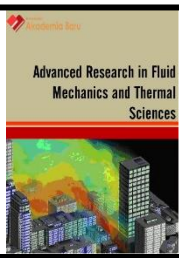
Penerbit Akademia Baru

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage: www.akademiabaru.com/arfmts.html
ISSN: 2289-7879



Influences of Oral Environment on Natural Enamel and Zirconia Crown: A Short Review

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ARTICLE INFO

Article history:
Received 12 January 2019
Received in revised form 4 April 2019
Accepted 15 June 2019
Available online 15 July 2019

Keywords:
Zirconia; enamel; oral pH; oral temperature; wear

ABSTRACT

Changes in the oral environment can affect the properties of teeth and restorative materials. Teeth tend to demineralize when exposed to an acidic oral environment, thereby decreasing the mechanical strength of the natural enamel. The demineralization of enamel worsens with temperature since the rate of chemical reaction is usually increased at an elevated temperature. As for restorative materials, exposure to an acidic oral environment resulting from external or internal factors and temperature change would increase the risk of surface degradation of zirconia where the tetragonal–monoclinic phase transformation occurs and the surface roughness increases. This condition would increase the possibility of wearing out the opposing tooth and tooth erosion. Furthermore, other wear processes, such as attrition and abrasion, might occur separately or simultaneously on the teeth during daily functions. The combination of the wear processes on teeth may increase the wear of natural enamel and restorative materials. This paper briefly discusses the effect of various oral conditions on natural enamel and restorative materials, particularly dental zirconia.

1. Introduction

Wear is a complex process that involves the removal of materials surface as a result of a direct sliding contact between two materials or exposure to a chemically active substance [1]. Wear is mainly determined by the mechanical properties of materials, such as surface hardness, roughness, fracture toughness and resistance to fatigue [2]. In the oral environment, human dentition is subjected to wear owing to the functional roles of teeth in our daily life. Teeth are essential for mastication, breathing, speech as well as facial esthetics [3]. Similar to teeth, dental materials used to restore decays are also exposed to changes within the oral cavity and can experience wear [4]. Severely worn teeth and restorations may not only affect functions and facial appearances but also

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cause pain and discomfort [5]. Therefore, understanding the wear behavior of natural teeth and restorative materials would be a major help in selecting good restorative materials that will minimize the wear of the opposing teeth.

Tooth surface loss can be attributed to three major causes: attrition, abrasion, and erosion. Attrition occurs from tooth-to-tooth contact without intervening foreign materials, such as the nature of contact between restorative materials and their opposing teeth. Meanwhile, in abrasion lesions, an extrinsic agent is present that causes friction on teeth such as brushing or coarse dietary intake [6]. Apart from mechanical wear, tooth substances are also susceptible to erosion by acidic or alkaline dissolution [7]. Erosive wear may be due to extrinsic factors involved in consumption of food and beverages with high acidity or intrinsic causes, such vomiting and regurgitation of gastric juice [8, 9]. Apart from that, temperature also contributes to the erosive potential of food and beverages. In general, the rate of chemical reaction increases at an elevated temperature [10]. In tribology, loss of tooth tissue can be characterized in terms of two-body wear (attrition) or three-body wear interacting under an acidic or abrasive fluid/slurry (erosion and abrasion). Interestingly, tooth wear may be a result of more than one causes acting singly or concurrently [11]. The current study also explores the effects of pH and temperature changes on dental enamel provides a brief overview of current knowledge on dental erosion.

In dentistry, the use of zirconia 3YSZ (3mol% yttria stabilized zirconia) as a dental restorative material has increased due to its good biocompatibility and excellent mechanical and aesthetic properties [12-16]. As a restorative material, zirconia is required to withstand the harsh oral condition including extreme changes in pH, temperature and masticatory load [17]. It is, therefore, the purpose of this review to provide a brief description on the wear behavior of zirconia in different pH and temperature surroundings.

2. Effect of Oral Environment on Enamel

In a healthy individual, the saliva pH is slightly alkaline with pH ranging from 7.1 to 7.5 [18]. However, salivary pH can drop when acid is introduced in the form of food, beverages or regurgitated gastric acid. For example, citric acid with pH approximately 3, which is commonly found in carbonated drinks can contribute to chelation of calcium ions [19]. The presence of hydrogen ions (H+) from the citric acid which can produce up to three H+ ions from each molecule (Figure 1) when it dissociates in water is the main cause to loss of tooth minerals. The H+ ions will dissolve the tooth minerals by combining with carbonate ions, as shown in Eq. (1) [20]. However, the removal of minerals mainly calcium and phosphate ions by citrate through ligand-promoted dissolution only occur at pH approaching 6 [21]. At this point, the demineralization of enamel starts [3,22]. This is known as critical pH of enamel. Critical pH can be defined as the pH at which the solution is saturated with a specific mineral. When the pH of the solution (saliva) falls below the critical pH, the solution is said to be unsaturated with that specific mineral and thereby hydroxyapatite in dental enamel tends to dissolve until the solution becomes saturated [23]. As a result, there will be net loss of minerals from the enamel or demineralization. In general, the critical pH of enamel is at pH 5.5, but it is not a constant value since it depends on the quality of saliva [21].

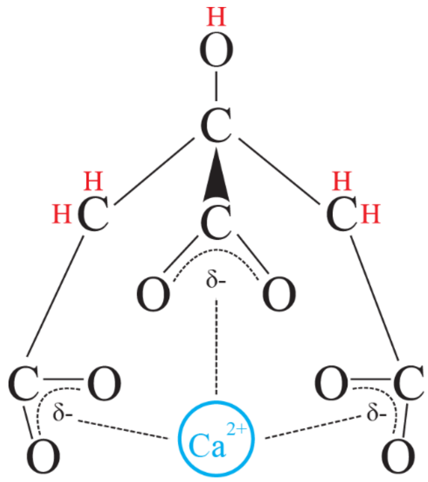

Fig. 1. Schematic of citrate ions chelating on calcium ions

$$Ca_{10-x}Na_x(PO_4)_{6-y}(CO_3)_z(OH)_{2-u}F_u + 3H^+ \rightarrow (10-x)Ca^{2+} + xNa^+ + (6-y)\left(HPO_4{}^{2-}\right) + z(HCO_{3-}) + H_2O + uF \quad (1)$$

The pH of acidic beverages is affected by the ambient temperature. The acid dissociation from acidic beverages increases with the increase in temperature [10]. Studies reported that the rate of enamel erosion increases when the acidic temperature increases from 5 °C to 60 °C [24-26]. The hardness and elastic modulus of the enamel also are affected by the acidic environment and high temperature [10]. The increase in enamel erosion and the mineral loss at high temperature can be explained by the acceleration of the chemical reaction between the liquid (saliva) and the enamel surface. More energy is present at high temperature, thereby facilitating the reaction between the saliva to the enamel surface [27].

Saliva is essential for the dilution and buffering the acidic beverages that is introduced to oral cavity [28]. The buffering capacity of saliva derives from the concentration of calcium, phosphorus and fluoride ion in the saliva that determines the degree of saturation with respect to tooth minerals [21]. These ions will be deposited into crystal voids thus reversing the effect of demineralization of enamel by acid. The dissolution of enamel also depends on other factors, such as, exposure time, type, concentration and amount of acid [23, 29]. In general, the time needed for the saliva pH to return to its original state is 2 – 5 minutes. However, the time taken for the saliva to return to its neutral condition is dependent on anatomical structure of enamel and eating habit [21]. Therefore, if the acidic ions remain for extended time period inside an oral cavity, it will contribute to erosion of enamel when the saliva pH is less than the enamel critical pH [22]. As the intraoral pH decreases, the hydroxyapatites of enamel become more soluble [30]. In short, dental erosion arises from the intricate dynamics of demineralization-remineralization of teeth.

Interestingly, dental erosion may occur concurrently with attrition or abrasion. Both attrition and abrasion are mechanical friction processes. The introduction friction process to the enamel after it is exposed to the acidic environment could lead to severe tooth wear (Figure 2). Combination of abrasion and erosion is a typical scenario seen in chewing acidic food, such as, pickles or citrus fruits. Upon contact with acidic food, demineralization of enamel rods will result in increase in the roughness (by micrometer) and porosity appearance on the enamel surface [31]. The softening of enamel will be further abraded by the coarse texture of food (Figure 2). Furthermore, when teeth come into contact at the end grinding cycle, attrition can also takes place. Attrition of enamel is especially observed when the natural enamel interdigit against restorative material. Enamel is more susceptible to wear in an acidic environment when it opposes restorative materials [32] because unlike enamel where the dissolution of enamel occurs, the restorative material has superior mechanical properties and high corrosive resistance [33]. Therefore, the soft layer of the enamel exposed to the acidic environment may be shaved off through friction.

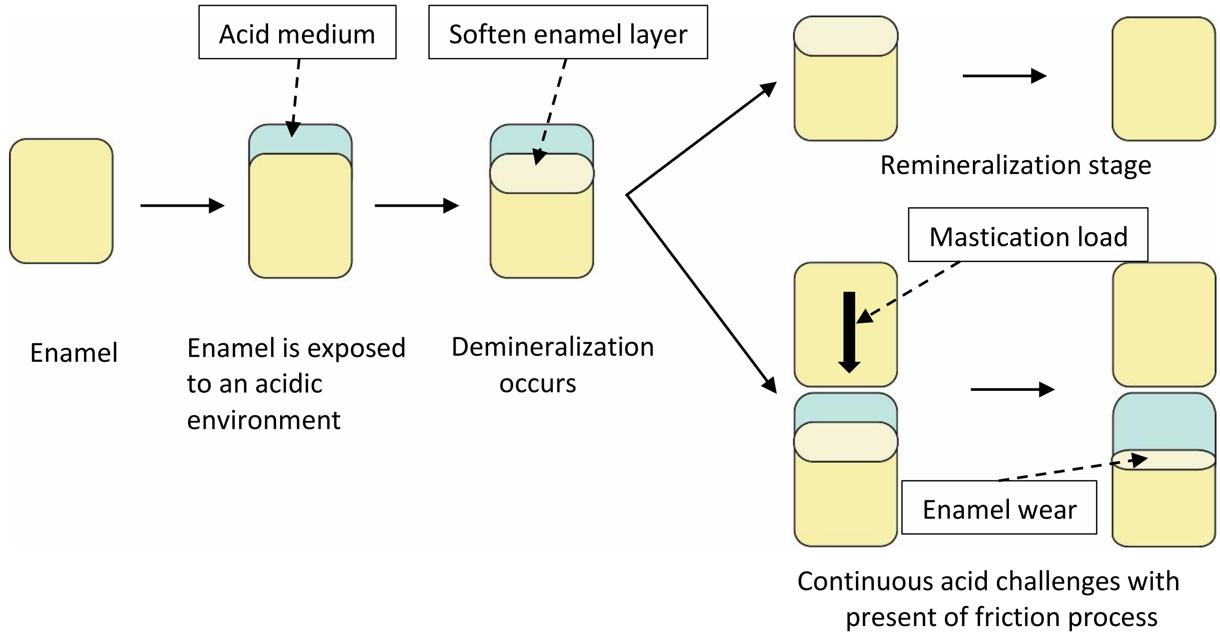

Fig. 2. Enamel demineralization and remineralization

Nevertheless, it remains to be seen whether the intraoral acidity negatively affects the mechanical properties and the surface of natural enamel. Previous research has reported contradictory results. Some researchers [9, 34] found that the enamel surface is smooth and almost similar to the original polished surface when it was tested with distilled water. However, the enamel surface tested in citric acid is rough because of corrosion in an acidic environment. On the contrary, Eisenburger and Addy [35] showed that the enamel loss obtained from in vitro wear test is higher at neutral condition compared to an acidic condition. The reason behind this situation might be due to the polishing effect on the enamel surface. Meanwhile, in the neutral environment, the enamel is prone to cracking during wear. The particles release from a crack can change the type of wear process from two-body attrition to three-body abrasion [34]. The difference in enamel loss in the neutral and acidic condition from the literature is probably due to different type and concentration of acid used in the study, since there are several factors that influence the erosive potential of the acid as discussed previously.

3. Effect of Oral Environment on Zirconia

Excessive intake of acidic food and beverages affects the mechanical properties and surface of monolithic zirconia [36, 37]. Zirconia that is exposed to an acidic environment exhibits lower flexural strength, hardness, fracture toughness, and stabilizer content, as well as an increase in volume fraction of the monoclinic phase than zirconia in a neutral condition [38]. The reduced mechanical strength of zirconia can be explained by the loss of yttria content on the surface exposed to a low-pH environment, thereby causing zirconia to be susceptible to tetragonal–monoclinic phase transformation [39]. Therefore, the volume fraction of the monoclinic phase is higher than that of the tetragonal phase in acidic environment. As a result, mechanical strength deteriorates because monoclinic-phase zirconia has poorer mechanical properties than tetragonal-phase zirconia [33, 40, 41]. This phenomenon is known as aging process. Although this process occurs at very slow rate at normal oral temperature, other factors, such as temperature of the oral environment and repeated high mastication load, could accelerate the aging process and further degrade the mechanical properties [42, 43]. The behaviour of zirconia surface that is exposed to various oral pH and temperature are still unknown. As described in the previous section, the rate of chemical reaction between the zirconia surfaces and surrounding medium is accelerated at high temperature [27]. This condition could worsen the effect of the aging process and increase the percentage of monoclinic phase in zirconia, resulting in further degradation of the mechanical properties.

The wear of restorative materials in an acidic oral environment depends on the type and concentration of acid, pH, period of exposure to the acidic environment, and temperature [44, 45]. A lubricant medium with low pH, high viscosity, and long exposure time to lubricants increases the surface degradation of restorative materials and the wear rates of the opposing teeth [46]. Degradation on a ceramic restorative surface may occur when exposed to dietary acid and alkaline substances in an oral environment during consumption of food, fruits, snacks, or beverages [47]. The lifespan of restorative materials is affected by the roughened surface because of surface degradation and can lead to bacterial colonization [16], which increases abrasion of restorative materials toward the opposing teeth. The measurement of ions leaching from zirconia surface will give better understanding about its behaviour in various oral environments [48].

4. Conclusions

This review addresses some of the effects of oral environment on natural enamel and zirconia as dental restorative materials. Several factors that influence the erosive potential of food and beverages and contribute to the dissolution of enamel (acid type, concentration and amount of acid, calcium chelating properties, exposure time, temperature, buffering capacity, and saliva flow rate) are discussed. An increase in daily consumption of acidic diet also increases the risk of enamel and zirconia wear through the combined processes of attrition, abrasion, and erosion. These processes can cause severe effects on dental enamel and zirconia. With the combination of the two wear processes, numerous factors (e.g., load, mastication cycles, speed, type and concentration of lubricant, pH, and temperature) must be considered in the analysis of wear behaviour. To the best of the authors' knowledge, further studies are needed to understand the behaviour of enamel surface on alkaline environment and zirconia surface, as well as the wear behaviour of the tooth opposing zirconia when exposed to various pH under varying oral temperature.

Acknowledgement
This work was supported by the Universiti Kebangsaan Malaysia (UKM) via research grant of DIP-2016-001.

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