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IMPACT OF SIMULATED GASTRIC ACID AND THERMOCYCLING ON COLOR STABILITY FOR DIFFERENT TYPES OF DENTAL CERAMICS USING A SPECTROPHOTOMETER

Salsabil Gaber Massoud*, Haifa Beefathimathul**
and Alaa I. Abdelhamid***

ABSTRACT

Introduction: The introduction of digital techniques in dentistry has led to advancements in various areas, including the evaluation and restoration of dental ceramics. One important aspect in this field is the study of color stability of dental ceramics, as it directly affects the esthetics and longevity of restorations.

Purpose: Using a spectrophotometer, the study examines the effect of simulated gastric acid and thermocycling on color stability in various dental ceramics.

Materials and Methods: In this study, 4 types of Monolithic CAD-CAM discs were milled, and immersed in artificial gastric acid solution monitored every 24 hours. Thermocycling was applied to all the groups and analyzed using a spectrophotometer.

Results: VITA Enamic showed statistically significant color change.

Conclusion: The present study demonstrated that the hybrid ceramics and leucite-reinforced ceramics suffered the most significant color changes after exposure to simulated gastric acid solution and thermocycling and showed that gastric acid with thermocycling changed the color of all types of dental ceramics.

KEYWORDS: Ceramics, color change, gastric acid, thermocycling, zirconia.

* Assistant Professor, Department of Prosthetic Dental Science, College of Dentistry, Qassim University, Qassim, Saudi Arabia

** Associate Professor, Department of Prosthetic Dental Science, College of Dentistry, Qassim University, Qassim, Saudi Arabia

*** Professor, Periodontology and Implant Dentistry Department, College of Dentistry, Qassim University, Qassim Province, Saudi Arabia

INTRODUCTION

Recently, the dental ceramic restoration materials have made substantial advances within the field of dentistry[1]. With the patients' growing preference for aesthetics which have a critical role in both functionality and aesthetic appeal, searching for the ideal anterior ceramic material has escalated. These ceramics' longevity is critically depending on the stability of color [2].

All ceramic restorations offer a close aesthetic appearance to the natural Optical properties of the tooth structure[2-4]. Computer aided design & computer aided manufacturing (CAD/CAM) system have allowed monolithic restorations which have been widely used in dentistry due to their stable quality[5]. CAD/CAM technology satisfies aesthetic demands such as color, translucency and chromatic stability under clinical conditions [6].

Many reports have stated extensive details on monolithics' features.[7] While, only few reports have explored surface behavior of monolithic in contact with endogenous gastric juice as well as the temperature's impact.

Gastric juice comes into contact with teeth, restorations, ceramics or even oral cavity as a result of gastroesophageal reflux disease or bulimia nervosa [8], also cases of pregnant women with sever nausea episodes for long time during pregnancy can face the issue of gastric juice [9].

As a dynamic field, the oral cavity has several parameters that impact the color stability. These parameters include pH, the humidity, temperature, food or drinks' chemicals and forces[10]. Thermo-cycling mainly consists of 2 water baths: one at 5˚C, while the other at 55˚C. As the restoration remains in the oral cavity for a year, the specimens endure 10000 cycles. Thermo-cycling technique can decrease the thermal stresses generated by the water as well as any solubility effect of the stored water on the ceramic glaze. The possibly occurring alterations may affect the ceramic's surface besides causing changes within the ceramic surface topography as well as the ceramic's optical characteristics [11].

Erosion is defined as permanent loss of dental hard tissue by acids not caused by bacterial action, these acids may be from food or drinks and this is called external or intestinal like gastric secretions [12]

The severe degradations in both dental structures and ceramic restorations have been linked to the gastric acid, most likely because of the acidic pH[13,14]. These chemicals can cause a polished, hard, and smooth depression on the surface of tooth[15]. Moreover, the composition, microstructure, chemical and optical properties, and durability of the ceramic restorations can be affected by acidic agents, exposure time, and temperature although dental ceramics can provide the most natural replacement for teeth and are considered chemically inert [16].

The chemical degradation caused by the gastric acid can lead to micro-structural alterations, which can impact the color's stability and perception along with light reflection, [17]

Comprehending the interaction among the ceramic materials, gastric acid and thermal variations can be beneficial to the dentist in order to choose the suitable material to be applied for prosthetic restorations in certain cases. The present study aimed to evaluate the color stability of the different CAD/CAM ceramic materials after exposure to a simulated gastric acid juice followed by thermo-cycling by means of a spectrophotometer. The null hypothesis was that there will be no changes within color stability of different CAD/CAM ceramics exposed to a simulated gastric acid juice and followed by thermo-cycling.

MATERIALS AND METHODS

A total of 40 plates were obtained and equally divided into 4 groups (n=10) according to the cad/cam material used. (Table 1)

TABLE (1) 4 groups according to the cad/cam material used.

Material	Classification	Manufacturer	Composition
Cerasmart	Nanoceramic resin	GC Europe (Tokyo, Japan)	71% silica and barium glass nanoparticles
Vita Enamic	Hybrid ceramic	CITA Zahnfabrik (Bad Säckingen, Germany)	SiO_2 5-63%, Al_2O_3 20-23%, Na_2O 6-11%, K_2O 4-6% B_2O_2 0.5-2% CaO <1% Tio_2 <1%
Empress CAD	Leucite-reinforced glass ceramic	Ivoclar Vivadent (Zurich, Switserland)	SiO_2 60-65% Al_2O_3 16+20% K_2O 10-14% Na_2O 2.5-6.5%
IPS emax CAD	Lithium disilicate ceramics	Ivoclar Vivadent AG Schaan, Liechtenstein	>57% SiO_2 LiO_2, K_2O, P_2O_2, ZrO_2, K_2O, P_2O_2, ZrO_2, Al_2O_3 and pigments

Blocks of CAD/CAM have been sliced into plates (thickness=1mm, length=14mm, width=12mm) with a precision saw (**ISOMET 1000-Buehler, lake Bluff, IL, USA**), the resulting ceramic plates were finished with abrasive paper (**Klingspor, Haiger, Germany**) by means of different granulations (400, 800, 1000, 1.500). Empress CAD and IPS emax CAD plates were crystallized using an Ivoclar Vivadent furnace (Programat 500) according to the manufacture instructions and for standardization, the final plate sizes were checked with a digital caliper.

Gastric acid preparation:

The specimens were individually immersed at 37ºc for 96 hour corresponds with 10 years of clinical exposure [16,25]. in an artificial gastric acid solution (5ml) in a tightly sealed container. This artificial solution had been prepared with 0.113% (0.06M) hydrochloric acid solution (HCL) using deionized water. Also, the pH was adjusted to be 1.2 besides being monitored every 24 hrs. [17,18]. Given that a bulimic patient experience frequent vomiting and acid regurgitation, thus the contact time between the gastric acid and restoration was under 1min [19].

Thermo-cycling:

In the current study, the technique of Thermo-cycling was applied for all the studied groups. All the collected specimens from the groups were subjected to 10000 thermo-cycles [16,20]. Then, they were kept for 18 sec in each bath with a transferring time of only 8 sec. The specimens were held and submerged in place with a metallic grid. The utilized sequence was: 5ºc to 55ºc to 5ºc [20]. all the tested specimens were rinsed thoroughly under running water, blot dried prior to color measurements

Spectrophotometer:

A Digital spectrophotometer (**VITA Easyshade U, Bad Säckingen, Germany**) was employed for analyzing the specimens' color. After being immersed in the artificial gastric acid solution, and subjected to thermo-cycling. The obtained values of CIELab metric were documented and stored for measurements of the color differences. The spectrophotometer was Calibrated before measuring each specimen.

Before both the immersion and thermo-cycling, L*, a*, b* mean values were compared to the collected data. Calculations for the total change of color (ΔE) were done for each material utilizing the equation:

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

Measurements were labeled CIE L*1, a*1, b*1 just before exposure and thermo-cycling. Then, measurements were labeled CIE L*2, a*2, b*2 after the exposure and thermo-cycling. The samples' ΔE of both pre- and post-gastric acid immersion and thermo-cycling were analyzed by using the formula:

$\Delta L^* = L^*2 - L^*1$

$\Delta a^* = a^*2 - a^*1$

$\Delta b^* = b^*2 - b^*1$

Where L* = the lightness coefficient (0-100), 0 (black) to 100 (white)

a* = change of the shade of redness (+ ve values) and greenness (- ve values)

B* = denotes yellowness (+ ve values) and blueness (- ve values)

Statistical analysis:

After determining the mean values and evaluating the differences among the studied groups, ANOVA or the one-way analysis of variance was applied for evaluating the statistical significance for each studied group.

RESULTS

The results show that there is no statistical significant difference was found between Cerasmart and IPS.emax CAD after 96hrs of immersion in simulated gastric acid solution and thermocycling , both of them have ($\Delta E < 1$), for Empress CAD material the difference between before and after the exposure and thermocycling was also slightly statistically insignificant as ΔE values was >1, according to this study only VITA Enamic material that had a slight discoloration after the exposure and thermocycling.

One way ANOVA was conducted between groups to compare the effect of gastric acid immersion and thermocycling on optical characteristics (color stability) for the four types of ceramics (cerasmart, VITA Enamic, Empress CAD, IPS emax CAD).

There was statistically significant difference ($p<0.05$) between all groups except between cerasmart and emax CAD, there was no statistically significant difference ($p>0.05$). The highest color change was recorded for VITA Enamic followed by Empress CAD, IPS emax CAD and the least one is Cerasmart.

TABLE (2) Illustrates ΔE mean values for all the tested groups after the exposure to the simulated gastric acid and thermo-cycling ± standard deviation (SD).

After 96h of exposure & thermo-cycling	Cerasmart	VITA Enamic	Empress CAD	IPS.emax CAD
	0.92±0.2	1.91±0.93	1.42±0.61	0.98±0.13

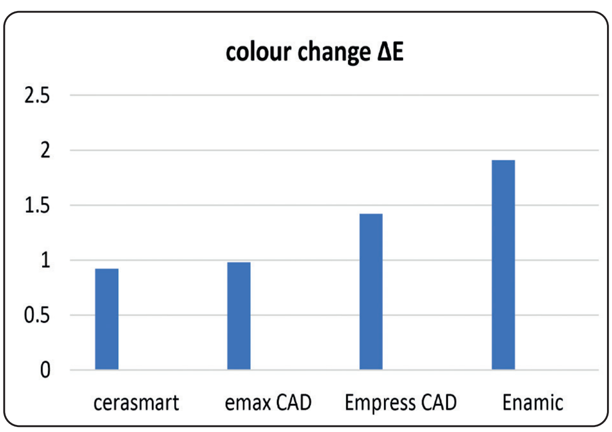

Fig. (1) A column chart showing color change among different materials

DISCUSSION

The present research was performed for evaluating if the exposure to an artificial gastric acid and the thermo-cycling may cause a color alteration of some of the available ceramic material within the market.

Our findings, the used ceramic monolithic materials were affected by the simulated solution of the gastric acid along with thermo-cycling.

In the current study, the ceramic restorative materials were chosen due to their biocompatibility, wear resistance and their exceptional aesthetic qualities. Since the optical and mechanical qualities of these materials closely resemble those of normal teeth, they can serve as a substitute for the lost tooth structure.

Throughout their lifetime, the ceramic restorations are subjected to an array of complicated oral conditions. The recurrent regurgitation of stomach contents into the mouth cavity is considered as the hallmark of the gastro-esophageal reflux [21]. The dentist must take the gastric acid effect on the restorative ceramic materials into account in case of patients requiring ceramic prosthesis.

Several *in vitro* reports have illustrated the factors responsible for triggering the acid's impact on the dental ceramics' surface. These factors include the acid's concentration, time of exposure, and temperature [22,23].

In this research, the CAD/CAM ceramic plates were immersed at 37°c for 96 hrs with the **pH**=1.2, according to the ISO testing for the ceramics' degradability, De Rijk et al [24] have reported that using 4% acetic acid at 80°c for 161hr would be parallel to an *in vivo* period of 2 years. Our study utilized the Method of Hunt and McIntyre [25] who instructed the usage of a strong acid (HCL), PH=1.2. Their immersion period duration was at 37°c for 96 hrs which is designed to resemble around 10 years of clinical exposure.

Due to its very low PH, the gastric juice affects enamel, the cementum and dentin by having a demineralization effect on them. Also, it can dissolve the glassy matrix of the ceramic materials[26-28].

In a study conducted by Aljanobi and Al-sowygh[29] who revealed that after 10,000 cycles of thermo-cycling, the translucency of Lithium disilicate and Zirconia have been reduced [29]. There are few parameters that influence the stability of color within the oral cavity. These parameters include humidity, thermo-cycling which is similar to the thermal stresses made by water as well as any solubility effect of natural water on the ceramic tinting glaze, any occurring alterations that impact the external surface of the ceramic material and might lead to modifications in the ceramic's color stability and light reflection.

In the work of Eran Dolve [20], they indicated that after thermo-cycling, the percentage of light reflection for Lithium disilicate was elevated considering that the partial removal of glaze. The specimens within this research were exposed to 10,000 cycles which signifies 1 year of exposure within the oral cavity. [16,20]

Utilizing the spectrophotometer and the used types of ceramic material in the present study (**Nano ceramic, Hybrid ceramic, reinforced glass ceramic, and Lithium disilicate ceramic**) has revealed that after the exposure, there are noticeable alterations within the stability of color for these materials in both the simulated gastric acid and thermo-cycling.

In this research as ΔE were (0.92±0.2), Cerasmart (Nano-ceramic) had an acceptable color change These findings were similar to the work of Pirvulescu I [23]. They reported that after immersion in gastric acid, Cerasmart was the only material that didn't have alterations in the surface morphology or any detectable color changes in compare to the other used materials. This could be owing to their exposure to the simulated gastric acid which caused surface roughness. Also, it might be elucidated by the presence of acid besides the constant leaching of particles.

Furthermore, Lithium disilicate ceramics ($\Delta E = 0.98 \pm 0.13$) have had acceptable color alterations. These findings have displayed comparable results about the lithium disilicate ceramics having a low discoloration rate. This might be because of the lithium disilicate properties such as structure, high resistance, and their atoms capability of slowing down the light progression [30].

On the other hand, Empress CAD and VITA Enamic have had a significant change color where ΔE was (1.42 ± 0.61) and (1.91 ± 0.93) respectively. This may be due to the heightened surface roughness and irregularities which allows the accumulation of bacteria and depresses which suggested by study conducted by Hagge M, Lindemuth J[11] and Pirvulescu I[23] who revealed that Color perception and light reflection may be impacted as the material becoming more porous with irregularities due to either the dissolution of the confined ceramic part within the monolithic material or other constituents [30,31].

In the study performed by Cruz et al [32], they have discovered that the simulated gastric acid caused color alterations in Zirconia reinforced lithium disilicate (VITA suprinity). They classified the resulted color change as unnoticeable. In comparison to our findings, their data indicated that the difference occurred because of the relatively shorter time of exposure. Besides, their specimens were not subjected to thermo-cycling.

The observed changing in color of the hybrid ceramics ($\Delta E = 1.91 \pm 0.93$) could possibly be due to the materials including polymers have higher stain content than the pure ceramic material. Additionally, the weaker the polymer matrix which is viably separated from the ceramic network along with the acid media capability of softening the resin-based materials which influences surface roughness and change color perception. Alternatively, Stawarczyk K et al [33] have shown that simulated gastric acid led to color changes but was undetectable.

Moreover, Pirvulescu et al [23] have proven that after immersion in simulated gastric acid for 18hrs, the leucite-reinforced glass ceramic can display the lowest surface roughness, while hybrid ceramic presented the highest surface roughness. Also, the surface roughness was the cause of color alterations where it reflects as an irregular and diffuse pattern of light [34].

In this study, our main limitation was that there is a difference between the clinical environment and the adopted *in vitro* environment. This is in regards to the saliva's nature and amount as its variations from one individual to the other. In addition to this, each individual's habits and frequency of the tooth brushing. Also, the ceramic plates were polish-treated and not glazed because polishing is considered the best concluding technique.

CONCLUSION

Based on our findings this *in vitro* research as well as the scope of this research's limitations, this research has evidently revealed that the gastric acid along with thermo-cycling were responsible for altering the color of all the dental ceramics' types. The present study showed that after exposure to the simulated solution of gastric acid and thermo-cycling, both the leucite-reinforced ceramics and the hybrid ceramics have endured the most significant color alterations. On the contrary, Cerasmart has proven to be unchanged after the same exposure.

RECOMMENDATIONS

Based on the *in vitro* study's results and its limitations, our results showed that there is a great need to improvise or have a novel intervention for the mechanical optical and properties of restorative ceramic materials. They can remunerate the patients' special requirement with clinical issues such as gastro-esophageal reflux, bulimia, or protracted severe episodes of nausea throughout pregnancy. In the current investigation, the obtained results will help clinicians in selecting the best material for patients having other health issues.

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