EFFECT OF CHLORINATED WATER ON MICROHARDNESS AND SURFACE ROUGHNESS OF ESTHETIC RESTORATIVE MATERIALS: AN IN VITRO STUDY

تأثير المياه المضاف إليها الكلور على مدى صلادة وخشونة الأسطح لمواد الحشو التجميلية: دراسة معملية

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الخلاصة: السباحة رياضة ممتعة وهامة في حياة الإنسان وبناء الجسم ولكن التعرض لمياه حمامات السباحة لفترات طويلة قد يؤثر على كلٍ من أسنان السباحين وكذلك مواد الاستعاضة التجميلية، حيث يستخدم الكلور في حمامات السباحة ليجعل المياه نظيفة وآمنة للسباحين. وقد يؤدى زيادة نسبة الكلور في الماء عن حد معين إلى تآكل أجزاء من طبقة المينا أو يسبب الأصباغ الصفراء على الأسنان. لذلك لابد من حساب كميه الكلور المضافة ونسبة الحامضية لمياه حمامات السباحة بدقة حتى لا تسبب أي أضرار. ويهدف هذا البحث إلي دراسة تأثير النقع في الماء المضاف إليه الكلور بتركيزات مختلفة ولفترات زمنية مختلفة على الصلادة وخشونة أسطح مواد الحشو التجميلية.

في هذا البحث، تم تحضير عدد 160 عينة من مواد الحشو التجميلية وهي مواد حشو راتينجية مركبة ومواد الحشو الكمبومير ووضعها في الماء المقطر لوقت الدراسة ثم قياس مقدار الصلادة لنصف العينات (80 عينة) ودرجة خشونة السطح (80 عينة). تم تقسيم العينات مرة أخري إلى 16 مجموعة فرعية (5 عينات في كل مجموعة فرعية) حسب مدة النقع (العادي لمدة ساعتين والمركز لمدة أربع ساعات) وكذلك نسبة الحامضية حسب تركيز الكلور المستخدم وقد كانت نسبة الحامضية المستخدمة (4.5، 5.5، 6.5، 7.5). ثم تم تحضير المياه المضاف إليها الكلور وحساب نسبة الحامضية يومياً. تم وضع المجموعة الأولى من العينات لمدة ساعتين (العادي) لتزال وتوضع في ماء مقطر حتى اليوم التالي. وكذلك تم وضع عينات المجموعة الثانية (المركز) على فترتين متساوتين كلٍ منهما ساعتين يتم خلالها إزالة العينات وغسلها بالماء المقطر. بعد ذلك يتم إزالة جميع العينات ووضعها في الماء المقطر حتى اليوم التالي. تم تكرار هذه العمليات لمدة شهر كامل وبعدها تم قياس مدى الصلادة وخشونة السطح مرة أخرى لكل العينات المستخدمة (120 عينة + 40 عينة للمقارنة). تم استخدام العينات التي وضعت في تركيز نسبة الحامضية 7.5 للمقارنة مع باقي العينات. ثم تم جمع المعلومات وتحليلها إحصائياً. وجد أن الكلور له تأثير على مدى صلادة مواد الحشو المركبة والكمبومير، حيث يؤدى إلى نقص مقدار الصلادة للعينات بزيادة نسبه الكلور المستخدمة حيث تقل نسبه الحامضية. كما وجد أيضاً أن له تأثير على درجة خشونة السطح حيث تزداد خشونة سطح مواد الحشو المركبة والكمبومير مع زيادة نسبه الكلور في الماء. كما وجد أن هناك علاقة عكسية بين كمية الكلور المضافة ونسبة الحامضية في المياه. وقد وجد أيضاً أن مدة النقع (الفرق بين ساعتين أو أربع ساعات) لها تأثير على مدى صلادة العينات لكل التركيزات المستخدمة كما أن لها تأثير على درجة خشونة سطح العينات المستخدمة في جميع التركيزات الحامضية.

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Abstract

Chlorine levels and pH receive much attention in the swimming world as they determine whether the pool water will be people–friendly that are safe, comfortable and enjoyable for swimmers or causing irritation and negative effects on the body. Restorative material samples were prepared for testing microhardness and surface roughness. A total of 160 specimens were prepared for this study. They were divided into two main groups (Composite and compomer) each group 80 specimens. Each group was divided into four subgroups according to pH of chlorinated water (7.5, 6.5, 5.5 and 4.5) (Slightly alkaline, slightly acidic, medium and highly acidic) each group 20 specimens. Each group was further classified into two classes according to the frequency of immersion (Regular = 2 hours/day and intensive = 4 hours/day). Each class was divided according to the testing procedure (Microhardness or surface roughness) into two equal subclasses. The subgroup placed in pH 7.5 was used as a control as recommended by many investigators. Microhardness and surface roughness of each specimen were tested before and one month after immersion in chlorinated water. From the results, it was found that there is a linear direct correlation between pH value and microhardness of the tested hybrid resin composite and compomer samples. A reverse linear correlation exists between pH values of chlorinated water and surface roughness of hybrid composite and compomer; the lower the pH value the greater the surface roughness. The effect of pH of chlorinated water on surface roughness is more significant with hybrid composite than of compomer.

Key words

Esthetic restorative, chlorinated water, surface roughness, microhardness

1 Introduction

Health conditions of swimming pools are of great importance, since there is possibility of transmission of various diseases to bathers. Pool's water is commonly disinfected with sodium hypochlorite or chlorine gas [1]. Chlorination is the most popular mean of disinfecting and oxidizing swimming pool water. A major advantage of chlorine is that it provides two functions: disinfection of bacteria, viruses, algae and other pathogens and oxidation of organic debris and swimmer waste. This prevents the transmission of disease and bleach out many organic impurities that are introduced to the pool by swimmers [2]. Chlorine acts on foreign substances in water to keep pools clean and safe for swimmers. Too little chlorine results in algal and bacterial growth, water illness, cloudy water and insufficient sanitation of the water [3-4].

1.1 Water chlorination

The importance of water chlorination and recommended pH values were discussed by [1-4]. Griffiths stated that chlorination is the most popular mean of disinfecting and oxidizing swimming pool water [2]. It was recommended that pH levels should be maintained between 7.2 and 7.8 [2, 4-7]. Czeczelewski studied the characteristics of physico-chemical and bacteriological features of water quality in three swimming pools of standard type accepted for most pools in the town of Biała Podlaska [8]. It was noted that falling free chlorine concentration in a pool was associated with increasing bacterial contamination of water.

Abdou studied the environmental health aspects of swimming pools in Alexandria City [9]. The high incidence of recorded itching and redness of the eyes followed by ear infections was attributed to the exposure to excess chlorine, and to the presence of pathogenic microorganisms. La Torre carried out a survey on private and public managers of 80 Italian swimming pools to evaluate the hygienic aspects and safety of the swimming pools [10]. The authors pointed out to the need of greater attention to hygienic aspects in order to reduce health risks, and provide a greater comfort to the users of swimming pools.

1.2. Effect of water chlorination and pH values on esthetic restorative materials

Munack et al. [11] determined surface microhardness and surface roughness of four poly-acid modified composite resins "compomers" after 1-year storage in water and various solutions. They concluded that Vickers hardness of all experimental samples dropped significantly due to wet storage during the first month. Surface roughness was not altered for most modified composite resins by wet storage. Nicholson et al. [12] studied the interaction of three polyacid-modified composite resins (compomers) with various acidic storage solutions, and also water, over periods of time up to 6 months and compared them with those of a glass-ionomer and a composite resin. Citric acid was found to be the most aggressive storage

medium for glass-ionomer cement, and also for the compomers.

1.3.Microhardness and surface roughness of esthetic restorative material

Watts et al. [13] studied the effect of pH and time of immersion on surface degradation in a compomer biomaterial. It was found that the surface integrity of compomers remained excellent under neutral conditions but appreciably softened under acidic conditions. EL-Kalla and Garcia-Godoy [14] studied the microhardness and surface roughness of three compomers relative to a resin-modified glass-ionomer cement and a resin composite. They stated that all tested products showed microhardness values significantly lower than composite resin material (Z100). Yap et al. [15] studied the effects of food-simulating liquids on the surface roughness and hardness of composite and polyacid-modified composite resins. They concluded that the surface roughness of all restoratives evaluated was not significantly affected by food-simulating liquids. No significant change in surface hardness was noted in the various food-simulating liquids. Yap et al. [16] studied the effects of chemical media on surface hardness of four composite restoratives. They concluded that there was no significant difference in degradation layer between the different chemicals for SF. The effects of chemical media on degradation layer were found to be material dependent. A significant but weak positive correlation exists between change in hardness and thickness of the degradation layer.

Basting et al. [17] studied the microhardness of glass ionomer/composite resin hybrid materials at different post-irradiation times. The polynomial regression showed an increase of microhardness over time for the glass-ionomers/composite resin hybrid materials, although there were differences of microhardness among these materials. There were no significant changes in microhardness levels for the composite resin over time. Gomec et al. [18] studied the effect of dietary acids pH values on surface microhardness of various tooth-colored restorations. They observed differences in the surface microhardness of various tooth-colored esthetic restorative materials conditioned in several media varied not only with the pH but also the nature of the acidic solution. Tahir et al. [19] studied the effects of pH on the microhardness of resin-based esthetic restorative materials. They concluded that the effects of pH on the microhardness of resin-based restoratives were material dependent. The compomer and giomer materials were more affected by acids of low pH than the composite material that was evaluated.

Abu-Bakr et al. [20] studied the surface roughness of compomer by laser scanning microscopy. They studied the effect of alcoholic and pH soft drinks on the surface roughness of compomer esthetic restorative materials. It was claimed that low pH media induce the chemical erosion of the hybrid esthetic restorative materials by etching the surface and leaching the principle matrix forming cautions (Na, Ca, Al, Sr). Turssi et al. [21] studied the effect of different storage media upon the surface micromorphology of resin-based restoratives. They concluded that surface roughness of resin-based restoratives subjected to a pH-cycling model was significantly higher compared with both distilled deionized water and artificial saliva. Badra et al. [22] studied the effect of different beverages on the microhardness and surface roughness of resin composite. They concluded that microhardness/surface roughness had negative impact on the composite depending on characters of materials, type of beverage and the evaluated period, the greater number of immersions in beverages resulted in a more accentuated impact on the resins' properties. In a previous work, authors investigated the effect of different pH values of chlorinated water on microhardness and surface roughness of human enamel [23]. On the other hand, no researches were found to study the effect of chlorinated water on human esthetic restorative materials. Therefore, it was thought it would be valuable to investigate the effect of different pH values of chlorinated water on microhardness and surface roughness of esthetic restorative materials.

2 Materials and methods

2.1 Materials

Two types of esthetic esthetic restorative samples were prepared for testing microhardness and surface roughness. These esthetic restorative materials are Minifill hybrid composite resin (Filtek Z250) and polyacid modified composite (Compomer) (F2000). Filtek Z250 esthetic restorative material was manufactured by 3M ESPE, is a visible- light activated radio-opaque, minifill hybrid resin composite esthetic restorative material. It is designed for use in both anterior and posterior restorations. The filler in Filtek Z250 esthetic restorative is zirconia/silica. The inorganic filler loading is 60% by volume

(without silane treatment) with a particle size range of 0.01 to 3.5 μm. Filtek Z250 esthetic restorative contains BiS-GMA*, UDMA** and BiS-EMA*** resins. It is packaged in traditional syringes. Shade A3 was used, exposure time 20 seconds and thickness was 2 mm according to the manufacturer's instructions.

The F2000 compomer is a polyacid modified resin composite esthetic restorative was manufactured by 3M ESPE, is a one part, light-curable, Fluoride releasing, radio-opaque paste that has excellent handling characteristics and physical properties. The filler in F2000 is silica with 3-10 μm particle size and 84% by volume loading. It also contains CMDA**** and GDMA***** resins. It is packaged in single-use capsules. Shade A3 was used, exposure time 40 seconds and thickness was 2 mm according to the manufacturer's instructions. Chlorine was added to water for preparing different pH values of chlorinated water.

* *BIS-GMA= Bisphenol-A-glycidyl methacrylate.*
** *UDMA= Urethane dimethacrylate.*
*** *BIS-EMA= Ethoxylated biphenol A-glycol dimethacrylate.*
**** *CMDA= Dimethacrylate functional oligomer derived from citric acid.*

**** *GDMA=glycerol dimethacrylate.*

Specimen Grouping

A total of 160 specimens were prepared for this study as shown in Table 1. They were divided into two main groups (Composite and compomer) each group 80 specimens. Each group was divided into four subgroups according to pH of chlorinated water (7.5, 6.5, 5.5 and 4.5) (Slightly alkaline, slightly acidic, medium and highly acidic) each group 20 specimens.

Table 1 Variables of the study

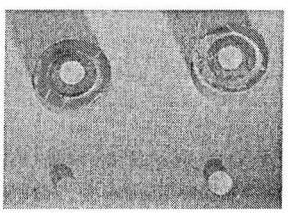
Materials	T	Resin composite
	P	Compomer
Concentration of Immersion Medium (pH value)	C0	Slightly alkaline (pH=7.5)
	C1	Slightly acidic (pH=6.5)
	C2	Medium (pH=5.5)
	C3	Highly acidic (pH=4.5)
Frequency of immersion	R	Regular (2 hours/day)
	I	Intensive (4 hours/day)
Test	M	Microhardness
	S	Surface roughness

Each group was further classified into two classes according to the frequency of immersion (Regular = 2 hours/day and intensive = 4 hours/day). Each class was divided according to the testing procedure (Microhardness or surface roughness) into two equal subclasses. The subgroup placed in pH 7.5 was used as a control as recommended by many investigators. [2, 3, 24-26]. Microhardness and surface roughness of each specimen were tested before and one month after immersion in chlorinated water.

2.2 Methods

Preparation of disks of esthetic restorative materials

Disks were prepared from Filtek Z250 composite and compomer filling materials following manufacturer's instructions. The materials were packed into Teflon mold of 5 mm diameter and 2 mm thick [20], Fig. 1. The mold was placed over a glass slab covered with a Mylar strip and the material was packed into the mold to a slight overfill using a plastic spatula with composite resin and a gun for compomer. Another Mylar strip was placed on the top surface of the specimen and covered with another glass slab. Standardized weight of 500 grams was placed over the glass slab to extrude the excess material. Then, the material was light cured (20 seconds for Filtek Z250 composite and 40 seconds for F2000 Compomer) according to the manufacturer's instructions using Cromalux-E Halogen light curing unit. The light was applied at zero distance from the top surface. The specimen was removed from the Teflon mold using back of hand of mirror. Samples were examined using a magnifying lens to discard any sample with surface voids. Samples were then embedded in acrylic resin blocks and stored in distilled water at 37°C in an incubator (Heal Force® HF, Nison Instument (Shanghai) limited, China) till the time of treatment.



(a) (b)

Fig. 1 Acrylic blocks of (a) composite and (b) compomer samples.

Preparation of chlorinated water

Chlorine tablets (Trichlor, Trichloroisocynuric acid, Nanning chemical industry Co., LTD.) were made as powder and several tests were made to reach the correct weight which gives us the required pH values. Adding 0.18, 0.4 , 1.2 , 1.7

grams weights of the powder dissolved in two liters of water produces solutions with pH 7.5, 6.5, 5.5 and 4.5 as four concentrations of chlorinated water (Slightly alkaline, Slightly acidic, Medium and Highly acidic). Each five specimens were placed in 100 ml chlorinated water, one group (Regular) for two hours/day [27] and the other (Intensive) for four hours/day, removed after 2 hours, rinsed with distilled water and air dried then placed in the chlorinated water again for 2 hours, then all specimens were removed from chlorinated water, gently rinsed with distilled water and air dried then placed in distilled water to the second day. Chlorinated water was freshly prepared before every immersion. These processes were done for six days and one day rest every week for one month [3].

Measurements of pH

Measurements of pH of chlorinated water were done using Benchtop pH/ISE (Ion Selective Electrode) Meter Model 720A Orion (Orion Research, Cambridge, England), Fig. 2. The meter/electrode was calibrated with standard buffer solutions with pH 7.0 and pH 4.0 immediately before placement into the chlorinated water. The electrode was removed from the buffer and rinsed with deionized water then placed into sample when "RDY" is displayed the sample results were recorded.

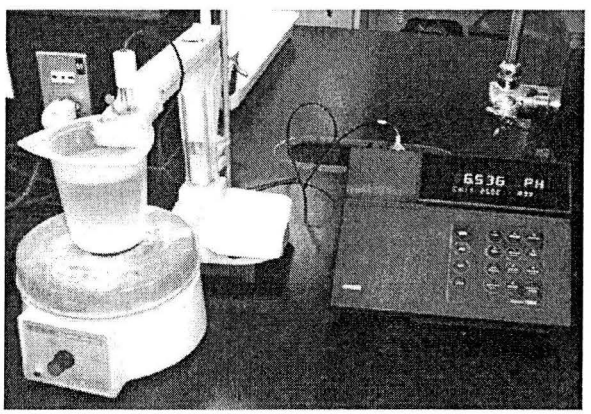


Fig. 2 pH meter (ORION model 720 A)

Measurements of microhardness

Assessment of microhardness was done for esthetic restorative material disks before and after immersion in chlorinated water. Microhardness testing was done using microscopic hardness tester (Model HV-1000, Laizhou Huayin Testing Instrument Co., China). Indentation with a Vicker diamond was done under a (4.90 N = 500 gm) load for 15 seconds [18-19]. The length of the indent diagonal was measured in the microscope to determine d_1 and d_2. The microscopic hardness value was shown on the display. Five indentations were performed on each specimen and averaged.

Measurements of surface roughness

A portable surface texture measuring instrument, Surftest SJ-201 P (Mitutoyo Corporation, Japan), was used for surface roughness assessment of the esthetic restorative material surface, Fig. 3. A diamond stylus with tip radius 5 μm is used in the measurements. The measured roughness parameter is the average roughness height of the surface Ra. The detector moves over the specimen by a driving speed 0.5 mm/s for a measured length 4.0 mm (sampling length 0.8 mm). The measured roughness parameter was the average roughness height of the surface Ra. Five traces were recorded for each specimen in different locations to get its roughness average (Ra) using ISO1997 filter type. Ra is one of the first parameters used to quantify surface texture and it is the most commonly used parameter in dentistry applications [33-35]. Most surface texture specifications include Ra either as a primary measurement or as a reference. Ra is used as a good monitor as to whether something may have changed during subsequent treatment of the surface. The collected data were tabulated and statistically analyzed using ANOVA procedure, SAS system.

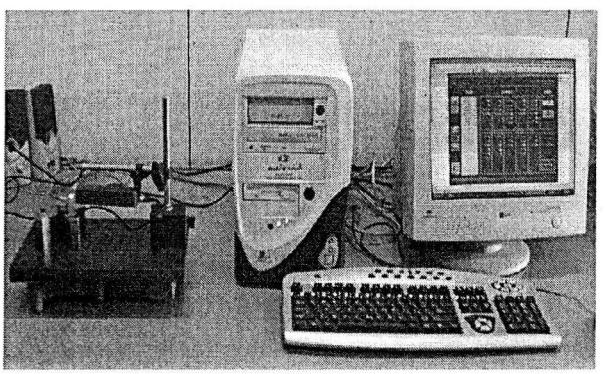


Fig. 3 Surface Roughness tester surf test SJ-201 P Mitutyo corporations Japan.

3 Results

The results of microhardness and surface roughness of the tested 160 esthetic restorative material samples after immersion in chlorinated water were gathered and statistically analyzed. In addition, histograms and curves were drawn, Figs. 4-11, to facilitate comparison among the means of the collected data.

3.1 Effect of water chlorination on microhardness

The results of testing microhardness (VHN) of composite resin material samples placed in chlorinated water at different concentrations and immersion periods were collected and statistically analyzed.

Figure 4 shows the effect of different concentrations of pH (7.5, 6.5, 5.5 and 4.5) for 2 hours/day (Regular) and 4 hours/day (Intensive). The results showed the highest mean microhardness value of composite resin material (Filtek Z250) was that of the control specimens stored in pH 7.5 (Intensive) [mean microhardness was 83.84 VHN] and the lowest mean microhardness was that of the specimens stored in pH 4.5 (Intensive) [mean microhardness was 67.66 VHN]. Statistical analysis showed that there was a significant decrease in mean microhardness values of composite resin material between the four different concentrations of pH (7.5, 6.5, 5.5 and 4.5). However, there were insignificant differences ($P>0.05$) in mean microhardness values for pH 7.5 between regular and intensive periods.

Figure 5 shows the effect of different concentrations of pH (7.5, 6.5, 5.5 and 4.5) for 2 hours/day (Regular) and 4 hours/day (Intensive) on composite resin material (Filtek Z250). The results showed that the highest % of change in microhardness value of esthetic restorative material after immersion was that of the specimens stored in pH 4.5 (Intensive) [% of change in microhardness was 16.94 after immersion] and the lowest % of decrease microhardness was that of the specimens stored in pH 7.5 (Regular) [% of decrease microhardness was 7.14]. There were direct correlations between pH and % of change in VHN for regular and intensive immersion periods.

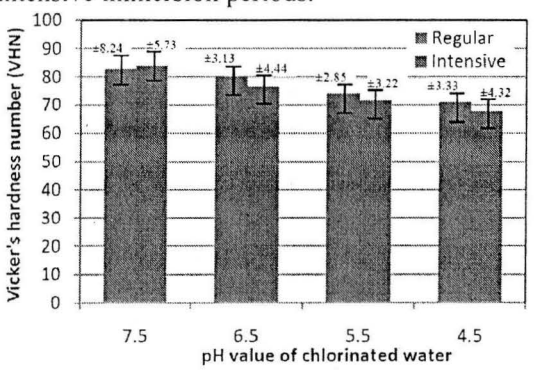


Fig. 4 Relation between microhardness of composite resin (Filtek Z250) and chlorinated water at different pHs.

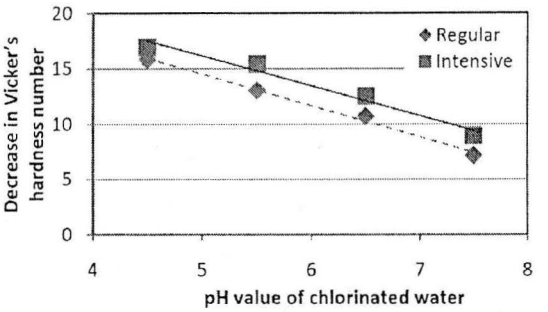


Fig. 5 Percentage change in microhardness of composite resin (Filtek Z250) as a function of chlorinated water.

Figure 6 shows the effect of different concentrations of pH (7.5, 6.5, 5.5 and 4.5) for 2 hours/day (Regular) and 4 hours/day (Intensive). The results showed the highest mean microhardness value of compomer (F2000) was that of the control specimens stored in pH 7.5 (Intensive) [mean microhardness was 61.10 VHN followed by those immersed in pH 5.5]. Whereas, there were insignificant differences between VHN of samples immersed in pH 6.5 and 4.5. It was also found that the effect of immersion period (intensive and regular) was insignificant in all tested conditions.

Figure 7 shows the effect of different concentrations of pH (7.5, 6.5, 5.5 and 4.5) for 2 hours/day (Regular) and 4 hours/day (Intensive) on compomer (F2000). The results showed that the highest % of change in microhardness value of esthetic restorative material after immersion was that of the specimens stored in pH 4.5 (Intensive) [% of change in microhardness was 24.74 after immersion] and the lowest % of decrease microhardness was that of the specimens stored in pH 7.5 (Regular) [% of decrease microhardness was 9.40]. There were direct correlations between pH and % of change in VHN for regular and intensive immersion periods.

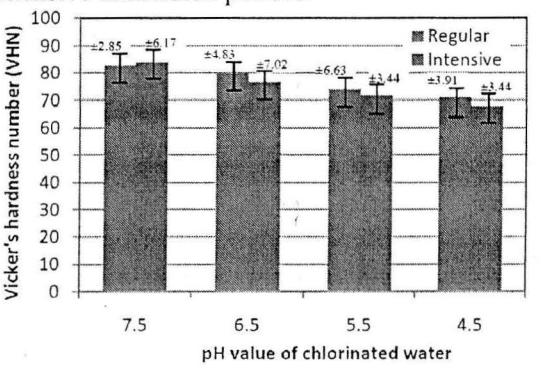


Fig. 6 Relation between microhardness of compomer (F2000) and chlorinated water at different pHs.

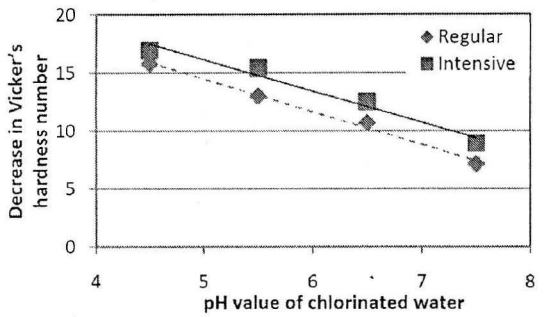


Fig. 7 Percentage change in microhardness of compomer (F2000) as a function of chlorinated water.

3.2 Effect of water chlorination on surface roughness

The results of testing surface roughness of esthetic restorative material samples placed in chlorinated water at different concentrations and immersion periods were collected and statistically analyzed.

Figure 8 showed the effect of different concentrations of pH (7.5, 6.5, 5.5 and 4.5) for 2 hours/day (Regular) and 4 hours/day (Intensive). The results showed that the lowest mean surface roughness (R_a value in μm) of composite resin (Filtek Z250) was that of the specimens stored in pH 6.5 (Intensive) [Surface roughness R_a was 1.042 μm]. Statistical analysis showed there was a significant increase ($P \leq 0.0001$) in mean surface roughness R_a values of composite resin (Filtek Z250) between the three different concentrations of pH (6.5, 5.5 and 4.5) (Slightly acidic, medium, and highly acidic). In addition, it was found that the time of immersion in chlorinated water produced increase in surface roughness reading directly proportional to the exposure time. There were insignificant differences ($P>0.05$) in mean surface roughness values for pH 7.5 between regular and intensive periods.

Figure 9 showed that the highest % of change in surface roughness (in μm) of composite resin (Filtek Z250) was that of the specimens immersed in pH 4.5 (Intensive) [% of change in surface roughness was 391.81] and the lowest % of change in surface roughness was that of the specimens stored in pH 7.5 (Regular) [% of change in surface roughness was 84.09. There was inverse relation between pH values and surface roughness, the lower the pH the greater the increase in surface roughness.

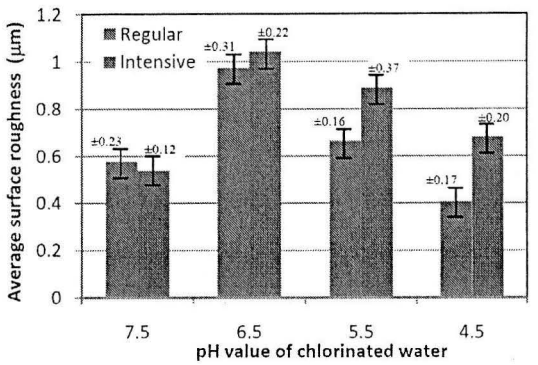


Fig. 8 Relation between surface roughness (in µm) of composite resin (Filtek Z250) and chlorinated water at different pHs.

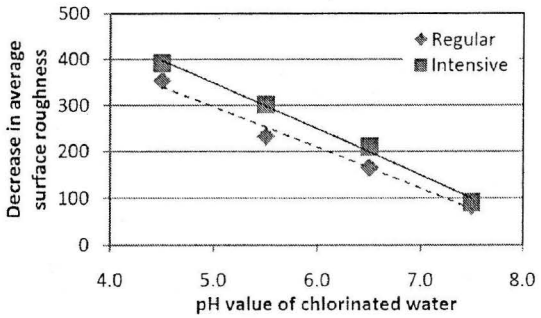


Fig. 9 Percentage change in surface roughness of composite resin (Filtek Z250) as a function of chlorinated water.

Figure 10 showed the effect of different concentrations of pH (7.5, 6.5, 5.5 and 4.5) for 2 hours/day (Regular) and 4 hours/day (Intensive). The results showed that the lowest mean surface roughness (R_a value in μm) of compomer (F2000) was that of the specimens stored in pH 6.5 (Intensive) [Surface roughness R_a was 0.680 μm]. Statistical analysis showed there was a significant increase ($P>0.05$) in mean surface roughness values between regular and intensive periods of each of the tested pH values except pH 4.5.

Figure 11 showed that the highest % of change in surface roughness (in μm) of compomer (F2000) was that of the specimens immersed in pH 4.5 (Intensive) [% of change in surface roughness was 211.86] and the lowest % of change in surface roughness was that of the specimens stored in pH 7.5 (Regular) [% of change in surface roughness was 57.94. There was an inverse relation between pH values and surface roughness of the tested compomer, the lower the pH the greater the increase in surface roughness.

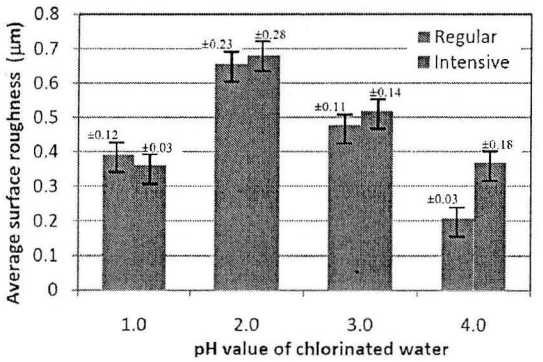


Fig. 10 Relation between surface roughness (in µm) of compomer (F2000) and chlorinated water at different pHs.

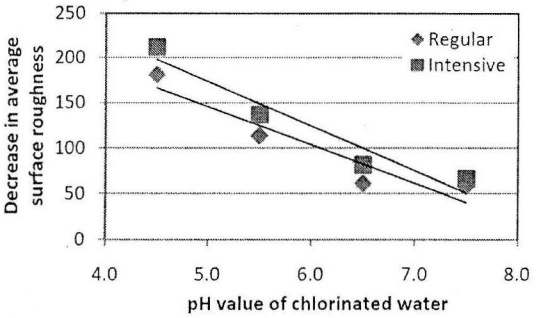


Fig. 11 Percentage change in surface roughness of compomer (F2000) as a function of chlorinated water.

4 Discussion

The idea of this investigation arose from the claims of many clinicians who noticed that a great number of competitive swimmers suffer from painful rough teeth with yellow or chalky white color [25, 31]. These were in accordance with the conclusions of Griffith [2] that aggressive water is like cancer, while basic water is similar to bad cholesterol.

Thereby, this investigation was done to point out the importance of chlorine dose placed in water for disinfection. Hence it was thought that studying the effect of pH changes of chlorinated water on esthetic restoratives would be of value. On the other hand, microhardness and surface roughness assessment were chosen because they were the most physicochemical properties affected by pH changes. In addition, they influence esthetics, plaque retention, secondary caries risk and gingival irritation [18]. It was found that the lower hardness values corresponded to high caries risk patients [32]. Wear and abrasion are also related to change in microhardness levels and this property can be considered an important parameter to predict the clinical performance of the material [33].

Trichlor tablets were used for preparation of chlorinated water as they are powerful, stabilized and having chlorine content 90% [2]. Control samples were immersed in pH7.5 as it was the recommended value by many investigators to be the safest and comfortable pool pH [2, 4, 34]. The assessed pH values (4.5, 5.5, and 6.5) were chosen as they represented above and below the suspected value (pH 5.5) which was shown to cause dental erosion by Matta and Irakawa [34] Scheper [31].

Moreover, the immersion periods selected (regular and intensive) were chosen to simulate the swimming training programs of competitive swimmers. Sweetenham and Atkinson [27] mentioned that members of swimming team are frequently subjected to swimming workouts of 4 hours in 2 sessions daily, 6 times a week or 2 hours daily 6 times a week. Whereas, the period of one month of immersion before testing was chosen as recommended by Geurtsen [26], as he reported dental erosion of competitive swimmers subjected to low pH of chlorinated water within 27 days. On the other hand, resin composite and compomer restoratives were evaluated in terms of sensitivity to chlorinated water as they represent the two main categories of esthetic restoratives. They are widely used in dentistry despite the fact they are not stable to degradation and erosion [31].

4.1 Effect of chlorinated water on microhardness of esthetic restoratives

Figures 4 and 5 revealed that that there were insignificant changes in micro hardness of resin composite samples at pH 7.5. Whereas, there was significant decrease in microhardness of resin samples immersed in acidic media. This was explained by Ortengren et al. [26], who found that acidic pH increase degradation of resin composite materials as it affects sorption and solubility. However, there were insignificant differences between results of regular and intensive immersions.

Moreover, the effect of acid media on hybrid composite was explained by Turssi et al. [15] to be due to increasing the rate of degradation of resin matrix or silane coupling agents leaving voids. Another explanation was mentioned by Abu-Bakr et al. [27] as low pH media lead to etching the surface and leaching the principle matrix forming cations . As a result individual particles are dissociated from each other.

From Figs. 6-7, it was observed that there were significant changes in microhardness of the tested compomer in all the tested conditions even with pH 7.5. However, there were insignificant differences between microhardness of samples immersed in regular or intensive periods.

This was supported by the findings of Watts et al. [26] that the surface integrity of compomers remained excellent under neutral conditions but appreciably softened under acidic conditions with loss of structural ions from the glass phase. Kwon et al. [30] showed that there was a linear correlation between the % of filler and microhardness of compomer. Thereby, loss of filler due to acidity enhanced decrease in micro hardness of compomer. The mechanism of change in microhardness was explained by Nicholson et al. [34] that acidic media enhance water sorption and promote secondary acid base reaction.

4.2 Effect of chlorinated water on surface roughness of esthetic restoratives

Figs. 8-9 revealed that there was highly significant increase in surface roughness in all the tested composite samples. However, the effect of immersion period was significant only at pH 5.5 and 4.5. This could be explained by the findings of Turssi et al. [15] that acidic water enhanced water sorption causing hydrolysis and dissolution of some of the components of resin composite. Acids cause more pronounced filler degradation. It was concluded that dissolution can increase the surface roughness. Moreover, Nicholson et al. [34] concluded that acid media are capable to soften resin based restorative materials and can provoke loss of surface integrity. It was claimed that surface roughness increase after being immersed in acidic media due to protruded particles after matrix degradation.

On the other hand, Figs. 10-11 showed that there was significant increase in surface roughness of tested compomer in each of the tested condition. The greatest increase was observed with pH 4.5 with intensive immersion. However, the effect of immersion period was insignificant in all the tested pH values except pH 4.5. These results were in agreement with those of Watts et al. [26] who found that acidic media increased surface roughness of compomers. It was found that the surface integrity of compomer remains excellent under neutral conditions but appreciably softened under acidic conditions. It was proposed that acids promote dissolution and eroding the materials leaving rough surface.

Another explanation was mentioned by Nicholson et al. [34] that acidic media enhance secondary acid-base reaction which was confirmed by Fourier-transform infrared spectroscopy. The reaction includes deposition of insoluble salts in the surface layer. This was supported by Abu-Bakr et al. [27] who reported that low pH media deteriorate the surface of compomer resulting in clinically rough and dull surface.

5 Conclusions

This investigation was designed to study the effect of immersion in chlorinated water at different concentrations and different frequencies of immersion on microhardness and surface roughness of human restorative materials. It can be concluded that there is a linear direct correlation between pH value and microhardness of the tested hybrid resin composite and compomer samples. The effect of pH of chlorinated water on microhardness is more significant with compomer than of the composite resin material. Regular and intensive immersions have insignificant differences on the decrease of microhardness of the tested composite or compomer. A reverse linear correlation exists between pH values of chlorinated water and surface roughness of hybrid composite and compomer; the lower the pH value the greater the surface roughness. The effect of pH of chlorinated water on surface roughness is more significant with hybrid composite than of compomer. The effect of immersion period on surface roughness is more significant in composite at pH 5.5 and 4.5 samples placed in all acidic media followed by compomer at pH 4.5. The recommend pH value (7.5) has insignificant effect only on microhardness of hybrid composite. So, it can be recommended that:

1. Chlorinated swimming pools should be regularly checked to have pH slightly alkaline.
2. Protective measures as fluoridation before and after swimming should be considered.
3. Other esthetic restoratives should be checked for resistance against chemical degradation.

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