Effect of Some Beverages and Mechanical Tooth-Brushing on the Surface Properties and Bond Strength of Resin-reinforced Glass Ionomer Cement

Thesis
Submitted to Faculty of Dentistry, Ain Shams
University in Partial Fulfillment of the Requirements for
Doctor Degree in Operative Dentistry

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2018

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Acknowledgement

I am greatly honored to express my gratitude to ***Professor Dr. Moukhtar Nagy Ibrahim,*** Professor of Operative Dentistry, Faculty of Dentistry, Ain Shams University for his kind guidance, sincerity, extraordinary supervision during this research work.

I would like to express my sincere thanks and deep gratitude to ***Dr. Farid Mohamed Sabry El-Askary,*** Professor of Operative Dentistry, Faculty of Dentistry, Ain Shams University for his valuable unlimited guidance, and mentor attitude. I benefited greatly from his experience and knowledge throughout this research work.

I would like to express my gratitude to ***Dr. Zainab Mohamed Diaa El-Din Soliman,*** Lecturer of Operative Dentistry, Faculty of Dentistry, Ain Shams University for her excellent advices, valuable guidance and help during this study.

Dedication

I wish to dedicate this work to my parents.

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In clinical practice, Glass ionomer cements (GICs) have been widely used mainly in class III, V and primary dentition. Chemical adhesion to tooth structure, long-term fluoride release and low coefficient of thermal expansion and contraction are characteristics that make GICs clinically attractive. Resin-modified GICs (RMGICs), one of the major modifications of the commercial GICs, were developed to partly overcome the problems associated with conventional GICs, such as poor handling characteristics, sensitivity to moisture during initial setting and poor mechanical strength(1,2).

Dental erosion can be clinically defined as the consequence of irreversible mineral loss from tooth surfaces due to an acidic dissolution process not involving bacteria from oral biofilms. Along with attrition and abrasion, dental erosion is considered an important factor in tooth wear and may be caused by a series of extrinsic factors, among them is the dietary habits as well as intrinsic factor, such as gastroesophageal reflux. High consumption of acidic beverages currently represents the most important external risk factor for erosion in children and adults(3).

Tooth-brushing constitutes another important issue in wear process in non-stress bearing areas, such as cervical areas. Even though tooth-brushing plays an important role in oral hygiene, its continuing action might damage the surface of resin based restorations. This might lead to a rough surface which is prone to staining, plaque accumulation, soft tissue inflammation and recurrent caries(4).

Different in-vitro studies aimed to evaluate the effect of beverages and/or tooth-brushing simulation on surface properties of RMGICs and/or tooth substrates and their associated bond strength(5–8). Increased soft acidic drinks consumption associated with tooth-brushing may lead to change in surface properties of RMGICs and enamel, which may affect the longevity of RMGIC restorations used in cervical lesions. Accordingly, it might be of value to evaluate the surface properties of RMGIC and enamel as well as bond strength of RMGIC-to-RMGIC and RMGIC-to-enamel after pH-cycling protocol associated with mechanical tooth-brushing.

I. Glass-Ionomer Cements:

Glass-ionomer cements (GICs) were invented by Wilson and Kent in 1970s(9) in an attempt to overcome toxicity and poor esthetics of dental amalgam. (GICs) are esthetically more attractive than metallic restorations(10). Their main advantages are relative ease of use, good biocompatibility, long-term fluoride ion release, low coefficient of thermal expansion and chemical bonding to tooth substrate in contrast to resin composites which bond micromechanically(11). Regarding their unique properties, GICs may be used in a wide range of clinical applications as luting cements, filling materials and lining cements due to ability to modify their physical properties by changing the powder/liquid ratio or chemical formulation.

I.1. Conventional glass ionomer cement:

I.1.1. composition of GIC:

Conventional GIC is the product of an acid-base reaction between an ion leachable fluoro-alumino-silicate glass powder that can react with water soluble acids such as polyalkenoic acids, either homopolymer poly(acrylic acid) or the 2:1 copolymer of acrylic acid and maleic acid. The main components of the powder are silica (SiO_2), alumina (Al_2O_3), calcium fluoride (CaF_2), sodium fluoride (NaF) and aluminum phosphate ($AlPO_4$). The main structure of the glass is the alumina and silica which form the skeletal backbone of the glass.

The polyacid that reacts with the ionomer glass is usually a polycarboxylic acid. The reactivity depends on the ingredients of the acid or copolymeric acid, as well as on its molecular weight and concentration. By adding maleic or itaconic acid, the number of carboxylic groups relative to the total molecular weight increase and thus the reactivity is increased. The polyacid is either part of the liquid as an aqueous solution or is incorporated into the cement powder as a dried powder. In the latter case the liquid is simply water in which the dried polyacid dissolves upon mixing (12).

I.1.2. Setting reaction of GIC:

Glass ionomers set within 2-3 minutes from mixing by an acid-base reaction. Polyacrylic acid protons attacks the surface layer of glass network which results in the release of cations, mainly Al^{3+} and Ca^{2+} or Sr^{2+}. The cations subsequently serve to form salt bridges between the polyacid chains and result in the formation of silica hydrogel, the calcium polyacrylate formation exhibiting faster reaction kinetics than that of aluminum polyacrylate(13). The carboxylic acid attacks the surface layer of glass powder, whereas the glass core remains intact. The glass core acts as filler in the cement matrix. When this setting reaction occurs, all of the water becomes incorporated into the cement, and no phase separation occurs. The reactivity of the glass surface determines the quality of the set cement. A silica gel layer with gradient properties is formed at the interface between the glass particle and the cement matrix. The polycarboxylic acid is typically used in aqueous solution at a concentration of 45 wt %. In order to control the GIC setting kinetics, a certain amount of dried polycarboxylic acid is added to the glass powder. After this initial hardening, there are further reactions, which take place slowly and are together known as maturation. They are associated with various changes in the physical properties of the resulting GIC. Strength and translucency typically increases. In addition, the proportion of tightly-bound water within the structure increases(14).

Role of water

Glass ionomer cements are water-based materials. Incorporation of water with glass-ionomers is associated with increases in the translucency of the glass-ionomer cement. Water is the solvent for the polymeric acid, it allows the polymer to act as an acid by promoting proton release, it serves as the reaction medium needed for acid dissociation and ion transfer initially, it is the medium in which the setting reaction takes place, and lastly, it is a component of the set cement. During the first stages of the setting process, water from the cement liquid is fully incorporated into cement structure. At the end of the setting reaction, it slowly hydrates the cross linked matrix and the siliceous hydrogel leading to the formation of a stable gel structure that is stronger and less susceptible to moisture(15).

The water present in the set cement is in two forms: loosely bound water, the fraction that can be easily removed by desiccation leading to crazing and cracking which presented as a chalky surface appearance and tightly bound water, which is bound within the matrix structure and cannot be removed by desiccation. As the cement ages the proportion of loosely bound water decreases relatively to the proportion of tightly bound water(16).

Fluoride release

Fluoride release is considered one of the important advantages of GICs. It can be sustained for very long periods of time, and shows a pattern of an initial rapid release (“early burst”), followed by a sustained, lower level diffusion-based release(17,18).

During the setting reaction a variety of ionic constituents is released from the glass, including fluoride. Two mechanisms have been proposed by which fluoride may be released from glass-ionomers into an aqueous environment. One mechanism is a short-term reaction, which involves rapid dissolution from outer surface into solution, whereas the second is more gradual and resulted in the sustained diffusion of ions through the bulk cement(19). An initial high release from glass-ionomers over the first 24h is likely due to the burst of fluoride released from the glass particles when reacting with the polyalkenoate acid during the setting reaction. After the initial burst, fluoride release slows down and is followed by a prolonged long-term fluoride release, which occurs when the glass dissolves in the acidified water of the hydrogel matrix(20).