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داليا ممدوح جلال حموده

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جامعة القاهرة

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المشرفون

أستاذ دكتور / محمد محمود عبد المحسن

أستاذ العلاج التحفظي
كلية طب الفم والأسنان
جامعة القاهرة

دكتور / علا محمد ابراهيم فهمي

أستاذ مساعد العلاج التحفظي
كلية طب الفم والأسنان
جامعة القاهرة

دكتور / ايمان عزت والي

مدرس الميكروبيولوجي
كلية طب
جامعة القاهرة

List of Contents

Title	Page
List of Contents	i
List of Tables	ii
List of Figures	iii
Introduction	1
Review of Literature	4
Aim of the Study	33
Materials and Methods	34
Results	53
Discussion	63
Summary and Conclusions.....	76
References	78
Arabic Summary	—

List of Tables

Table		Page
Table (1)	Variables of the Study	35
Table (2)	Interaction between Variables	35
Table (3)	Materials and their Specifications	36
Table (4)	Microbiologic Media Used	37
Table (5)	Sugar Fermentation Tests	41
Table (6)	Statistical Analysis for the Agar Diffusion Inhibitory Test on Streptococci	55
Table (7)	One-Way ANOVA (Streptococci)	56
Table (8)	Statistical Analysis for the Agar Diffusion Inhibitory Test on Lactobacilli	57
Table (9)	One-Way ANOVA (Lactobacilli)	58
Table (10)	Statistical Analysis for Fluoride Ion Release from Different Materials	61
Table (11)	One-Way ANOVA (Fluoride)	61

List of Figures

Figure		Page
Fig (1)	Mitis Salivarius and Bacitracin	43
Fig (2)	TISAB II Solution	43
Fig (3)	Standardized Fluoride Solutions (10ppm and 100ppm)	43
Fig (4)	The split teflon mould and the accessory ring	44
Fig (5)	Primary Culture of Streptococci Mutans on Mitis Salivarius Agar	44
Fig (6)	Primary Culture of Lactobacilli on Rogosa Agar	45
Fig (7)	Anaerobic jar with gas pak inside.....	45
Fig (8)	Sugar Verification test	46
Fig (9)	S. Mutans on Blood Agar	46
Fig (10)	Bacteriologic Loop	47
Fig (11)	Adjusting to 0.5 MacFarland turbidity.....	47
Fig (12)	Results of the agar disk-diffusion tests on day 2....	48
Fig (13)	Inhibition zone around the Vitremer disk measured by a ruler	49

Fig (14)	Fluoride ion electrode, reference electrode and temperature probe connected to ion meter	52
Fig (15)	The results of fluoride release in ppm and temperature measurement in °C displayed on LCD	52
Fig (16)	Streptococci inhibition zones(in mm) caused by the different restorative materials on the tested time periods	56
Fig (17)	Lactobacilli inhibition zones(in mm) caused by the different restorative materials on the tested time periods	58
Fig (18)	Fluoride ion release from the different restorative materials on the tested time periods	62

Secondary or recurrent dental caries is by far the most frequent reason for replacement of restorations (**Mjor, 1996**). It is by definition found at the interface of tooth and restoration and is, in general, a result of microleakage (**Arends et al, 1995**). The persisting bacterial presence, together with the lack of a thoroughly hermetic seal between the filling and the cavity walls, thus allowing bacterial leakage, may be involved in the development of recurrent caries (**Herrera et al, 1999**). The ability of a restorative material to resist secondary caries and microleakage at its margins will, to a great extent, determine whether a restoration will succeed or fail (**Attar and Onen, 2002**).

Development of an ideal restorative material that provides a permanent seal with tooth structure has always been the aim of restorative dentistry. Unfortunately, complicating factors present in the oral environment, such as changes in intraoral temperature (thermal expansion); solubility of certain restorative materials in saliva and changes in pH (**Olsen et al, 1989; Donly and Ingram, 1997**) make it difficult for such an ideal restorative material to exist. Therefore increased emphasis has been placed on developing restorative materials with anticariogenic properties.

The beneficial effect of fluoride for the prevention of dental caries is well documented and has prompted the inclusion of fluoride into a host of dental materials (**Forsten, 1991; Donly and Ingram, 1997; Dionysopoulos et al, 1998; Grobler et al, 1998**). Fluoride releasing dental restoratives have an effect on secondary carious lesions at the interface of the restoration (**Garcia and Gensen, 1990; Marcushamer et al, 1993**).

The caries preventive mechanisms of fluoride include increased resistance of tooth substance to demineralization, promotion of remineralization and antibacterial effects (**Van Dijken et al, 1997**). The

antibacterial effects include, inhibiting the enzyme enolase leading to reduced glucose uptake, and interfering with the bacterial acid production thus allowing the growth of other species of bacteria and inhibiting proliferation of cariogenic bacteria (**Hamilton, 1990**). This antibacterial effect is an important property because inactivation of bacteria means a direct strategy to eradicate the cause of dental caries (**Imazato et al, 2003**)

Glass-ionomer cements were first introduced to the dental profession by Wilson and Kent in 1972. Their main characteristics are; an ability to chemically bond to enamel and dentine, biocompatibility with the pulp and periodontal tissues, and fluoride release producing a cariostatic and antimicrobial action against *Streptococcus mutans* in plaque (**Olsen et al., 1989; Forsten, 1991; Donly and Ingram, 1997; Dionysopoulos et al., 1998**).

The conventional glass-ionomer systems, however, suffer from certain disadvantages. These disadvantages are the short working time, the long set time, susceptibility to early moisture contamination, desiccation after setting, and brittleness (**Dionosopoulos et al, 2003**). In order to overcome these limitations yet preserve their benefits, two types of hybrids of glass-ionomers and resin composites were introduced. The first is the resin modified glass-ionomer, or a glass-ionomer modified by the addition of methacrylate resins. This hybrid of glass-ionomer offers longer working and controlled setting times, rapid development of strength, lower sensitivity to environmental moisture changes, and can be finished and polished immediately after being light cured (**Sidhu and Watson, 1995; Musa et al, 1996**). The second hybrid is the polyacid-modified resin composite (or 'compomer'), which contains some components of a glass-ionomer but lacks the typical glass-ionomer acid/base reaction during the initial setting process (**McLean et al, 1994**).

Recently, fluoride-releasing composites were launched on the market by many manufacturers. They are loaded with fluoride-containing filler or fluoride compounds aimed at remineralizing effects, and are also expected to exhibit some antibacterial effects due to the release of fluoride ions.

Despite the efficiency of glass-ionomers in reducing secondary caries, relatively little work has been done on new generation fluoride releasing restorative materials. These include resin-modified glass-ionomer cements; polyacid modified resin composites (compomers) and fluoride releasing resin composites. The purpose of this study was to determine the antibacterial effect of the different groups of fluoride releasing materials and the short term fluoride release (1 week), during which the highest release of fluoride occurs. The relationship between the antibacterial effect and the fluoride release potential was also investigated.

Antibacterial properties of dental restorative materials

Updegraff et al, in 1971, studied the antibacterial activity of different restorative materials under various conditions. Samples of 21 commercial dental restoratives were prepared, formed into disks and laid on an inoculated agar plate. The bacteriostatic activity of each sample was assayed against *Staphylococcus aureus*, streptococcus species, *Lactobacillus plantarum*, *Bacillus subtilis* and mixed bacteria from the mouth. After incubation the diameter of the zone of inhibition was measured for each sample. Different conditions, such as sterilization, aging, air oxidation and leaching in water or saliva were tested for their effect on antibacterial activity of the exposed surface. The sterilization procedures had little or no effect on results. The duration of bacteriostatic activity was decreased rapidly by leaching in water.

McComb and Ericson, in 1987, investigated the antibacterial activity of commercial lining cements. A liner which contains calcium hydroxide and is polymerized by visible light (Prisma VLC Dycal) and a glass-ionomer lining cement (GC lining cement) were compared with two more established lining cements (Advanced Formula II Dycal (AF II Dycal) and Life). Antibacterial activity at 24, 48 and 72 hours was measured on blood agar plates inoculated with *Streptococcus mutans* (*S. mutans*); *Lactobacillus casei* and chewing-stimulated saliva.

Prisma VLC Dycal did not affect bacteria. The glass-ionomer lining cement with an acidic pH at setting had the most pronounced effect on all tested organisms. Even after 48 hours' setting it inhibited growth of *S. mutans*. The control lining cement (AF II Dycal) showed antibacterial activity towards both specific microorganisms as well as some activity against the salivary organisms. The material 'Life' showed only partial

inhibition of microbial growth. The surface pH of the freshly set cements containing calcium hydroxide was alkaline. It would seem that a simple correlation between high surface pH and antibacterial activity among these cements does not exist.

Scherer et al, in 1989, studied and compared the antimicrobial properties of 14 different restorative materials, 9 of which were glass-ionomer cements. The materials were mixed according to manufacturer's specifications and exposed to four types of bacteria commonly found in caries and plaque. Zones of bacterial inhibition were measured for all materials in millimeters. Glass-ionomer cement materials, materials containing zinc oxide, and amalgam produced measurable zones of inhibition.

Meiers and Miller, in 1996, evaluated the antibacterial effects of the dentin bonding systems Syntac, ProBOND, Gluma 3-step, the resin modified glass-ionomers Photac-Fil, Fuji Lining LC, Fuji II LC, and the poly acid-modified composite resins Variglass, Geristore, and Infinity were evaluated using the cariogenic bacteria *S. mutans*, *Lactobacillus (L) salivarius*, *Streptococcus(S) sobrinus*, and *Actinomyces (A) viscosus* in vitro with a modified cylinder drop plate agar diffusion assay. All glass-ionomers, the polyacid-modified composites, and the primers and adhesives of the dentin bonding systems exhibited various degrees of antibacterial activity against most of the tested bacteria. The antibacterial activity of the adhesives of dentin bonding systems was anticipated because of the glutaraldehyde used in their formulations.

Benderli et al, in 1997, investigated the effects of filling and lining materials in various compositions on *S. mutans*. Five glass-ionomer

cements (Vitrebond, XR Ionomer, Ketac-Bond, Shofu Base Cement, and Shofu Lining Cement) and two composite materials (Heliomolar, Concise) were used in this study. Samples from these materials were prepared in sterilized conditions and hung in tryptic soy broth medium containing 5% sucrose. The media were inoculated with *S. mutans*. After 5 days, the plaque that had accumulated on the surfaces was scraped off and weighed in wet and dry conditions. Then the colonies were counted and evaluated in comparison with each other. The least amount of plaque and colony numbers were found on Vitrebond material disks. There were no differences among XR Ionomer, Heliomolar and Ketac-Bond. Concise gave better results than some materials containing fluoride; whereas the most abundant amounts of plaque were found on Shofu Base Cement and Shofu Lining Cement.

Herrera et al, in 1999, examined the in vitro response of 32 strains belonging to the genera Streptococcus, Lactobacillus, Actinomyces, Porphyromonas and Clostridium to the presence of 4 different glass-ionomer cements: Ketac-Fil, Ketac-Silver, Fuji II LC and Vitremer. Agar plate diffusion was the method used for the bacterial cultures, which included a chlorhexidine control. All four glass-ionomer cements were photocured in agar wells. They were found to inhibit bacterial growth, though with noteworthy differences in their spheres of action. Vitremer was the cement determined to have the greatest antibacterial effect, whereas Ketac-Silver presented the least inhibitory action.

Herrera et al, in 2000, studied the antibacterial activity of resin adhesives, glass-ionomer and resin-modified glass-ionomer cements and a compomer in contact with dentin caries samples. A total of 103 clinical samples of carious dentin were used to study the antibacterial action of

different dental resin adhesive materials (Gluma 2000, Syntac, Prisma Universal Bond 3, Scotchbond Multi-Purpose and Prime & Bond 2.0), glass-ionomer cements (Ketac-Cem, Ketac-Bond, Ketac-Silver, Ketac-Fil), resin-modified glass-ionomer cements (Fuji II LC, Vitremer and Vitrebond) and a compomer (Dyract). The agar plate diffusion method was used for the microbial cultures and a chlorhexidine control. The growth of the caries-producing microorganisms was effectively inhibited by the Vitremer and Vitrebond cements and to a lesser extent by the Scotchbond Multi-Purpose adhesive system. Overall, there were statistically significant differences in the antibacterial activity of the products tested.

Karanica-Kouma *et al*, in 2001 examined the antibacterial activities of the bonding systems Syntac, EBS and Scotchbond 1, the polyacid-modified composite resins Hytac and Compoglass, and the composite resins Tetric, Z100 and Scalp-it. They were evaluated using the cariogenic bacteria *S. mutans*, *L. salivarius*, *S. sobrinus* and *A. viscosus* in vitro with a modified cylinder drop plate agar diffusion assay. Four wells were created in the agar and filled to the rim with either 1·0% glutaraldehyde, which acted as a control, or the material to be evaluated. The dentin bonding systems, the compomers and the composite resins were irradiated for 60 s with a visible light curing unit immediately after placement into the agar wells. All materials were handled under aseptic conditions according to the manufacturer's instructions. All plates were incubated at 37 °C in an atmosphere of 5–10% CO₂ for 48 h. Zones of bacterial growth inhibition were measured to the nearest 100th of a millimeter. All measurements of zone diameter included the diameter of the well and were measured at the widest part of the zone. Antimicrobial

tests were repeated three times, and the mean diameter of the inhibition zone values for each compound was determined.

All adhesives of the dentin bonding systems and the polyacid-modified composite resins exhibited various degrees of antibacterial activity against all of the tested bacteria. On the contrary, composite resins did not affect bacterial growth. The data suggest that the use of these adhesives and polyacid-modified composite resins may reduce the consequences of microleakage owing to their antibacterial properties.

Herrera et al, in 2001, studied the in vitro antibacterial activity of the glass-ionomer restorative cements Ketac-Cem, Ketac-Bond, Ketac-Silver and Vitrebond, in conjunction with 32 strains of five bacteria involved in the development of caries: *Streptococcus* spp., *Lactobacillus* spp., *Actinomyces* spp., *Porphyromonas* spp. and *Clostridium* spp. The agar plate diffusion method was used for the cultures, which included a chlorhexidine positive control. All the glass-ionomer cements tested inhibited bacterial growth, but with considerable differences in the scope of their action. Of the four cements, Vitrebond, resin-modified glass-ionomer cement, was determined to be the most effective bacterial inhibitor.

Boeckh et al, in 2002 investigated the antibacterial effects against *S. mutans* of a fine-hybrid resin composite (FH-RC; Tetric Ceram), an ion releasing resin composite (Ariston pHc), a self-curing glass ionomer cement (SC-GIC; Ketac-Molar), a resin-modified GIC (RM-GIC; Photac-fil), and a zinc oxide eugenol cement (ZOE; IRM). Bacterial suspensions were placed into narrow 20- μ l conical cavities within the materials. The suspensions were removed from the restoratives, after incubation for 0, 4, 8, 24, 48h and 1 week, and the numbers of viable bacteria were