Original Article

International Journal of Dental and Health Sciences
Volume 04,Issue 04

ASSESSMENT OF SURFACE TOPOGRAPHY AND COLOR DIFFERENCE OF DIFFERENT CERAMIC SYSTEMS AFTER SIMULATED GASTRIC ACID EXPOSURE: A LABORATORY STUDY

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ABSTRACT:

Objective: To evaluate the effect of long term exposure to simulated gastric acid on surface roughness and color change of different ceramic systems.

Materials and methods: A total 50 discs were divided into five groups (n= 10) according to the type of ceramic system: Zolid FX, IPS e.max CAD, Vita Mark II, Vita Enamic and Vita Suprinity. All discs were immersed in (0.06 M) HCl with pH 1.2 for 144 hours at 37°C. Surface topographical changes of the discs were measured with atomic force microscope and scanning electron microscope, while the color changes were measured with a spectrophotometer and the mean values of color difference (ΔE) were calculated. The data were analyzed with One-way ANOVA followed by post-hoc tukey's test for pair-wise comparison between the groups.

Results: There was significant difference in ΔRa values ($p<0.05$) between all groups. The mean values of color difference (ΔE) within a range from 2.64 to 5.31. Zolid FX showed the lowest value, and Vita Enamic had the highest value.

Conclusions: The simulated gastric acid has direct effect on surface topography and the final color of tested ceramic materials.

Keywords: Dental ceramic; Surface roughness; Gastric acid; Atomic force microscope; Spectrophotometer; Scanning electron microscope

INTRODUCTION:

Advances in technology and research of the indirect teeth colored restorative materials lead to the development of many new types of ceramic materials. The all-ceramic materials become more popular as a result of their excellent esthetic properties in term of translucency and good color reproduction of the natural teeth, also to their biocompatible properties and wear resistance. Nowadays, the advancement of monolithic restoration systems which consist of a single material with no veneering has been developed. [1]

A newly developed full-contour zirconia crowns have become popular due to its high flexural strength, insignificant wear of opposing teeth, conservative tooth preparation, and long term durability. [2] Also, a reinforced lithium disilicate glass ceramic was developed (IPS e.max CAD), which allows the fabrication of ceramic crowns on the anterior and posterior teeth without need for veneering. [3] One of the most recently introduced CAD/CAM materials is Vita Suprinity, which is zirconia-reinforced lithium silicate glass ceramic material composed

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of 10 % by weight of zirconia. This new material has been offered adequate translucency with superior mechanical properties. [4] A new material which combines the properties of ceramics and polymers was called "hybrid ceramic", [5] which has wear, flexural and elastic properties similar to the dentin. [6, 7]

Patients suffering from gastrointestinal disorder or complained from continuous vomiting must be considered when using ceramic restorations. This disorder may be in the form of gastroesophageal reflux disease which characterized by "involuntary muscle relaxing of the upper esophageal sphincter, that allows refluxed acid to move upward through the esophagus into the oral cavity". [8] Another form is called Bulimia nervosa which defined as a disorder associated with excessive concern about body weight and shape, binge eating, frequent self-purging and other inappropriate behavior to prevent weight gain. [9] Gastric juice affects the tooth by demineralization action on enamel, dentin, and cementum. [10, 11] Moreover, it may affect the ceramic restoration by dissolving its glassy matrix as it is characterized by low pH (pH< 1). [12] Tooth structure that affected by dental erosion may restored with direct or indirect restorations. Up to our knowledge there are limited studies have reviewed the effects of long term exposure of gastric acid on the ceramic restoration. Therefore, the aim of this in vitro study is to assess the effect of long term exposure to simulated gastric acid on surface texture and color change of different ceramic systems compared to polymer material.

MATERIALS AND METHODS:

Discs preparation

A light cured composite disc (Filtek Z 250, 3M ESP, Germany), 1.5 mm in thickness and 10 mm in diameter was prepared in a specially designed split Teflon mold to be scanned optically for CAD/CAM ceramic fabrication. The composite material was inserted into the mold and covered with a glass plate to assure flat and parallel surface. After complete curing, the disc was removed from the mold, finished to remove any excess materials with diamond finishing bur then polished to produce smooth and shiny surface with white stone and polishing rubber cups.

A total of 50 discs were divided into equal five groups (n=10) according to the type of the ceramic system and were distributed as the following:

Group I: Monolithic zirconia (Zolid FX, Amann Girrbach, Austria).

Group II: Glass ceramic (IPS e.max CAD, Ivoclar Vivadent, Liechtenstein)

Group III: Fieldspathic ceramic (Vita Mark II, Vita, Germany).

Group IV: Hybrid ceramic (Vita Enamic, Vita, Germany).

Group V: Glass ceramic with zirconia (Vita Suprinity, Vita, Germany).

All discs were produced in one dental laboratory using Ceramill motion 2 CAD/CAM milling unite, to assure consistent disc size. Moreover, all discs finished and polished according to the manufacturer's instructions.

Preparation of the simulated gastric acid and immersion time

All discs after finishing and polishing were cleaned ultrasonically in distilled water for 15 minutes and dried for 20 seconds. The simulated gastric acid was prepared with HCl (0.06 M and pH 1.2).[13] Each group was immersed 5 ml of the prepared HCl and placed into an incubator (BT1020, Egypt) at 37^{o}C for 144 hours. The amount of HCl must cover all surfaces of the discs.

Surface roughness evaluation

1. Atomic force microscope evaluation (AFM)

It was used for quantitative and qualitative analysis. AFM (Autoprobe cp-research head, MLCT-MT-A, Bruker) was used in contact mode to measure the mean surface roughness (Ra) before and after immersion in simulated gastric acid. AFM functions via a laser beam which scans the specified dimensions (10 μm X 10 μm) and transfers this information to the computerized software. This software automatically calculated the scanning results for the mean surface roughness.

2. Scanning electron microscope evaluation

The discs were prepared for SEM examination using (SPI-Module sputter, SPI Supplies, West Chester, PA, USA). The surface of the discs was scanned before and after immersion in simulated gastric acid using SEM (Jeol, JSM-6510LV, Japan).

Color change evaluation

A spectrophotometer (Cary 5000, Agilent Technologies, USA) was used to evaluate the color changes of all discs before and after immersion in simulated gastric acid. The wavelength scan in these measurements was carried out from 380 nm to 780 nm. CIE-Lab color values for each disc were then calculated from the diffuse reflectance data by using the color software application which is available through Cary WinUv instrument. The degree of color difference between the compared colors is expressed in ΔE units. The total color difference, according to L*, a*, b* coordinates, was calculated as shown in the equation

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

Where L*= lightness (0-100), a*= (change the color of the axis red/green) b*= change variation axis yellow/blue).

Statistical analysis

Statistical analysis was performed using SPSS 17.0 software for windows. One way analysis of variance (ANOVA) was used to compare between more than two groups of numerical data followed by post-hoc tukey's. P-values $\leq$ 0.05 were considered to be statistically significant in all tests.

RESULTS:

Surface roughness

The mean values and standard deviation of surface roughness of the tested ceramic groups before and after acid immersion were summarized in Table (1).

Figures (1 & 2) showed the AFM and SEM images, respectively of the tested ceramic groups before and after immersion in simulated gastric acid. After acid immersion the surface of all groups revealed increasing in surface roughness with different degree. 3D AFM image after acid immersion of Zolid FX (Figure 1b) illustrated minimal roughness, shallow holes, few peaks and valleys than (Figure 1a) before immersion in simulated gastric acid. (Figure 1d) showed the surface of IPS e.max CAD disc with more surface roughness, sharp peaks and valleys, v shape cleft and wrinkles more than Zolid FX and Vita Suprinity after immersion in simulated gastric acid. The surface of Vita Mark II (Figure 1f) showed irregular intrusion and protrusion, holes with different size, sharp peaks and valleys more than Zolid FX, Vita Suprinity and IPS e.max CAD. Vita Enamic (Figure 1h) illustrated multiple eroded areas with increasing in wrinkles and irregularities more than the other groups. Vita Suprinity (Figure 1j) showed moderate increasing in surface roughness with moderate irregularity, shallow cleft, peaks, valleys and wrinkles more than Zolid FX.

SEM image of Zolid FX after acid immersion (Figure 2b) illustrated bead like defect with small size indicating minimal change of the surface. However, the surface of IPS e.max CAD (Figure 2d) showed pores with different size more than Zolid FX and Vita Suprinity. Moreover, the surface of Vita Mark II showed more defects and pores with irregular border larger in size more than Zolid FX, Vita Suprinity and IPS e.max CAD (Figure 2f). For Vita Enamic (Figure 2h) illustrated multiple eroded area and gap between the crystals indicating surface change more than other ceramic groups. For Vita Suprinity (Figure 2j), the surface after acid immersion showed micro pores distributed on the surface more than Zolid FX.

The changes in the surface roughness of all discs were presented in Table (2) and were illustrated graphically in Figure (3). One-way ANOVA showed that the least mean change of surface roughness after acid immersion was for Zolid FX (ΔRa=3.61$\pm$0.71), while the greatest change was for Vita Enamic (ΔRa =11.67$\pm$1.30). Moreover, the obtained values of change of Ra showed statistically significant difference in surface roughness among different groups ($p \leq 0.05$).

Color changes

One-way ANOVA test was performed to compare the mean values of color changes (ΔE) between tested ceramic groups, which were presented in Table (3) and were illustrated graphically in Figure (4). One-way ANOVA test showed that the lowest mean value of (ΔE) was for Zolid FX (2.64±0.30) while the highest mean value of (ΔE) was for Vita Enamic (5.31±0.54). Moreover, the obtained values of (ΔE) showed statistically significant difference among different groups ($p \leq 0.05$).

DISCUSSION:

Esthetic dentistry has turned out to be a standout amongst the most encouraging ranges in dental practice. The improvement of new materials together with patient esthetic demands has enabled the clinical use of reconstructive systems for lost or esthetically compromised teeth. [1, 4] As there were few studies that evaluate the effect of gastric acid on monolithic restoration, therefore in the present in vitro study surface roughness and color measurement of Zolid FX, IPS e.max CAD, Vita Mark II, Vita Enamic and Vita Suprinity were studied after long term immersion on simulated gastric acid. These materials were selected as they are the most popular and the most widely used ceramics in the modern dental practice. The all-ceramic restorations have prompted various advances in reconstructive dentistry especially the monolithic restoration that known as a full contour restoration. [5]

There was no certain agreement in the literatures regards to the method of gastric acid simulation in laboratory studies to mimic an in-vivo model. Harryparsad et al. [14], found that exposure to HCl with pH= 2 for 7.5 hours, 45 hours and 91 hours represents gastric acid exposure in a bulimic patient for one month, 6 months and 12 months, respectively. Backer et al. [15], utilized gastric juice with pH= 1.2 for 6 hours and 18 hours that simulate two and eight years of exposure to vomiting, respectively.

It was found that exposure to HCl with pH= 1.2 for 96 hours at 37°C, simulate over 10 years of clinical exposure. [13] The immersion time in the present study was increased to 144 h at 37°C, which is supposed to simulate over 15 years of clinical exposure to understand the effect of prolonged exposure time on the different ceramic materials.

Surface roughness has a major effect on the discoloration so on the esthetic appearance of the restoration, secondary caries, wear of the opposing teeth and gingival irritation. Moreover, a smooth surface adds to the patient's comfort, as already a change of surface roughness in the order of 0.3 mm can be distinguished by the tip of the patient's tongue. [16]

The results of surface roughness values in the present study exhibited that none of the ceramics evaluated were observed to be chemically inert. The least mean change of surface roughness was for Zolid FX with mean ΔRa (3.61) and the greatest mean change was for Vita

Enamic with mean ∆Ra (11.67). These results was coincide with the other study in which monolithic zirconia system show the least surface roughness change after immersion in simulated gastric acid. [13] SEM images revealed that the bead-like shapes that appeared on the corroded surface of zirconia were oxides or alkali ions of either Al, Ca, K or Fe, leaching out of the zirconia, while Si, Ca and Mg ions were leaching out of the IPS e.max CAD, indicating a possible corrosive effect by the acidic solution, also they found that IPS e.max CAD had significant increase in surface roughness when compared to different types of zirconia. Vita Enamic showed small pores and fissures and this may related to dissolution of the glassy phase around the crystals. The changes in surface roughness as a result of long term exposure to simulated gastric acid may attributed to the local composition and the microstructure of the ceramic restorative materials. The result of the present study coincided with the previous study. [17] It was reported that the causes of surface roughness of dental ceramic as a result of acid immersion by two dominant mechanisms; firstly, the selective leaching of alkali ions, and secondly, the dissolution of the ceramic silicate network (Si-O-Si). These mechanisms are controlled by the diffusion of hydrogen ions (H_3O^+) from an aqueous solution into the ceramic and loss of alkali ions from the surface of ceramic into an aqueous solution to keep the electrical neutrality. The greatest change in the surface roughness of Vita Enamic may be attributed to its composition as it contains polymer 25% by volume UDMA (urethane dimethacrylate) and TEGDMA (triethylene glycol dimethacrylate). [18] Hydrolysis of methacrylate ester bonds of the resin matrix of polymer-based materials after immersion in acidic solution is related to the greatest change of the surface roughness.

It was reported that changes in color ΔE=3.7 considered as the threshold at which 50% of observers accepted the color difference. [19, 20] our results of color change showed the lowest mean value (ΔE) was for Zoild FX (2.64) while the highest mean value (ΔE) was for Vita Enamic (5.31). The color change in this study may related to the rough surfaces of the ceramic discs after acid immersion as the rough surfaces revealed more color changes than did smooth surfaces. This finding support the idea that surface roughness affects the appearance and color of the dental restoration as rough surface reflect the color in different direction, while smooth flat surface reflect the light in a narrow cone focused about the angle of reflectance. According to previous studies, the color change of the hybrid ceramic may be attributed to their composition. [21,22] Polymer network is made out of a mixture of triethylene glycol dimethacrylate (TEGDMA) and hydrophobic urethane dimethacrylate (UDMA), so the pores of the structured sintered ceramic matrix were loaded with a polymer material. TGDMA showed degree of water absorption thus permitted the penetration of the hydrophilic colorant into the resin matrix. Therefore, Vita Enamic ceramic discs were able to show more discoloration than other tested ceramic system when immersed in simulated gastric acid for prolonged time.

CONCLUSION:

On the basis of the results and conditions of this study, the following conclusions can be drawn:

1. Long term exposure to simulated gastric acid for 144 h has a noticeable effect on the color stability and surface roughness of the tested ceramic materials.
2. The least mean change of surface roughness and color change were for Zoild FX, while the greatest mean change of both was for Vita Enamic.
3. The color change of Zolid FX, IPS e.max CAD and Vita Suprinity was clinically acceptable (< 3.7), while for Vita Mark II and Vita Enamic was perceivable to the human eye and was clinically unacceptable.

Recommendations: From the results of the present in vitro study, following recommendations can be drawn:

1. Patients with gastrointestinal problems must be considered when restored the eroded teeth by all ceramic restoration.
2. Zolid FX ceramic restoration can be used in patients with Gastro-oesophageal reflux disease, however, Vita Enamic and Vita Mark II should be applied with caution.
3. Further investigation on the effect of gastric acid intra orally on different ceramic systems is recommended.

Acknowledgements: This research was supported by Mansoura University, Mansoura, Egypt.

REFERENCES:

1. Triwatana P, Nagaviroj N, Tulapornchai C. Clinical performance and failures of zirconia based fixed partial dentures: A review literature. J Adv Prosthodont. 2012; 4:76-83.
2. Kim H, Kim S, Lee J, Han J, Yeo I. Application of monolithic zirconia ceramics in dental practice: A case history report. Int J Prosthodont. 2016; 29(5):511-13.
3. Qamheya AH, Qamheya M, Arisan V. Lithium disilicate restorations: Overview and a case report. J Dent & Oral Disord. 2016; 2(9):2-5.
4. Majeed M, Al-Adel S. Evaluation of the marginal and internal fitness of full contour CAD/CAM crowns made from zirconia, lithium disilicate, zirconia reinforced lithium silicate and hybrid dental ceramic by silicone replica technique: A comparative in vitro study. J Genet& Environ Resour Conserv. 2016; 4(1):10-20.
5. Coldea A, Swain M, Thiel N. Mechanical properties of polymer infiltrated ceramic network materials. Dent Mater. 2013; 29(14):419-26.
6. Dirxen C, Blunck U. Clinical performance of a new biomimetic

double network material. Open Dent J. 2013; 7:118-22.

7. Della A, Corazza P, Zhang Y. Characterization of a polymer infiltrated ceramic network material. Dent Mater. 2014; 30(5):564-69.
8. Bartlett D, Evans D, Smith B. Oral regurgitation after reflux provoking meals: A possible cause of dental erosion. J Oral Rehabil. 1997; 24(2):102-8.
9. Keel P, Haedt A. Evidence-based psychosocial treatments for eating problems and eating disorders. J Clin Child Adolesc Psychol. 2008; 37(1):39-61.
10. Bartlett D, Coward P. Comparison of the erosive potential of gastric juice and a carbonated drink in vitro. J oral rehabil. 2001; 28(11):1045-47.
11. Holbrook W, Furuholm J, Gudmundsson K, Theodors A, Meurman J. Gastric reflux is a significant causative factor of tooth erosion. J Dent Res. 2009; 88(5):422-26.
12. Oh W, DeLong R, Anusavice K. Factors affecting enamel and ceramic wear: A literature review. J Prosthet Dent. 2002; 4(87):451-59.
13. Sulaiman T, Abdulmajeed A, Shahramian K, Hupa L, Donovan T, Vallittu P, Narhi T. Impact of gastric acidic challenge on surface topography and optical properties of monolithic zirconia. Dent Mater. 2015; 31(12):1445-52.
14. Harryparsad A, Dullabh H, Sykes L, Herbst D. The effects of hydrochloric acid on all-ceramic restorative materials: An in-vitro study. SADJ. 2014; 69(3):106-11.
15. Backer A, Munchow E, Eckert G, Hara A, Platt J, Bottino M. Effects of simulated gastric juice on CAD/CAM resin composites: Morphological and mechanical evaluations. J Prosthodont. 2015; 10:1-8.
16. Jones C, Billington R, Pearson G. The in vivo perception of roughness of restorations. Br Dent J. 2004; 196(1):42-45.
17. Anusavice K. Degradability of dental ceramics. Adv Dent Res. 1992; 6:82-9.
18. Arnetzla G, Arnetzlb G. Hybrid materials offer new perspectives. Int J Comput Dent. 2015; 18(2):177-86.
19. Douglas R, Przybylska M. Predicting porcelain thickness required for dental shade matches. J Prosthet Dent. 1999; 82(2):143-49.
20. Khashayar G, Bain P, Salari S, Dozic A, Kleverlaan C, Feilzer A. Perceptibility and acceptability thresholds for color differences in dentistry. J Dent. 2014; 42(6):637-44.
21. El Sayed S, Basheer R, Bahgat S. Color stability and fracture resistance of laminate veneers using different restorative materials and techniques. J Dent. 2016; 62:1-15.
22. Alencar E, Cunha E, Meireles S, Duarte R, Andrade A. The effect of drinks on color stability and surface roughness of nanocomposites. Eur J Dent. 2014; 8(3):330-36.

FIGURES:

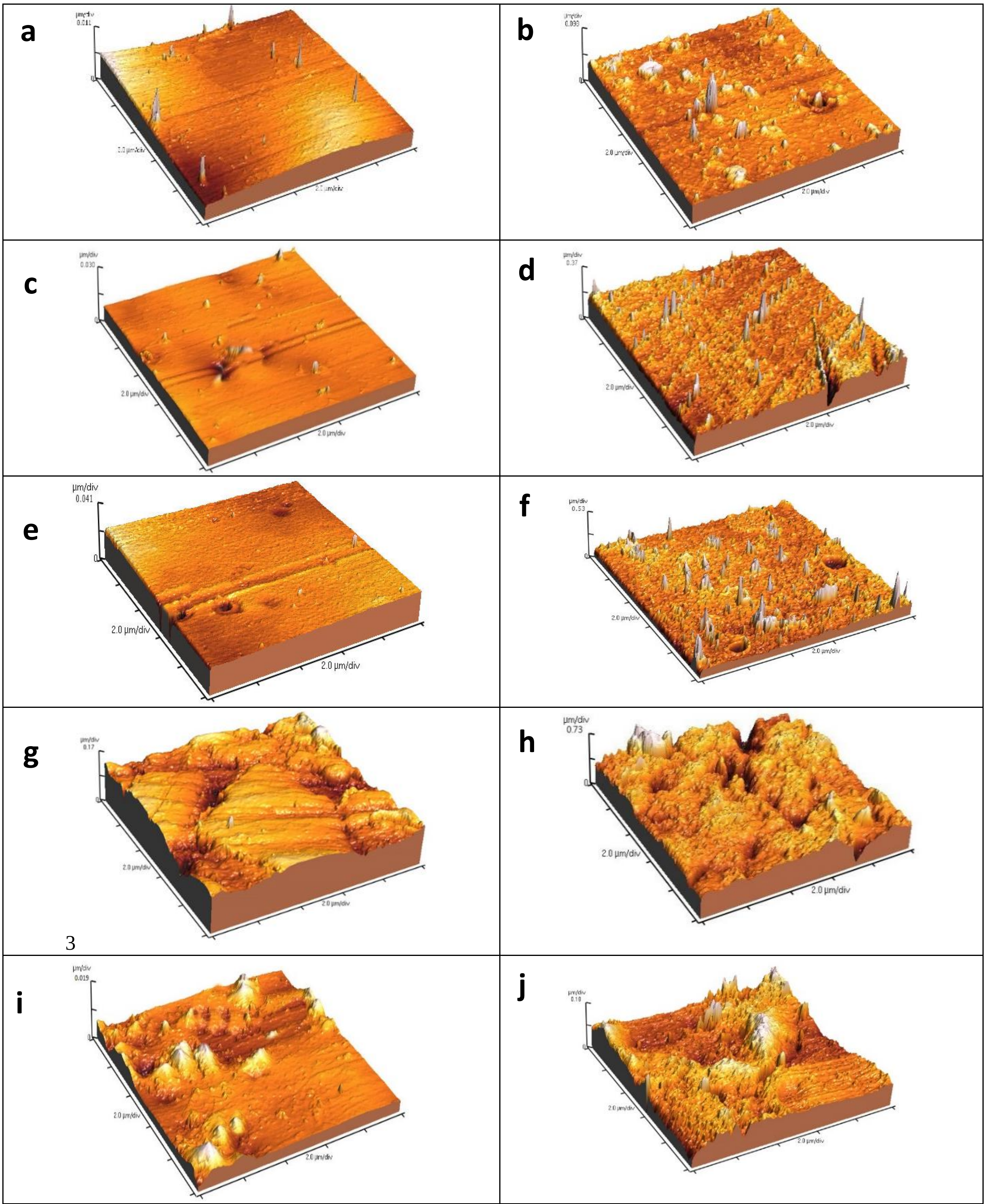

Figure (1): AFM 3D images a) Zolid FX before immersion, b) Zolid FX after immersion in simulated gastric acid, c) IPS e.max CAD before immersion, d) IPS e.max CAD after immersion in simulated gastric acid, e) Vita Mark II before immersion, f) Vita Mark II after immersion in simulated gastric acid, g) Vita Enamic before immersion, h) Vita Enamic after immersion in simulated gastric acid. i) Vita Suprinity before immersion, j) Vita Suprinity after immersion in simulated gastric acid.

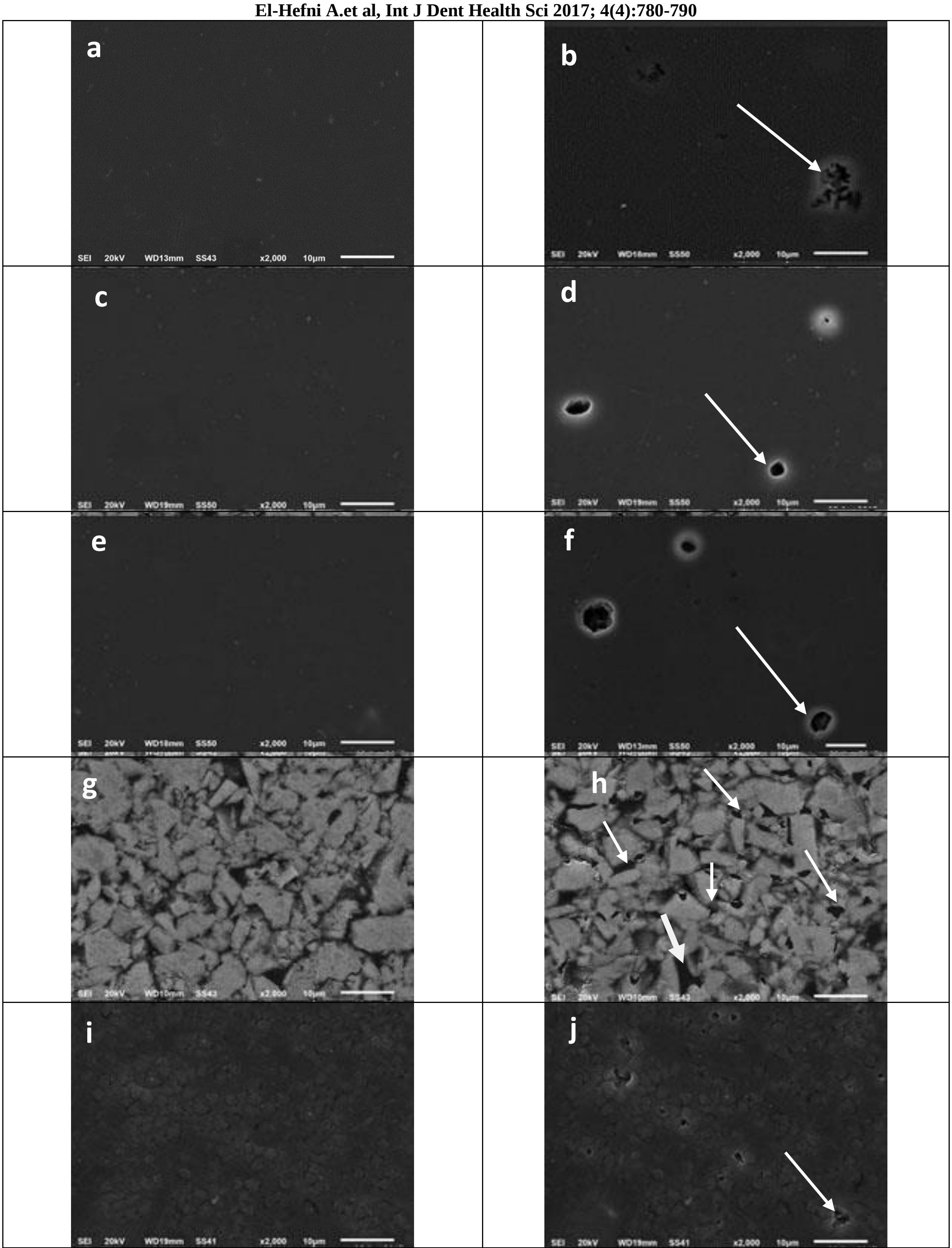

Figure (2): Selected SEM images; a) Zolid FX before immersion, b) Zolid FX after immersion in simulated gastric acid, c) IPS e.max CAD before immersion, d) IPS e.max CAD after immersion in simulated gastric acid, e) Vita Mark II before immersion, f) Vita Mark II after immersion in simulated gastric acid, g) Vita Enamic before immersion, h) Vita Enamic after immersion in simulated gastric acid, i) Vita Suprinity before immersion, j) Vita Suprinity after immersion in simulated gastric acid.

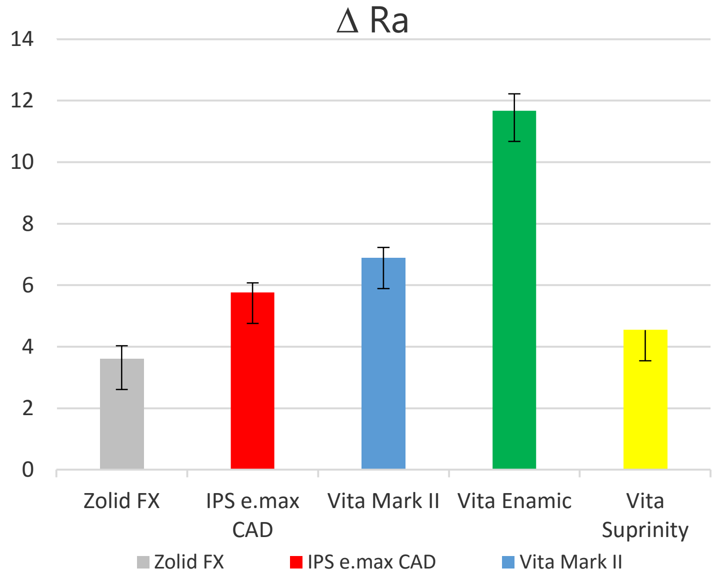

Figure (3): Bar charts represent mean values and standard deviation of changes in surface roughness (ΔRa) of tested ceramic groups.

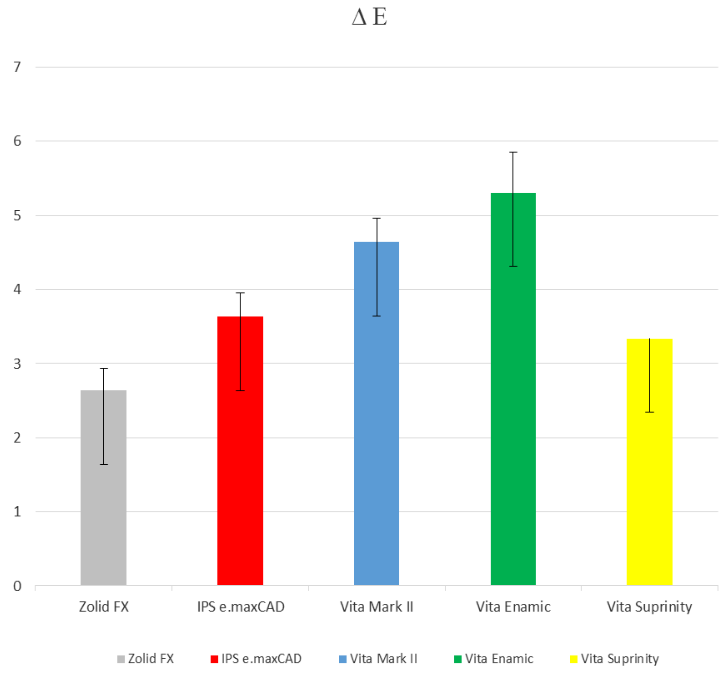

Figure (4): Bar charts represent mean values and standard deviation of color changes (ΔE) of tested ceramic groups.