, principally on concave surfaces, such as lingual/palatal surfaces of anterior teeth and, occlusal surfaces of posterior teeth.[6,12,14,15] Consequently, the use of carbide burs and/or diamond burs becomes necessary.[6,14,15] However, finishing procedures utilized to remove the excess of restored material may generate an increase of the restoration's superficial roughness.[5,18]

The analysis of the surface roughness of composite resin restorations can be carried out with the Atomic Force Microscope (AFM). Both quantitative data as surface roughness of the specimen as well as qualitative data as the image of the surface, can be obtained in a nanometric resolution with precise details.[23] Meanwhile, there are few studies that utilize this methodology to analyze surface roughness of restorative materials.[2,9]

Therefore, it becomes important to evaluate the influence of the most utilized finishing instruments in the clinical practice regarding surface roughness of composite resins, using the AFM. The null hypothesis tested was that there is not difference in the surface roughness of composite resin restorations submitted to different finishing instruments.

Materials and Methods

Nanofiller (Filtek Supreme XT, 3M ESPE, St. Paul, MN) and microhybrid (Point 4, Kerr Corp. Orange, CA) composite resins were used (Table 1). Twenty four standardized specimens were prepared in stainless steel bipartite matrix with two circular orifices of 11 mm diameter and 2 mm thickness. The composite resin was inserted into the matrix using a composite placement instrument followed by the application of an artist sable brush.

A 10 mm width Mylar matrix strip followed by a flat glass slab were used to cover the specimen. A 1 kg stainless steel weight was applied for 30 seconds over the specimen allowing the composite to flow in order to obtain a smoother and standardized surface.[24] After this period, the weight and the glass slab were removed. An 11 mm diameter polymerization tip was applied directly against the Mylar matrix strip, and the specimen light-cured with a halogen light (Demetron Optilux 501, Kerr Corp). The light output was constantly monitored by a radiometer with average of 880 mW/cm^2. All the procedures were done according to the manufacturer's instructions.

Two finishing instruments were used (Table 2). Finishing procedures were accomplished using a standardized finishing device. The device was design to guarantee that after specimen removal, the surface would remain flat. The device consisted in a bipartite stainless steel matrix with central height regulation that avoided the finishing instruments contact with the matrix surface. The pressure during the finishing procedures was standardized in 2 kg.

The specimens were randomly assorted into 6 experimental groups (n=4) according to: (i) composite resin; (ii) absence of finishing (Mylar matrix – M) and, (iii) type of finishing instrument (control groups: FM; PM; experimental groups: FC; FD; PC; PD).

All the specimens, during their manufacturing, were notched on its reserve side by a groove to serve as an orientation for the finishing procedures. The finishing procedures were carried out perpendicular to the notch.[2] Each finishing instrument was utilized over a surface during a period of 15 seconds with constant refrigeration.[7,25]

After the finishing procedures, the specimens were washed with air-water spray during 5 seconds and, stored in distilled water at a temperature of 37ºC ± 1 for 24 hours.[9] Next, the specimens were ultrasonicated in deionized water[26] for 30 minutes, with the objective of removing any debris deposited on the surface.

The mean surface roughness was assessed by the Atomic Force Microscope (Nanoscope IIIa, Digital Instruments, Santa Barbara, CA) on the contact mode. The scanning of the specimen's surface was done, using the Si_3N_4 (NT model) probe. On the AFM contact mode, the 2D and 3D surface images of each specimen were acquired according to the scanner variations in x, y and z directions.[27]

The specimens were positioned on the AFM piezoelectric scanner to initialize the roughness readings. Two areas[2] were random selected and scanned in the same direction as the finishing procedures. Images of 20 µm X 20 µm of each selected area[26] were obtained and the mean roughness (Ra) calculated using the Nanoscope IIIa Software version 4,22 R2 (Digital Instruments).

FM and PM groups were statistically assessed by the Student's T test, at 5% level of significance. FC, FD, PC, PD groups were submitted to variance analysis at 5% level of significance. Aiming to check if there was homogeneity variance and normality on the experimental errors, the Levene's Test and the Shapiro-Wilk Test were performed.

Results

Table 3 displays the mean surface roughness value (Ra) in nm and the standard deviation of the experimental groups.

As the surface roughness significantly increased after the finishing procedures (more than 10 times over the mean), two independent statistic analyses were carried out. Considering the absence of finishing, the mean roughness of the Filtek Supreme XT (3M ESPE) was significantly higher than that of the Point 4 (Kerr Corp) ($p= 0.002$), (Figure 1).

The Levene ($p=0.304$) and Shapiro-Wilk ($p=0.746$) tests respectively proved the variances homogeneity and the normality of experimental errors for application of variance analysis ($p>0.05$). It was possible to notice a significant effect of finishing instruments on the surface roughness of the studied composites ($p<0.001$). The mean roughness values were smaller in the groups that utilized the carbide bur as a finishing instrument (FC and PC), in comparison to groups with diamond bur (FD and PD) (Figure 2). However, there was no significant statistical difference between both composite resins regarding surface roughness after utilizing the instruments.

Figures 3 to 8 correspond to superficial images of FM, PM, FC, PC, FD, PD groups, obtained through the contact mode of the AFM.

Discussion

The roughness of a restoration is directly related to the restorative material and to the finishing and polishing instruments.[6] The surface texture may vary according to conversion degree,[6] composite microhardness[1,15,17,28] and, resin matrix composition.[6] However, shape,[10,29] size,[1,6,10,15,17,28,29] quantity and distribution of the filler in the composite[1,6,15,17,28,29] plays an important role to the surface roughness. A smoother surface may be obtained by the arrangement of fillers within the resin matrix or by higher filler content composites.[1,6,17]

The control groups displayed the lowest mean roughness. Nevertheless, there was significant statistically difference between the tested composite resins in the absence of finishing. The microhybrid resin (Point 4 - Kerr Corp.) showed lower roughness than nanofiller resin (Figures 3 and 4). This fact may be explained by the consistency of the Point 4 (Kerr Corp.) filler size (400 nm). Filtek Supreme XT (3M ESPE) has fillers size ranging from 5 to 20 nm. These nanofillers are much smaller than the ones in Point 4 (Kerr Corp). However, nanoclusters of 600 to 1400 nm, which are present in Filtek Supreme XT (3M ESPE), might caused increase of the surface roughness. Silikas et al[9] obtained similar result when comparing the surface roughness of this nanofiller resin with a 200 nm filler size microhybrid composite.

Despite the higher surface smoothness obtained with the polyester matrix[3,10,16,17,30] in comparison with the finishing instruments, the roughness was not completely absent.[3] When using the polyester matrix, Point 4 (Kerr Corp) revealed a mean roughness of 12.52 nm and Filtek Supreme XT (3M ESPE) of 23.63 nm. The restorative surfaces were not free of imperfections due to the nature of the resin matrix[3] and, possible irregularities in the polyester matrix itself.[17]

Though, when a polyester matrix is not used the polymerization of the top composite layer is inhibiting by the oxygen.[12] This oxygen inhibit layer may result in a viscous surface, with possibility to deterioration, staining, and hydrolysis.[12] Some authors[4,11,12,13,17,28] recommend the removal of the oxygen inhibit layer using finishing instruments, aiming at a more resistant and, esthetically even surface. However, the use of finishing instruments may generate microcracks, voids within the resin matrix as well as along the filler/matrix interface, and subsurface defects.[6,19,31] Cracks which dimension larger than the visible light wavelength, may become perceptible to the human eye,[6] compromising the quality of an esthetic restoration. Therefore, cracks ranging from 50 µm or more[19] and increase of roughness[32] results in degraded surface and subsurface composite regions.

Finishing procedures of composite resin restorations may be achieved with various instruments. The most clinically used finishing instruments are: carbide burs and diamond burs.[13] Finishing diamond burs vary according to abrasive granulation, distribution and, shape.[12] The greater the abrasive granulation the rougher the surface obtained.[6] In order to be an effective diamond finishing instrument, the abrasives must be harder than that of the filler of the restorative material.[1,7] Carbide finishing burs may vary according to the number of blades.[18] Carbide burs with a higher number of blades produce a smoother and more even surface. The choice of the instrument may depend of composite resin used. For hybrid resins it is recommended the use of carbide burs and, for microfilled resins the diamond bur is the best finishing instrument.[12,20] Finishing instruments may be associated to produce a smoother surface.[14]

The surface roughness of the tested composites increased significantly after the finishing. No difference between Filtek Supreme XT (3M ESPE) and Point 4 (Kerr Corp) was found after the finishing procedures. However, a significant difference was observed in the roughness values between carbide and diamond finishing burs. Carbide bur produced a lower surface roughness independent of the utilized composite resin (Figures 5 and 6).[31] Diamond bur offered a higher cutting effectiveness, but resulted in a rougher surface than that of the carbide bur (Figures 7 and 8).[1,7,14,18,19,31]

Finishing instruments produced a rougher surface in comparison to the polyester matrix. Comparing the data to human dental enamel in occlusal contact areas (Ra=640nm) all the tested specimens showed an lower roughness.[33] However, roughness values higher than 250 nm (as the values obtained after finishing) may be detected by the patient[34] and lead to bacterial plaque accumulation.[29] Therefore, polishing procedures is also imperative for composite resin restorations.

High definition AFM images allow an accurate and realistic measurement of the surface roughness. AFM permits the exclusion of artifacts that may interfere the data analysis like: cracks, fissures and, porosity on the restoration surface.[22,32] Furthermore, AFM has the following advantages in comparison to the perfilometer and the SEM: highly precision and sensibility,[35,36,37] easier atomic magnifying level,[37] 3D image in nanometric resolution[37] and, absence of artifacts generated by specimen preparation.[37] Therefore, AFM is an appropriate instrument to analyze surface roughness of composite resins.

It may be concluded that surface roughness significantly increased after the finishing. Carbide bur resulted in lower surface roughness when compared to diamond bur, independent of the composite resin tested. There was no statistical significant difference between the composite resins regarding surface roughness after the use of finishing instruments. The microhybrid resin (Point 4, Kerr Corp) presented lower roughness than the nanofiller resin (Filtek Supreme XT, 3M ESPE), in the absence of finishing.

Acknowledgments

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Table 1 – Characteristics of the tested composite resins.

Material	Manufacturer	Classification	Composition	Average Filler Size	Shade	Batch
Filtek Supreme XT (F)	3M ESPE, St. Paul, MN, USA	Nanofiller	Bis-GMA Bis-EMA UDMA TEGDMA	5 to 20 nm with nanoclusters of 600 to 1400 nm	A2E	5BL
Point 4 (P)	Kerr, Orange, CA, USA	Microhybrid	Bis-GMA TEGDMA EBADMA	400 nm	A2	424008

Table 2 – Tested finishing instruments.

Abbr	Type of instrument	Characteristics	Manufacturer	Batch
D	Diamond bur #4219FF	Cylindrical with ogive top, extra fine granules (30 µm), 10 mm active point	KG Sorensen, Barueri, SP, Brazil	040107
C	Carbide bur #284	Cylindrical with ogive top, 30 blades, 10.4 mm active point	KG Sorensen, Barueri, SP, Brazil	051201

Table 3 – Mean Roughness (Ra) in nm and standard deviation of the experimental groups.

Groups	Ra	Standard Deviation
FM	23.63 ^{b}	3.00
FC	283.88 ^{c}	53.70
FD	510.55 ^{d}	66.35
PM	12.52 ^{a}	3.19
PC	343.98 ^{c}	127.03
PD	531.64 ^{d}	57.38

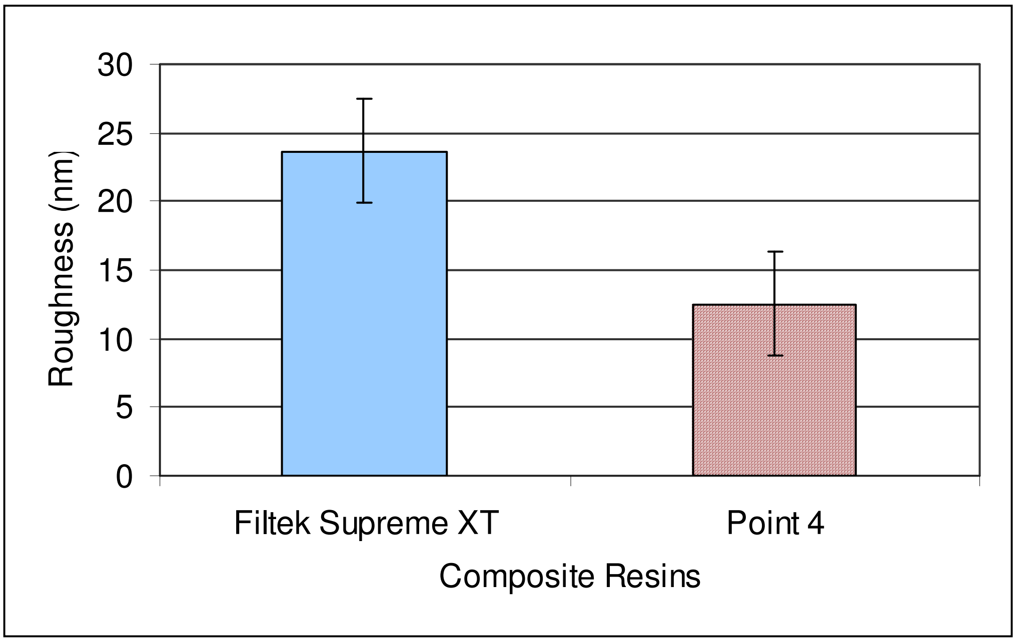

30
25
20
15
10
5
0
Roughness (nm)
Filtek Supreme XT
Point 4
Composite Resins

Figure 1

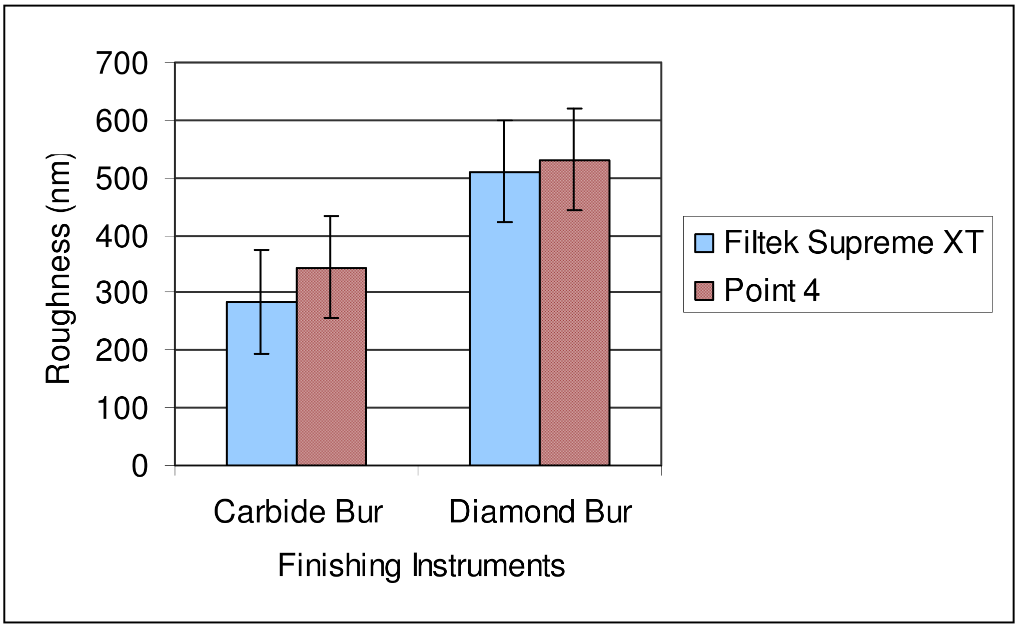

700
600
500
400
300
200
100
0
Roughness (nm)
Carbide Bur
Diamond Bur
Finishing Instruments
Filtek Supreme XT
Point 4

Figure 2

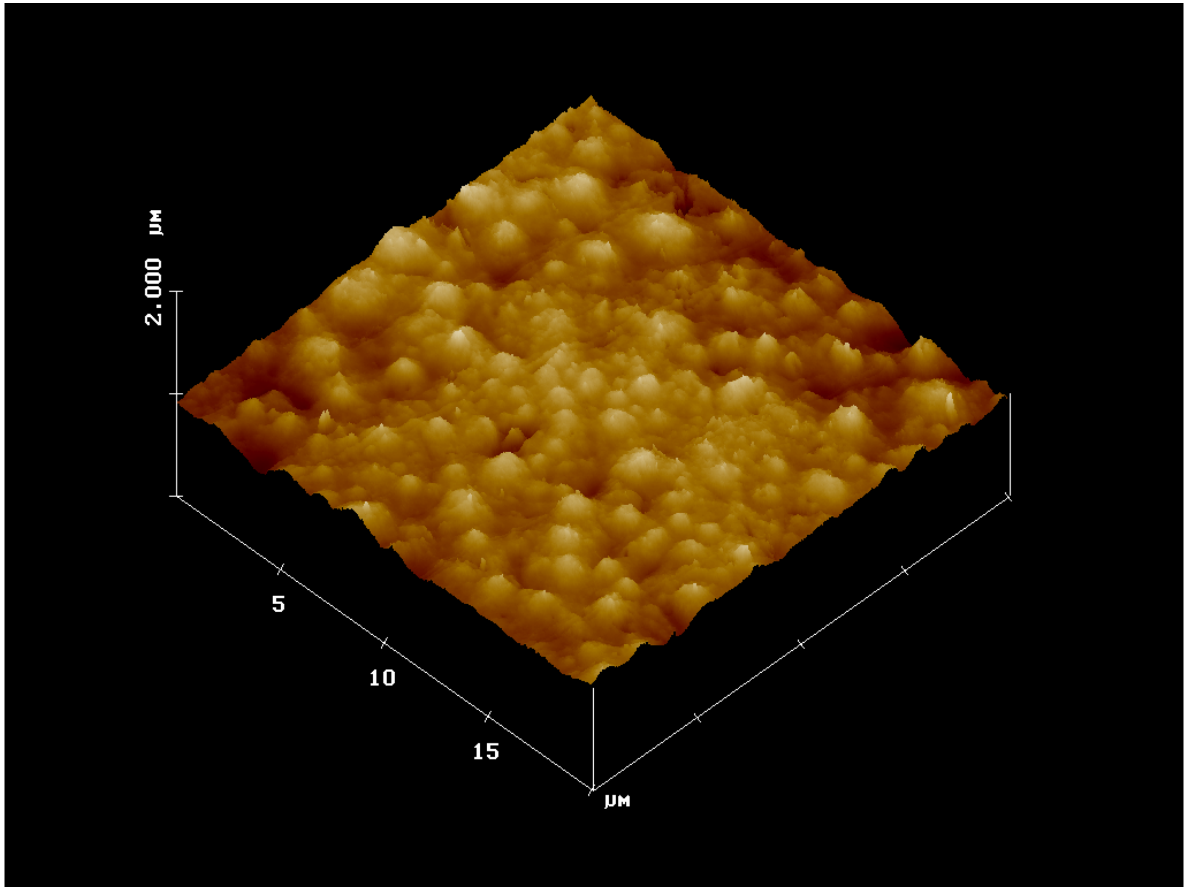


Figure 3

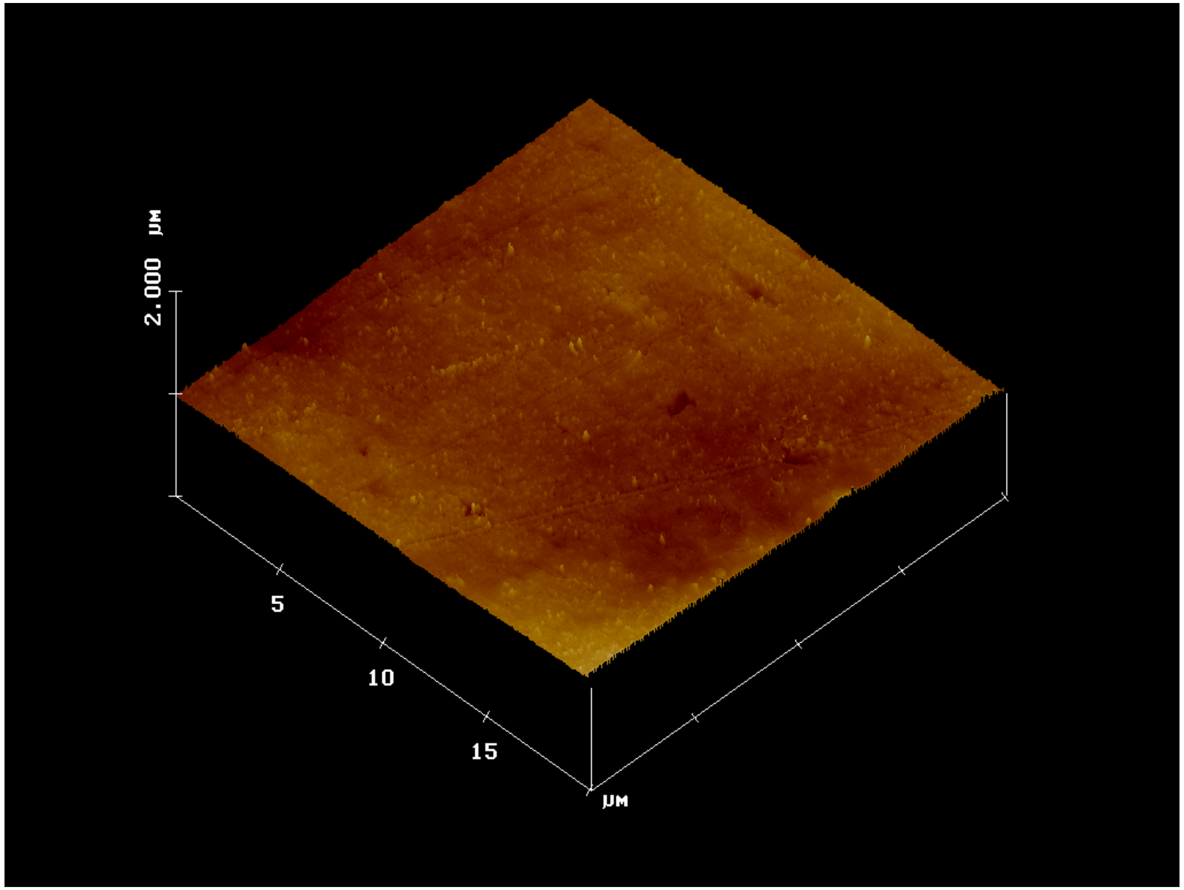
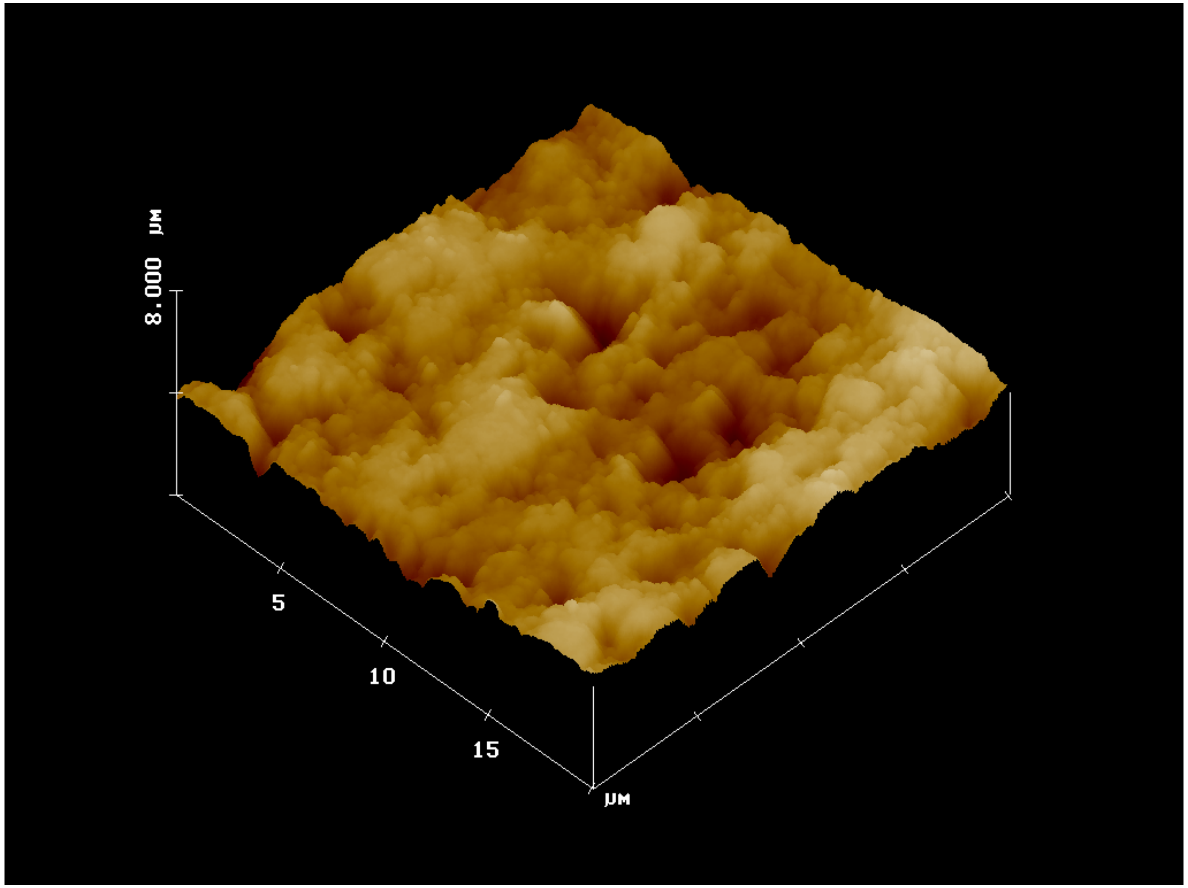


Figure 4



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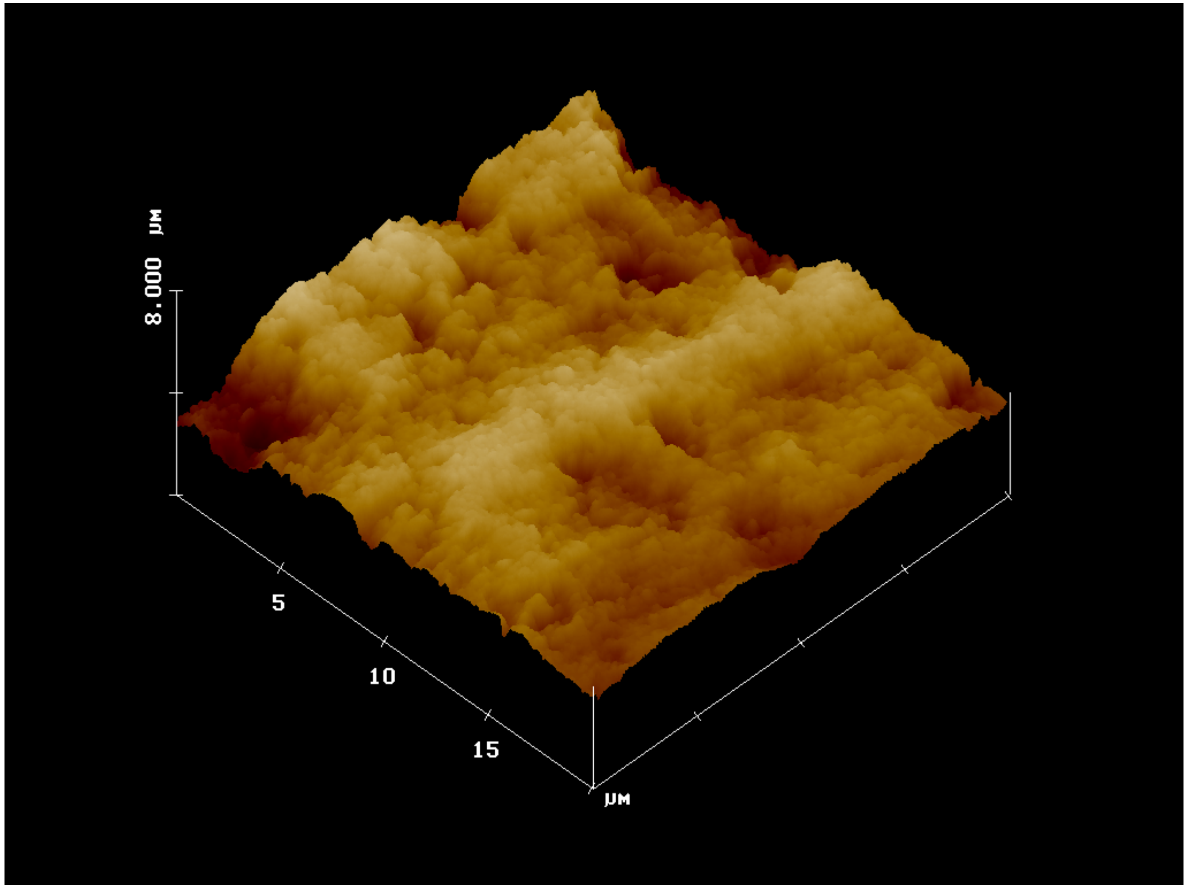

Figure 6

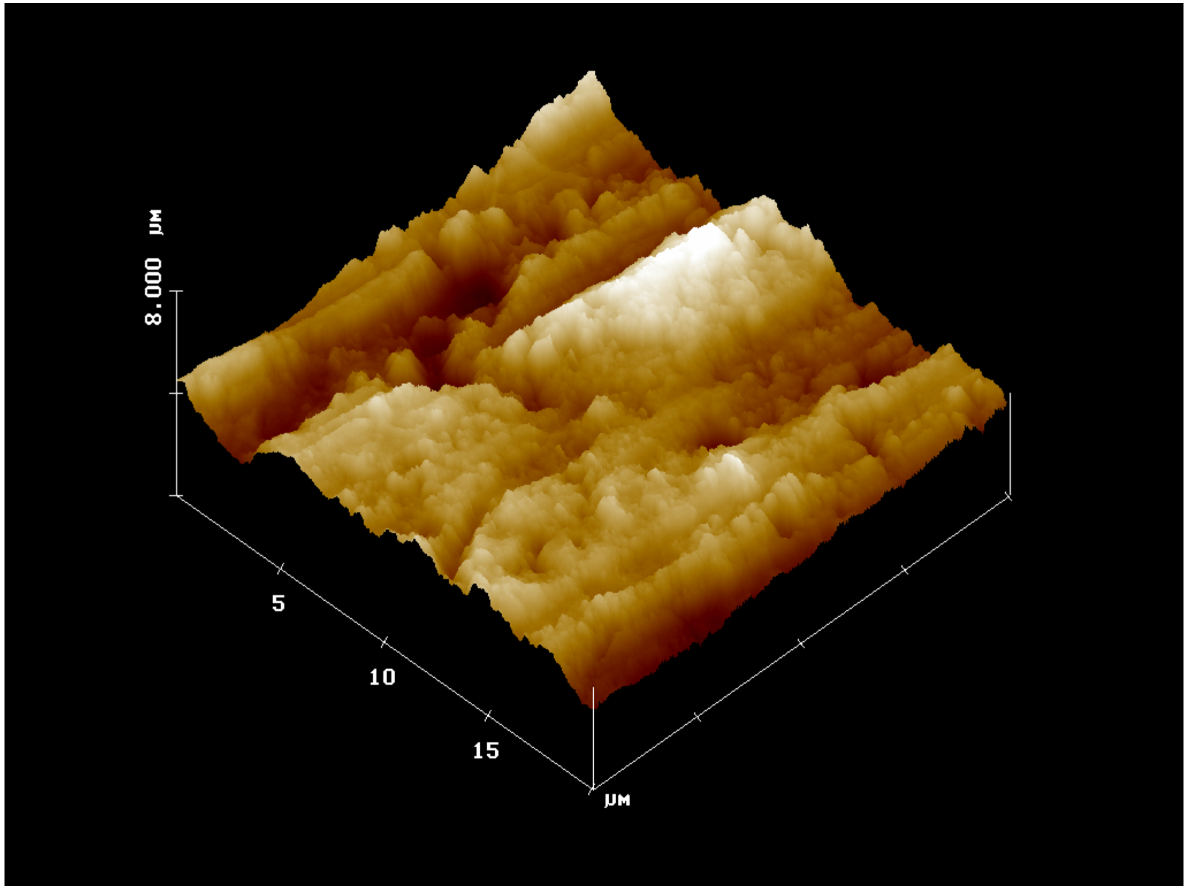

Figure 7

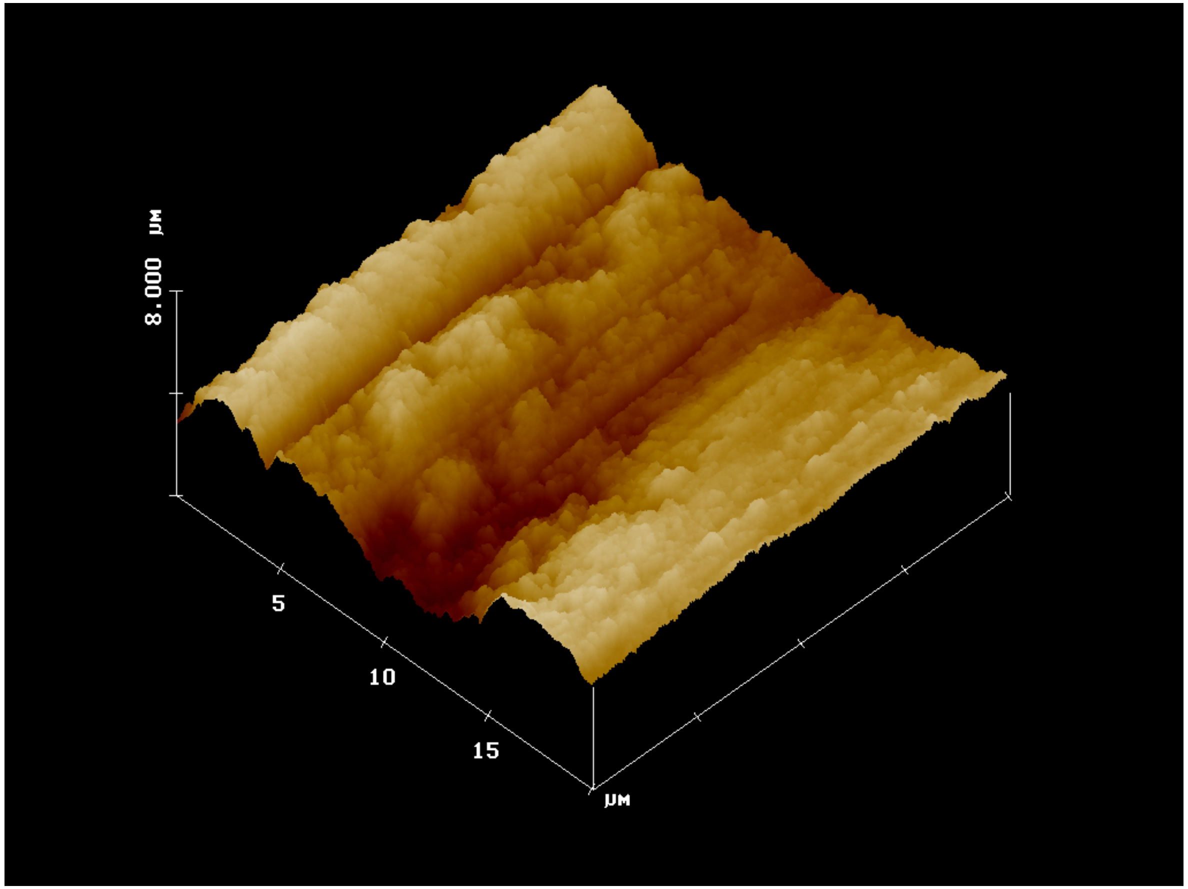

Figure 8

Figure Legends

Figure 1 – Mean surface roughness (Ra) in nm according to the composite resin in absence of finishing (controls). The vertical line represents a 95% confidence interval.

Figure 2 – Mean surface roughness (Ra) in nm according to the composite resin and the finishing instrument. The vertical line represents a 95% confidence interval.

Figure 3 - 3D images of 20 µm X 20 µm obtained by AFM of nanofiller composite resin Filtek Supreme XT with Mylar matrix.

Figure 4 - 3D images of 20 µm X 20 µm obtained by AFM of microhybrid composite resin Point 4 with Mylar matrix.

Figure 5 - 3D images of 20 µm X 20 µm obtained by AFM of nanofiller composite resin Filtek Supreme XT finished with carbide bur.

Figure 6 - 3D images of 20 µm X 20 µm obtained by AFM of microhybrid composite resin Point 4 finished with carbide bur.

Figure 7 - 3D images of 20 µm X 20 µm obtained by AFM of nanofiller composite resin Filtek Supreme XT finished with diamond bur.

Figure 8 - 3D images of 20 µm X 20 µm obtained by AFM of microhybrid composite resin Point 4 finished with diamond bur.

CAPÍTULO 2

Surface roughness of enamel and composite resins: evaluation of polishing techniques by Atomic Force Microscopy

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Abstract

Objectives: The aim of this study was to assess surface roughness of the intact enamel and of composite resins submitted to different polishing techniques. Methods: Flat buccal surface of four caries-free human maxillary central incisors were used for the roughness analysis of enamel. Nanofiller (Filtek Supreme XT, 3M ESPE), microhybrid (Point 4, Kerr Corp.), hybrid (Tetric Ceram, Ivoclar Vivadent) and, microfilled (Durafill VS, Heraeus Külzer) composite resins were selected. Four polishing techniques were tested (T0: Mylar matrix – control; T1: aluminum oxide discs; T2: felt disc + diamond paste; T3: aluminum oxide discs + felt disc + diamond paste). The specimens were randomly assessed into 17 experimental groups (n=4) according to: (i) surface: intact enamel (E) or composite resin and, (ii) polishing techniques for tested composite resins. The mean roughness (Ra) was evaluated under Atomic Force Microscopy (AFM) on the contact mode. The obtained data was submitted to Student´s t test, variance analysis (ANOVA) and, Tukey´s Test, at 5% level of significance. Results: The smoothest surface was obtained with Mylar matrix associated with Filtek Supreme XT (Ra=23.63nm), Point 4 (Ra=12.84nm) and Tetric Ceram (Ra=15.20nm). Durafill VS showed the lowest roughness with aluminum oxide discs (Ra=43.05nm). Surface roughness of enamel was of 46.55nm. Significance: Diamond paste increased the roughness of composites. Aluminum oxide discs may be used as standard polishing technique for all composite resins, except for hybrid resin. For

Tetric Ceram none of the tested polishing techniques promoted a similar or lower roughness to the dental enamel, except the Mylar matrix.

Keywords: Surface roughness, composite resin, nanofiller composite, microhybrid composite, hybrid composite, microfilled composite, human enamel, polishing, abrasive disc, felt disc, diamond paste, Atomic Force Microscopy.

Introduction

Finishing and polishing procedures of composite resin restorations are essential steps in restorative dentistry [1-3]. The esthetics and longevity of direct restorations of composite resin are dependent on the quality of the polished surface [1,3-5]. Highly polished restorations are more esthetics and more easily maintained than restorations with rougher surfaces [4,6]. Non polished restorative surface may generate: surface staining [3-5,7-15], plaque accumulation [3-5,16], gingival irritation [3-5,7,9-11,13,14] and, recurrent caries [3-5,7,10,11,13].

Polyester matrix produces a smoother surface when compared to other polishing techniques [14]. However, polyester matrix lack of adaptation is most likely to occur in areas of difficult access. Despite careful placement of the matrix and composite placement, the removal of overhangs and recontouring are often necessary [3,10,17,18]. These finishing procedures may alter the smoothness obtained by the matrix [3,10]. Therefore, polishing instruments becomes indispensable to reduce the scratches created by the finishing instruments [6,8,10] and, to obtain a texture similar to the adjacent enamel [6,10,18-21].

Different instruments can be used to polish composite resin restorations such as aluminum oxide discs [2,8,12-14,17,20-23], resin embedded abrasive points [10,17,21] and, polishing pastes [17,21,23].

Polishing instruments varies according to their geometry, flexibility of the backing material, the hardness of the abrasive, and the grit size [7,8,14,21]. The features described above are determinant to select an appropriate polishing instrument. The select polishing instrument has a vital effect on the composite roughness [14]. The quality of the polish depends on the ability of the abrasive to polish, nevertheless not damage the surface of the composite or the adjacent enamel [24]. Different polishing instruments may be associated to produce a surface similar to human enamel [6].

Therefore, it becomes important to evaluate the surface roughness of the intact human enamel and of composite resins submitted to different polishing techniques, using the Atomic Force Microscopy (AFM). Two null hypotheses were tested: (1) There is not difference on the roughness of composite resin submitted to different polishing techniques; (2) The surface roughness of composite resins obtained after polishing procedures is similar to the intact human enamel.

Materials and Methods

Four caries-free human maxillary central incisors were selected and stored in 0,5% cloramine for a week and distilled water at 4°C prior to preparation. The teeth were used within 6 months following extraction (ISO 11405). Flat buccal surface of the selected teeth were obtained and used for the roughness analysis of enamel.

Nanofiller (Filtek Supreme XT, 3M ESPE, St. Paul, MN), microhybrid (Point 4, Kerr Corp. Orange, CA), hybrid (Tetric Ceram, Ivoclar Vivadent, Schaan, Liechtenstein) and, microfilled (Durafill VS, Heraeus Külzer, Hanau, Germany) composite resins were evaluated (Table 1). Sixty four specimens were prepared in stainless steel bipartite matrix with two circular orifices of 11 mm diameter and 2 mm thickness. The composite resin was inserted into the matrix using a composite placement instrument followed by the application of an artist sable brush.

A 10 mm width Mylar matrix strip followed by a flat glass slab were used to cover the specimen. A 1 kg stainless steel weight was applied for 30 seconds over the specimen allowing the composite to flow in order to obtain a smoother and standardized surface [25].

After this period, the weight and the glass slab were removed. An 11 mm diameter polymerization tip was applied directly against the Mylar matrix strip, and the specimen light-cured with a halogen light (Demetron Optilux 501, Kerr Corp.). The light output was constantly monitored by a radiometer with average of 880 mW/cm^2. All the procedures were done according to the manufacturer's instructions.

Four polishing techniques (Table 2) were tested. The specimens were randomly assessed into 17 experimental groups (n=4) according to: (i) surface: intact enamel (E) or composite resin and, (ii) polishing techniques for tested composite resins.

Polishing procedures were accomplished using a standardized polishing device. The device was design to guarantee that after specimen removal, the surface would remain flat. The device consisted in a bipartite stainless steel matrix with central height regulation that avoided the polishing instrument to contact with the matrix surface. The pressure during the polishing procedures was standardized in 2 kg.

All the composite resin specimens, during their manufacturing, were notched on its reserve side by a groove to serve as an orientation for the polishing procedures. The polishing procedures were carried out perpendicular to the notch [9]. Each polishing instrument was utilized over a surface during a period of 15 seconds with a slow-speed handpiece [7,26]. The specimens were rinsed and air-dried between steps to remove polishing debris [9,27].

After the polishing procedures, the specimens were washed with an air-water spray during 5 seconds and, stored in distilled water at a temperature of 37ºC ± 1 for 24 hours [15]. Next, the composite resin and intact enamel specimens were ultra-sonicated in deionized water [28] for 30 minutes, with the objective of removing possible debris deposited on the surface.

The mean roughness was assessed by the Atomic Force Microscope (Nanoscope IIIa, Digital Instruments, Santa Barbara, CA) on the contact mode. The scanning of the specimen’s surface was done, using a Si_3N_4 (NT model) probe with frequency of 1 Hz. On the AFM contact mode, the 2D and 3D surface images of each specimen were acquired according to the scanner variations in x, y and z directions [29].

The specimens were positioned on center of the AFM piezoelectric scanner to initialize the roughness readings. Two areas [9] were random selected and scanned in the same direction as the polishing procedures. The roughness readings of intact enamel specimens were performed in the flatness area of the sample in angles of 0 and 90 degrees. Images of 20 µm X 20 µm of each selected area [28] were obtained and the mean roughness (Ra) calculated using the Nanoscope IIIa Software version 4,22 R2 (Digital Instruments).

The homogeneity of variance and normality on the experimental errors were verified with Levene´s and Shapiro Wilk tests. The mean roughness of intact enamel was statistically assessed by the Student’s T test at 5% level of significance. A variance analysis was performed for composite resin and polishing technique, at 5% of significance. Multiple comparisons of the experimental groups were evaluated by Tukey´s test at 5% significance.

Results

There was not statistically significant difference between the mean surface roughness of enamel (Figure 1) in the angles evaluated (p=0.444), by the Student’s T test. Thus, the mean surface roughness of enamel in 90 degrees was used as reference for variance analysis.

There was statistically significant difference between association of composite resin and polishing techniques (p<0.001). The roughness is dependent of the composite resin and polishing technique.

Table 3 displays the mean roughness (Ra) in nm, standard deviation and, Tukey´s Test multiple comparison of the tested specimens, at 5% level of significance.

For nanofiller composite resin Filtek Supreme XT (3M ESPE) the lowest surface roughness values were obtained with T0 polishing technique (Figure 2a). T1 and T2 techniques presented intermediary surface roughness values (Figures 2b and 2c), without statistical difference. The highest mean roughness value was observed with T3 polishing technique (Figure 2d). The mean surface roughness of Filtek Supreme XT polished with T1 and T2 techniques was similar to surface roughness of enamel.

The lowest roughness values for microhybrid composite resin Point 4 (Kerr Corp.) were observed with Mylar matrix (T0) (Figure 3a). T1 technique promoted intermediary surface roughness values (Figure 3b), without statistically significant difference of intact human enamel. The highest mean surface roughness values were obtained with T2 and T3 polishing techniques (Figures 3c and 3d), without statistical difference.

For hybrid composite resin Tetric Ceram (Ivoclar Vivadent) the lowest surface roughness was obtained with T0 (Figure 4a). T1 polishing technique promoted intermediary surface roughness values (Figure 4b). The highest mean surface roughness values were obtained with T2 and T3 polishing techniques (Figures 4c and 4d), without statistical difference. All the tested polishing techniques promoted a rougher surface than human enamel for Tetric Ceram, except for T0.

Microfilled composite resin Durafill VS (Heraeus Külzer) presented the most irregular surface of all composite resins tested. Many peaks and valleys were observed in Durafill VS surface under AFM (Figure 5a). Aluminum oxide discs polishing (T1) promoted the lowest mean surface roughness in the microfilled composite resin (Figure 5b). The highest roughness values were obtained with T0, T2 and, T3 polishing techniques (Figures 5a, 5c and 5d), without statistically significant difference. T1 and T3 techniques promoted surface roughness comparable to human enamel for Durafill VS.

Graph 1 represents a summary of the mean surface roughness for all tested groups at 95% confidence interval. Figures 1 to 5 correspond on intact enamel and composite resins submitted to four polishing techniques, obtained through the contact mode on the AFM.

Discussion

The roughness of a given composite resin is determined by the inner features of the composite and by the polishing instrument characteristics. Size, hardness and, filler content plays an important role on the composite roughness [7,8,14]. For polishing instruments the flexibility of the backing material, hardness, and grit size of the abrasive influence the mean roughness of the composite [2,4,5,7,8,21,27]. In the present study, all the polishing instruments have the same geometry, planar motion that offers the lowers values of superficial roughness [6,18].

Additional features that affect polishing procedures includes: the load applied to the restoration [30,31], orientation of the abrading surface, amount of time with each polishing system [5,6,10,31], rotation speed of the handpiece [31] and; whether or not the specimens were polished with water spray [30]. The higher pressure applied for polishing procedures the rougher became the restoration [30,31]. The standard polishing procedures permitted a similar transferring of energy for all composite resins [32]. Therefore, only intrinsics characteristics of composite resins and polishing instruments affected the surface roughness.

Different polishing techniques promoted different surface roughness for all composite resins tested. Thus, the first null hypothesis was not accepted. The smoothest surface was produced with polyester matrix (T0) for all composite resins tested [1,17], except for microfilled resin (Durafill VS). There was not significant statically difference between nanofiller, microhybrid and, hybrid composite resins with T0 polishing technique. For Durafill VS, the lowest surface roughness was obtained with aluminum oxide discs [1,22] (Ra=43.05nm), being rougher than the other resins. Pre-polymerized blocks of resin (10000 to 20000 nm) with silica particles (40nm) and, UDMA resin matrix can explain the highest surface roughness of Durafill VS resin [33].

For a polishing procedure to be effective, the abrasives must be relatively harder than the filler materials [3,7,8] to remove the matrix as well as cut the moderately filler particles [5]. Otherwise, the polishing instrument only will remove the soft resin matrix and leave the filler particles protruding from the surface [3,7,8]. Aluminum oxide discs produced adequate results for the tested composite resins. Aluminum oxide discs do not displace the composite fillers [1] and, their malleability promotes a homogeneous abrasion of the fillers and resin matrix [1,5,6,18,22]. The hardness of aluminum oxide is significantly higher than of silica dioxide, observed in the microfilled resin Durafill VS, and generally, higher than most filler materials used in composite formulations [3,8]. In a recent study [34], it was observed that aluminum oxide discs produced the smoothest surface, similar to polyester matrix. Aluminum oxide discs were suggested as clinical standard for polishing of microfilled resins [1,20]. However, AFM investigation revealed scratches on the surface of all composite resins polished with aluminum oxide discs. Scratches produced for these discs also were verified by Scanning Electron Microscopy [19]. Frictional heat onto the polymer matrix might produce scratches [24].

For Point 4 and Tetric Ceram composite resins, the highest surface roughness was obtained with felt disc and diamond paste associated or not to aluminum oxide discs (T2 e T3). For nanofiller resin Filtek Supreme XT, the highest surface roughness also was observed with association of these polishing instruments (T3). The increase in surface roughness was probably due to diamond fillers size in polishing paste (2000 to 4000 nm). Therefore, the using polishing paste associated or not to abrasive discs did not improve the surface smoothness of the composite resins [6].

Hybrid composite resin Tetric Ceram presented rougher with polishing paste than the other tested composites. These differences in roughness may be ascribed to distinct patterns of filler size (700 nm) and their arrangement within the resin matrix [1,7,8,14]. Resin composite with larger filler particles are expected to have higher mean surface roughness values after polishing [5].

The morphological characteristic of fillers also influences inorganic content and surface roughness of composite resins. Irregular shaped fillers of composite resin Tetric Ceram contributes for rougher surface [33]. Spherical particles observed in Point 4 and Filtek Supreme XT resins improve their arrangement and increase the volume fraction of the filler in the composite [33].

Polishing procedures of composite resin are performed with objective of reproduce esthetic [18], contour [35] and, dental enamel surface texture [6,35]. Consequently, composite resin restorations polished should present lower or similar surface roughness values than intact dental enamel. In order to promote an acceptable polishing the composite filler hardness must be less than or equal to that hydroxyapatite [36]. Surface roughness of enamel is determined by height difference between enamel prisms and planar faces of hydroxyapatite [29]. None statistical difference was observed in surface roughness of intact enamel in the two directions evaluated. Mean surface roughness of enamel was higher (46.55 nm) than the value observed in another study with AFM (9.93 nm) [37]. However, there are not accepted standards for surface roughness of human enamel [3].

Polishing techniques that promoted surface roughness similar to intact enamel for all composite resins tested should be of choice [36]. Polishing effect about composite restorations depends of composite resin used [2,14]. Composite resins present diverse compositions that differ significantly from dental enamel structure. Aluminum oxide discs can be considered as a universal polishing technique for different composite resins, except for hybrid resin tested. Association of aluminum oxide discs, felt disc and, diamond paste presented similar surface roughness to enamel only for microfilled resin. Felt disc and diamond paste can represent an alternative polishing technique to aluminum oxide discs for nanofiller composite resin. Therefore, the second null hypothesis was partially accepted because different polishing techniques can or cannot produce surface roughness similar to intact human enamel.

Lack of studies with surface roughness evaluation of human enamel by AFM difficulties the data interpretation. Comparison of mean surface roughness values obtained by perfilometer and by AFM cannot be performed because the roughness analysis is done of different form. Both quantitative data as surface roughness of the specimen as well as qualitative data as the image of the surface can be obtained with AFM in a nanometric resolution with precise details [38]. AFM is the only microscopic technique that permits collection of high resolution information from surfaces with quantitative measurements of surface roughness and depth [29].

Conclusion

Mylar matrix promoted the smoothest surface for nanofiller, microhybrid and hybrid composite resins. Aluminum oxide discs may be used as standard polishing technique for all composite resins, except for hybrid resin. For Tetric Ceram none of the tested polishing techniques promoted a similar or lower superficial roughness to the dental enamel, except the Mylar matrix. The use of diamond paste increased the roughness of composite resins. Association of aluminum oxide discs, felt disc and diamond paste promoted higher or similar surface roughness to diamond paste, being indicated only for microfilled resin.

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Table 1 – Characteristics of the tested composite resins.

Abbr	Material	Manufacturer	Classification	Composition	Average Filler Size	Shade	Batch
F	Filtek Supreme XT	3M ESPE, St. Paul, MN, USA	Nanofiller	Bis-GMA Bis-EMA UDMA TEGDMA	5 to 20 nm with nanoclusters of 600 to 1400 nm	A2E	5BL
P	Point 4	Kerr Corp., Orange, CA, USA	Microhybrid	Bis-GMA TEGDMA EBADMA	400 nm	A2	424008
T	Tetric Ceram	Ivoclar Vivadent, Schaan, Liechtenstein	Hybrid	Bis-GMA UDMA TEGDMA	700 nm	A2	H22747
D	Durafill VS	Heraeus Külzer, Hanau, Germany	Microfilled	UDMA	40 nm	A2	010151

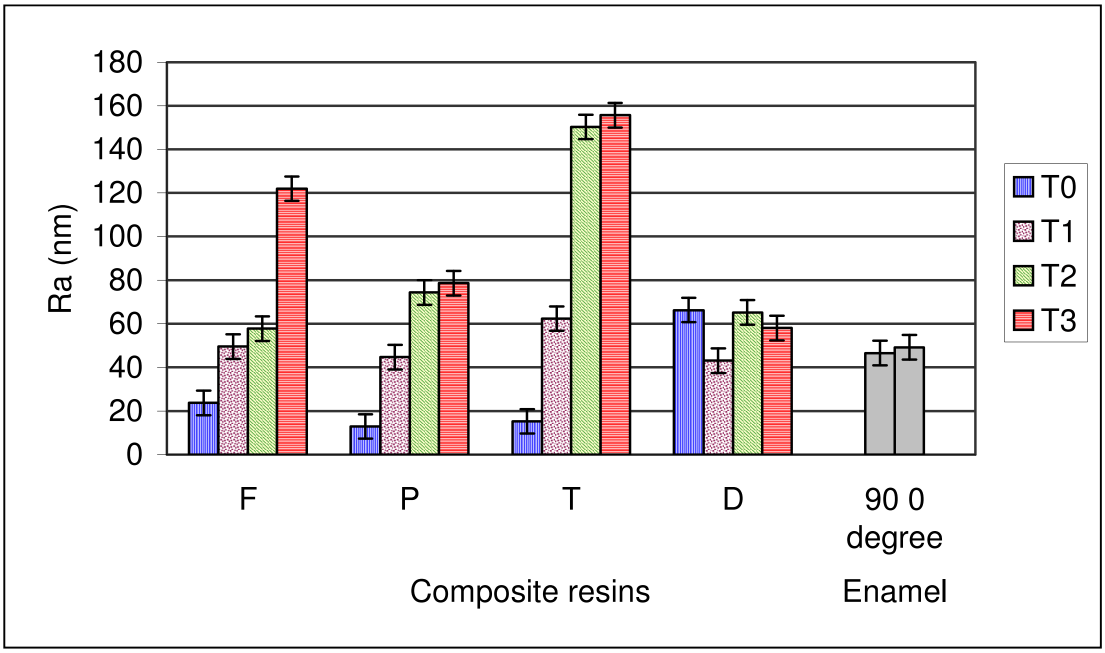
Table 2 –Tested polishing techniques.

Symbol	Techniques	Characteristics	Manufacturer	Batch
T0	Mylar matrix (control)	Polyester strip with 10 mm width, 120 mm length and 0,05 mm thickness	K-Dent – Quimidrol, Com. Ind. Importação Ltda, Joinville, SC, Brazil	005-0104
T1	Diamond Pro (sequence)	Aluminum oxide discs with granules of 3000 to 130000 nm and diameter of 12 mm	FGM Produtos Odontológicos, Joinville, SC, Brazil	020506
T2	Diamond Flex + Diamond Excel	Felt disc + Diamond paste with abrasives of 2000 a 4000 nm		030506 121205
T3	Diamond Pro + Diamond Flex + Diamond Excel	Aluminum oxide discs + Felt disc + Diamond paste		020506 030506 121205

Table 3 - Mean surface roughness (nm) and standard deviation of the intact enamel and of the composite resins submitted to polishing techniques (Means followed by different capital letter in column or lower letter in line are significantly different).

Surface	Techniques								*
	T0		T1		T2		T3		
Composite									
F	23.63(3.00)	$^{A}_{a}$	49.48(1.37)	$^{AB}_{b}$	57.76(6.15)	$^{AB}_{b}$	121.92(2.90)	$^{C}_{c}$	b
P	12.84(1.37)	$^{A}_{a}$	44.66(4.34)	$^{A}_{b}$	74.32(3.69)	$^{C}_{c}$	78.61(4.10)	$^{B}_{c}$	b
T	15.20(1.92)	$^{A}_{a}$	62.39(7.86)	$^{B}_{c}$	150.33(6.80)	$^{D}_{d}$	155.71(5.70)	$^{D}_{d}$	b
D	66.30(7.59)	$^{C}_{c}$	43.05(5.19)	$^{A}_{a}$	65.14(8.20)	$^{BC}_{c}$	58.07(3.61)	$^{A}_{bc}$	ab
Enamel									
90 degree	46.55(10.74)	^{B}		^{A}		^{A}		^{A}	
0 degree	49.14(9.78)	^{B}		^{A}		^{A}		^{A}	

* Comparisons of enamel in each line



Graph 1 - Mean surface roughness (Ra) and 95% confidence interval for enamel and composite resins submitted to polishing techniques.

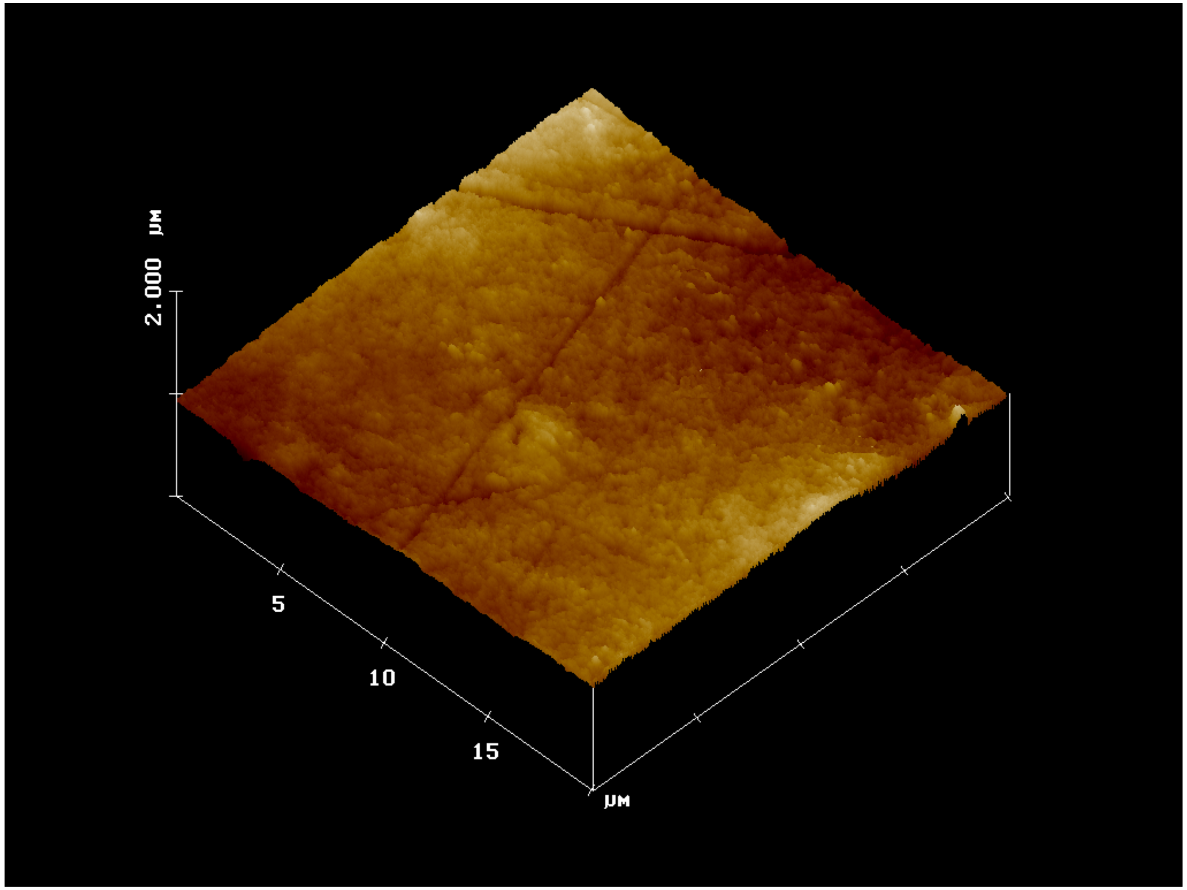
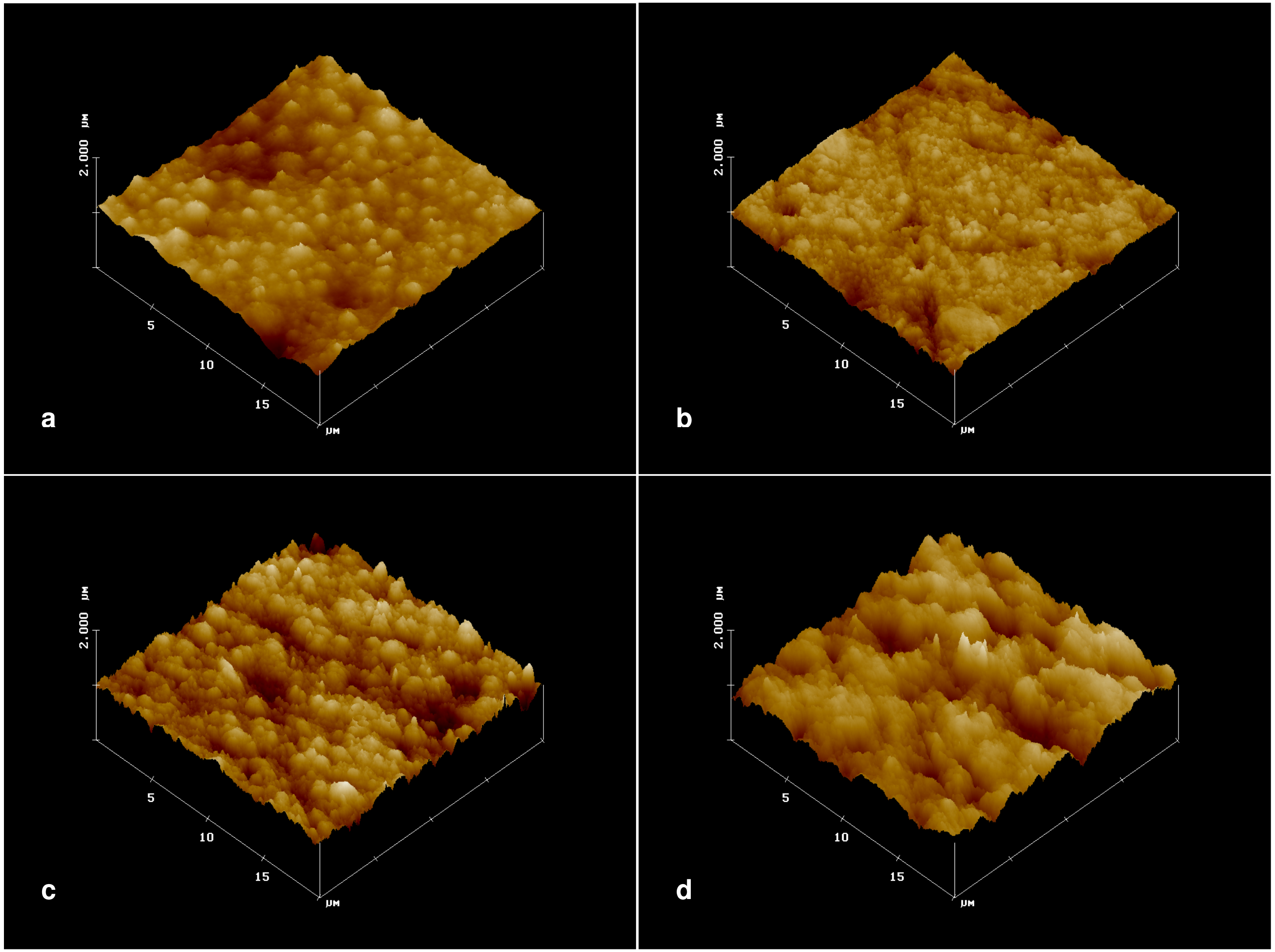


Figure 1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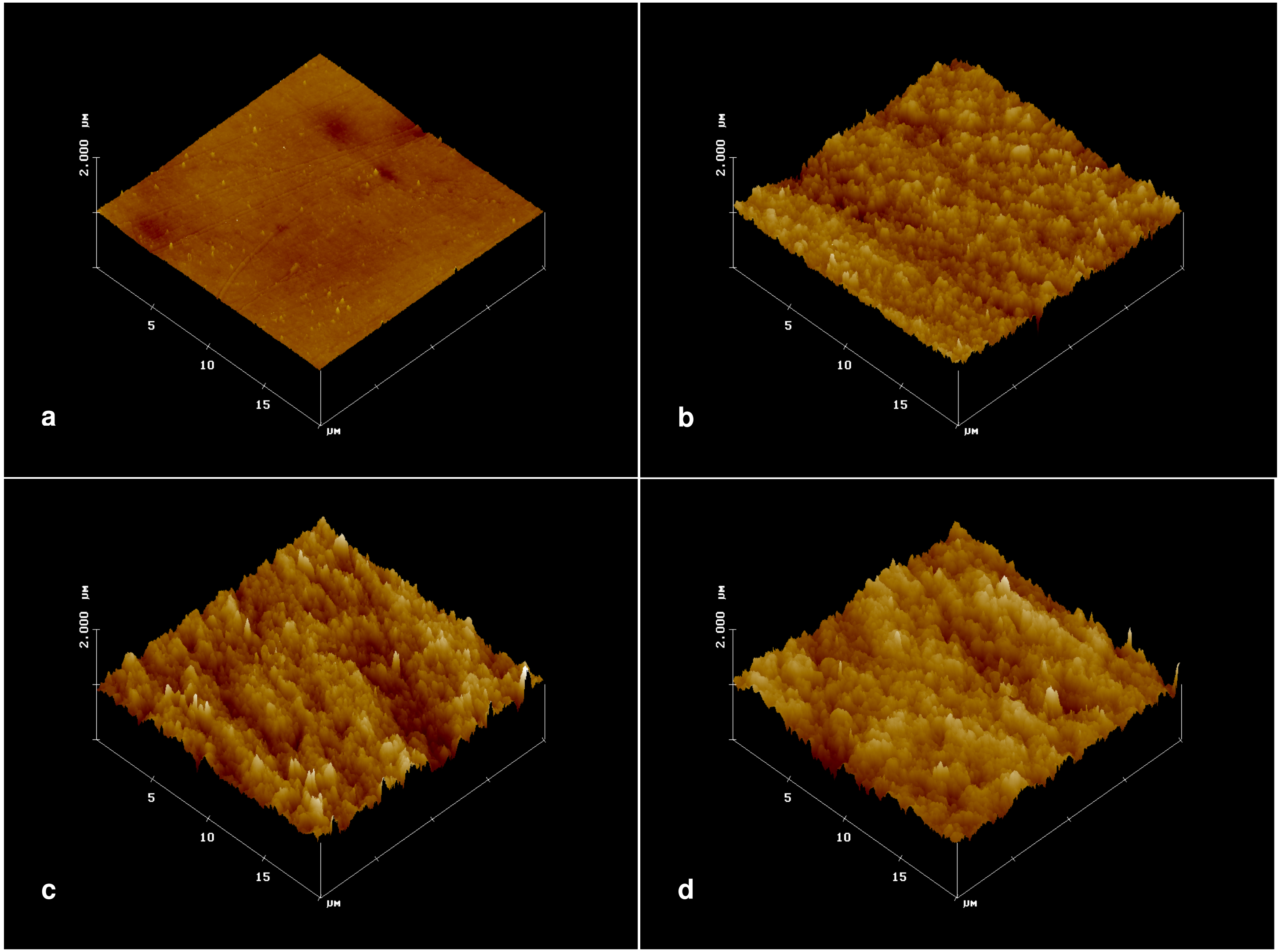
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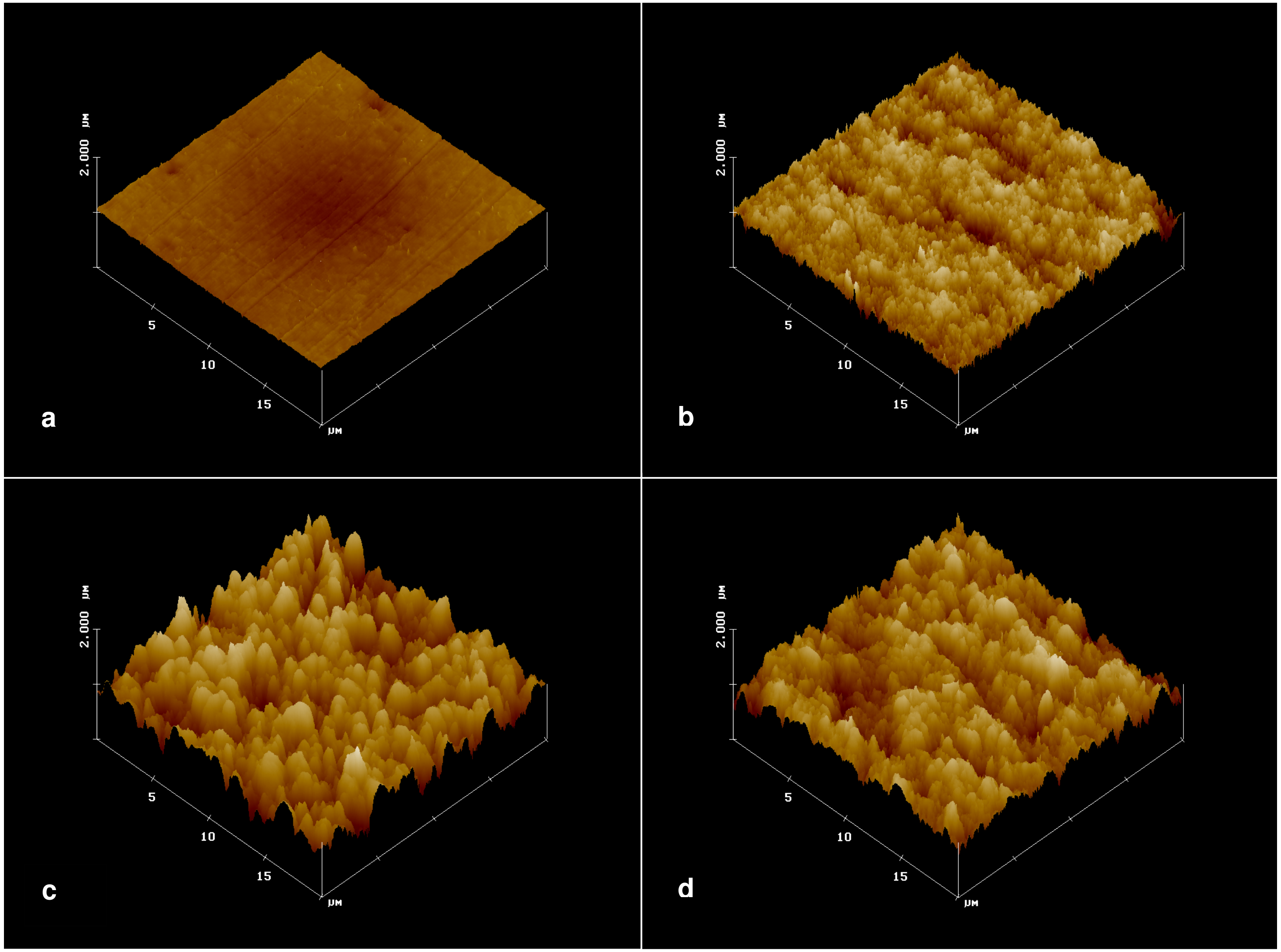
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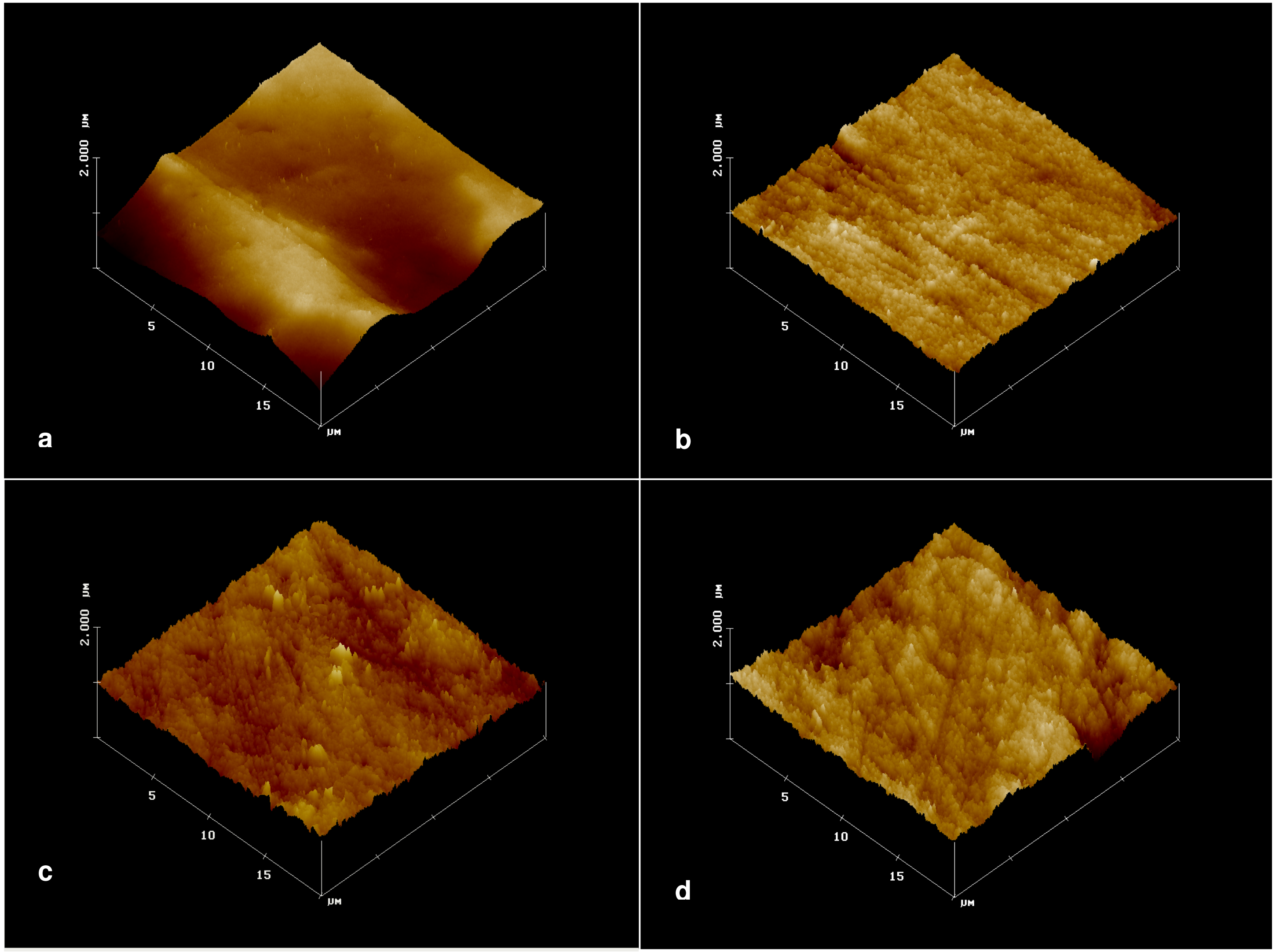
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Figure 5

Captions to figures

Figure 1 – 3D image of 20 µm X 20 µm of intact human enamel obtained by AFM.

Figure 2 - 3D images of 20 µm X 20 µm of nanofiller composite resin Filtek Supreme XT polished with: a: Mylar matrix; b: aluminum oxide discs; c: felt disc and diamond paste; d: aluminum oxide discs, felt disc and diamond paste.

Figure 3 - 3D images of 20 µm X 20 µm of microhybrid composite resin Point 4 polished with: a: Mylar matrix; b: aluminum oxide discs; c: felt disc and diamond paste; d: aluminum oxide discs, felt disc and diamond paste.

Figure 4 - 3D images of 20 µm X 20 µm of hybrid composite resin Tetric Ceram polished with: a: Mylar matrix; b: aluminum oxide discs; c: felt disc and diamond paste; d: aluminum oxide discs, felt disc and diamond paste.

Figure 5 - 3D images of 20 µm X 20 µm of microfilled composite resin Durafill VS polished with: a: Mylar matrix; b: aluminum oxide discs; c: felt disc and diamond paste; d: aluminum oxide discs, felt disc and diamond paste.

CONSIDERAÇÕES FINAIS

Considerações finais

A rugosidade superficial de resinas compostas foi influenciada pela composição do material restaurador e pelos procedimentos de acabamento e polimento. Nas duas pesquisas realizadas, as características intrínsecas das resinas compostas que mais influenciaram a rugosidade superficial foram o tamanho[12,18,20,22,29,31,32], a forma[12,20,24] e a distribuição das partículas na matriz orgânica[25]. As resinas compostas que se caracterizaram por conterem partículas grandes, com formato irregular e baixo conteúdo de carga apresentaram-se mais rugosas.

Com relação aos instrumentos de acabamento e polimento foi possível observar que a rugosidade superficial foi afetada pela granulação, dureza e flexibilidade dos materiais[6,8,21-23,31,33]. Instrumentos de polimento flexíveis e com partículas mais resistentes que a carga inorgânica das resinas compostas, como os discos de óxido de alumínio, promoveram maior lisura superficial. Entretanto, instrumentos de acabamento e polimento com tamanho de grãos superior às partículas resinosas, aumentaram a rugosidade superficial da resina composta como a pasta e a ponta diamantadas .

Dentre os instrumentos de acabamento testados, a fresa carbide promoveu a maior lisura superficial. Apesar da maior rugosidade superficial produzida por este instrumento em comparação ao esmalte e as técnicas de polimento avaliadas, a fresa carbide pode ser considerada o instrumento de acabamento de escolha para restaurações com as resinas nanoparticulada e microhíbrida testadas. Porém, novos estudos são imprescindíveis na busca de instrumentos ou técnicas de polimento para dentes posteriores que promovam uma textura superficial similar ao esmalte dental.

A maior lisura de superfície foi observada com o uso da matriz de poliéster ou discos de polimento de óxido de alumínio. Além da menor rugosidade superficial, estes materiais promoveram uma textura superficial semelhante ao esmalte dental, dependendo da resina composta utilizada. Apesar de serem importantes para o sucesso estético e para a longevidade de uma restauração de resina composta, estes materiais apresentam limitações em seu uso, principalmente em relação a determinadas superfícies da estrutura dental[18,19,31].

O Microscópio de Força Atômica apresentou algumas vantagens e limitações para análise da rugosidade superficial de resinas compostas e esmalte dental. As vantagens observadas são decorrentes da alta sensibilidade e precisão na análise de discrepâncias verticais[9,12,17,26,34], da produção de imagem tridimensional em resolução atômica[17,27,28] e ausência de meios de fixação e cobertura[17]. A necessidade de superfícies planas e rígidas[26] para que a sonda não cause deformações na superfície dificulta a análise principalmente da estrutura dental. Superfícies planas do esmalte dental são difíceis de serem obtidas, porém o fato da análise ser feita em uma pequena área minimiza esta limitação. O alto custo do equipamento e a baixa velocidade[26] na produção da imagem também limitam a sua utilização. A rugosidade superficial do material é representada pela análise de pequenas áreas[12,34], sendo a máxima rugosidade avaliada de 5,85 µm. Todas essas limitações, porém, são superadas pelos efetivos resultados obtidos e pelas inúmeras imagens em duas e três dimensões representativas das amostras analisadas. Dessa forma, o Microscópio de Força Atômica pode ser considerado um equipamento apropriado para análise da rugosidade superficial.

CONCLUSÕES

Conclusões

De acordo com os resultados obtidos nos diferentes estudos realizados, pode-se concluir que:

Capitulo 1:

1. A hipótese nula foi rejeitada, pois diferentes instrumentos de acabamento promoveram diferentes rugosidades superficiais.
2. A fresa carbide promoveu uma menor rugosidade superficial em relação à ponta diamantada, independentemente da resina composta utilizada.
3. A resina microhíbrida promoveu maior lisura de superfície em relação à resina nanoparticulada, quando utilizada matriz de poliéster.
4. Não houve diferença na rugosidade superficial entre as resinas compostas testadas após os procedimentos de acabamento, independente do instrumento utilizado.

Capitulo 2:

1. A primeira hipótese nula foi rejeitada, pois houve diferença estatisticamente significante na rugosidade superficial das resinas nanoparticulada, microhíbrida, híbrida e microparticulada submetidas a diferentes técnicas de polimento.

2. A matriz de poliéster promoveu a maior lisura de superfície para as resinas nanoparticulada, microhíbrida e híbrida testadas.
3. Para a resina microparticulada a maior lisura de superfície foi observada com o polimento com discos de óxido de alumínio.
4. O efeito da técnica de polimento sobre restaurações de compósitos depende da resina composta utilizada.
5. A segunda hipótese nula foi aceita parcialmente, pois diferentes técnicas de polimento produziram ou não rugosidade superficial similar ao esmalte humano íntegro.
6. Os discos de óxido de alumínio podem ser utilizados como técnica de polimento padrão para todas as resinas compostas analisadas, com exceção da resina híbrida.
7. Nenhuma das técnicas de polimento avaliadas promoveu uma rugosidade superficial menor ou similar ao esmalte dental íntegro para a resina híbrida, exceto a matriz de poliéster.
8. O disco de feltro e a pasta diamantada representam uma técnica de polimento alternativa aos discos de óxido de alumínio para a resina nanoparticulada.
9. O uso da pasta diamantada aumentou a rugosidade superficial das resinas compostas.

10. A associação de discos de óxido de alumínio, disco de feltro e pasta diamantada promoveu rugosidade superficial maior ou igual à pasta diamantada, sendo indicada apenas para a resina microparticulada.

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* De acordo com o estilo Vancouver.
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APÊNDICE

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FACULDADE DE ODONTOLOGIA DE ARARAQUARA

Comitê de Ética em Pesquisa

Certificado

Certificamos que o projeto de pesquisa intitulado ***"RUGOSIDADE SUPERFICIAL DO ESMALTE DENTAL E DE RESINAS COMPOSTAS: AVALIAÇÃO DE INSTRUMENTOS DE POLIMENTO PELO MICROSCÓPIO DE FORÇA ATÔMICA"***, sob o protocolo nº **34/06** e o relatório final de responsabilidade do Pesquisador (a) *SILLAS LUIZ LORDELO DUARTE JÚNIOR*, estão de acordo com a Resolução 196/96 do Conselho Nacional de Saúde/MS, de 10/10/96, tendo sido aprovado pelo Comitê de Ética em Pesquisa–FOAr.

Certify that the research project titled ***"SURFACE ROUGHNESS OF ENAMEL AND COMPOSITE RESINS: EVALUATION OF POLISHING INSTRUMENTS BY ATOMIC FORCE MICROSCOPY"***, protocol number **34/06**, and final technical report, under Dr *SILLAS LUIZ LORDELO DUARTE JÚNIOR* responsability, is under the terms of Conselho Nacional de Saúde/MS resolution # 196/96, published on May 10, 1996. This research has beem aproved by Research Ethic Committee, FOAr-UNESP.

Araraquara, 21 de março de 2007.

Profª Drª Mírian Aparecida Onofre
Coordenadora

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Ana Carolina Botta Martins de Oliveira