Dentinal Tubular Flow and Effective Caries Treatment

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Although dentistry has made great strides in the last century in terms of improving patient comfort, fine-tuning restorative techniques and developing advanced equipment to identify decay, it is all too apparent that the high incidence of recurrent decay is unacceptable and may actually be on the rise. Fontana, DDS, PhD and Gonzales-Cabezas, DDS, PhD recently reported that 71% of all restorative treatments are performed on previously restored teeth with recurrent caries as the predominant cause. (1)

Terry Donovan, DDS, Director of Advanced Education in Prosthodontics, USC reported a vast discrepancy in the longevity of various types of restorations with an emphasis on gold restorations. One, short-term study reported a 50% failure of Class II gold inlays within seven years. Two recent articles authored by Gordon J. Christensen, DDS, MSD, PhD, “Achieving Optimum Retention for Restorations” and “How to Kill a Tooth”, bring dentin bonding into question on two counts: effectiveness and safety. (3) The hypothesis can be made that current restorative failures and high rates of recurrent decay are indicators of the use of dental materials that function poorly in vivo.

Oral Cavity Function and Dentinal Tubular Flow

An understanding of dentinal tubular flow is essential to the evaluation of the biological effectiveness of dental materials. A review of research and literature by Ralph Steinman, DDS, Loma Linda University, explains the physiology of the teeth, the impossibility of maintaining a sterile field and the genesis of tooth decay. Dr. Steinman was one of the founders of Loma Linda University Dental School. He conducted over one hundred studies, spanning forty years, describing the relationship of cariology and the “dentinal fluid transport system”.
It is fortunate that Dr. Steinman’s work in collaboration with that of John Leonora, PhD (endocrine physiologist) has been resurrected by the diligence of Dr .Clyde Roggenkamp of Loma Linda University. Published in 2004, the book, Dentinal Fluid Transport, is an historical review of published data illustrating dental physiology and the genesis of tooth decay, both locally and systemically.

Genesis of Tooth Decay

Dr. Steinman’s research showed proof of interactivity between the oral cavity and the metabolism of the body. The occurrence of decay is not due primarily to external contamination of the tooth through acid producing foods and bacteria, but through an upset of normal tooth metabolism. (4) Teeth are not solid, but consist of a series of dentin tubules and parallel enamel rods. Dr. Steinman proved that substances moved from within the body, through the pulp chamber, through the interstitial fluid to inside the dentin tubules, through the enamel and into the mouth. He proved this fact by injecting radioactive acriflavin hydrochloride into the abdominal cavities of rats and recovering it in the dentin tubules within six minutes and in the enamel within an hour. He believed this action to be a self-cleansing mechanism.
The constant flushing of the tooth structure prevents the movement of microbes into the tooth and prevents the destructive effects of acids formed by foods. At the same time, essential nutrients are introduced into dentin tubules in order to provide a life-supporting environment for dentin, a tissue devoid of any blood supply or nerve innervations. (4) Major problems occur when endocrine function, poor diet or stress negatively affects the hypothalamus, the regulatory gland for dentinal tubular flow. Circulatory problems, associated with ill health or aging also affect dentin tubular flow leading to flow reversal and stagnation. (4) Odontoblasts, which lie outside dentin tubules projecting approximately one-third of the length of the associated dentin tubule, function as the pumps for the dentinal fluid.
Steinman demonstrated that odontoblasts were hormonally and biochemically linked to the metabolism of

the body, as well as to the health and function of the teeth. (4) If odontoblasts cease to pump fluid, capillary action sucks bacteria and other noxious materials from the mouth or surrounding periodontium into the tooth, leading to microbial contamination and biofilm formation within the dentin tubules. Steinman produced many slides demonstrating this flow going in both directions. Since the tooth is not an isolated structure, the continued maintenance of a sterile field is impossible. As part of the decay process, Steinman identified the early loss of magnesium, copper, iron and manganese, all of which are active in cellular oxidation and necessary for the metabolism of the odontoblasts. He showed that the addition of copper, iron, and manganese to a decay producing diet, almost abolished the decay rate. (4) Dr. Steinman's most dramatic discovery was that if you plot the course of dental decay: initially, function is altered, followed by the reversal of the dentinal tubular fluid flow. Next, inflammation occurs in the pulp chamber adjacent to the dentin, and finally, the disease spreads to the enamel, before the clinical appearance of the cavity. (4)

Relationship of Oral Health to Systemic Infection

Although it is generally accepted that good diet, good hygiene and overall good health is beneficial to oral health, it should be stressed that good oral health is essential for good overall health. Recent studies have identified more than 400 bacteria capable of forming biofilms leading to tooth decay, gum disease and periodontal disease. (8) They are capable of throwing-off planktonic bacterial forms, which can create a general bacteremia and infect other parts of the body. The relationship of oral health to heart disease, stroke, diabetes and pre-term, low birth weight babies has been substantiated with solid research. Links to pneumonia and respiratory disease are also indicated. (13) A tooth does not have to be non-vital before it can act as a focus of infection; a change in the regulation of dentinal fluid flow can lead to microbial contamination. Due to the interactive functioning of the oral cavity and the rest of the body, oral biofilm control is essential for overall health. The high incidence of recurrent decay not only poses a monetary strain on patients, it also exposes them to serious health risks. As dental professionals, we owe it to our patients to do everything possible to reduce the formation and presence of oral biofilms.

Biofilms and Their Role in Dental Disease

Around the year 2000, new scientific methods changed dental microbiology from its focus on planktonic forms of bacteria to biofilm research. These discoveries challenged current thoughts concerning the role of bacteria in dental disease. In a biofilm, microbes share nutrients and genetic information. A mucopolysaccharide (slime) layer is produced around the biofilm colony, which forms a barrier that is not permeable to antibiotics and traditional medicaments. These bacterial colonies become invisible to the immune system. All that is required for biofilm formation is a surface on which to adhere an initial bacterial attachment. (9) Tooth surfaces, porous composite surfaces, etched ceramic surfaces, stagnant dentin tubules and metal surfaces are perfect for biofilm attachment. Where biofilms reside, bacteremias prove resistant to almost all forms of treatment except mechanical removal and the use of activated copper. (10)

Proven Solutions to Recurrent Decay

It may be historically and currently supported that recurrent decay can be greatly reduced using cements containing essential trace minerals, including biocompatible levels of activated copper. Such a combination, while effective in destroying pathogenic microbes, also supports the metabolic processes within odontoblasts, which in turn supports dentinal tubular flow and the over-all health of the tooth. One study of an outstanding dentist's gold restorations, conducted by Donovan of USC, included 1,314 cast gold restorations covering 114 patients. The dentist's restorations presented a 97% survival rate at 9 years, 90.3% at 20 years, 94.9% at 25 years, 98% at 29 years, 96.9% at 30 years, and 94.1 % at greater than 40 years. All of these later restorations were cemented with zinc phosphate cement, containing the anti-microbial agent, bismuth. (2) The anticariogenic effects of copper, silver and mercury, all of which are present in amalgam fillings, provide decay resistance. Today's preferred esthetic restorations of polymers and resins serve esthetics, but do not offer decay resistance; however, by the use of a new generation of activated copper cements: decay resistance, safety and esthetics can all be achieved.

A Review of Copper-Containing Cements

Historically, most copper-containing cements consisted of zinc phosphate cement to which copper was added. Copper cements, as they were called, contained anywhere from 2% copper to 97% copper. Cements containing low concentrations of copper were shown to be just as germicidal as those with higher concentrations. (5) Some copper cements also contained other minerals, which may have increased their germicidal effectiveness. Paul Poetshke (Caulk Laboratories), Dr. M.R. Smirnow (Yale Medical School), Dr. Raymond F. Bacon (Melon Institute) and Marcus Ward (Ann Arbor, Michigan), all found that zinc phosphate cements containing 2% cuprous iodide were far more anti-microbial than the standard zinc phosphate cements. (5) Many present day dentists have discovered old, ill -fitting and worn-out gold swaged crowns with red copper cement still present and a baffling absence of recurrent decay. Unfortunately, dental material manufacturers began promoting cements with a high concentration of copper, based on the idea that “more is better” and the copper cements gained a reputation for being toxic. The chemical form of copper used in the cement was also a factor; the greater the solubility, the higher the rate of release of copper ions. Cupric oxide is the most soluble form, followed by cuprous oxide and cuprous iodide. Ames black copper cement, with 97% cupric oxide, was far different than Caulk’s white copper cement, with 2% cuprous oxide.In 1931, in the text, “Metallurgy for Dental Students” by K.W. Ray, it was stated that the use of copper-containing cements was staunchly advocated. Dr. Ray went so far as to say, whenever copper cements were used, no need for thorough cavity preparation presents itself. (7) Michael Dumas and Marvin Blush concluded in 1954, “

In view of the contradictory evidence and the definite advantages of a germicidal cement, especially where carious dentin removal may cause pulp exposure, it would seem that further investigation and reappraisal of the copper-containing cements is indicated”. (7)New ideas about obtaining a perfect marginal seal that would protect a sterile field seemed within reach, because of improved impression techniques and better casting techniques. In “The Science of Dental Materials”, by Dr. W.E. Skinner, we find the following: “If the cavity has been properly sterilized before the cement is applied and if a tight cement filling is possible, it is difficult to understand why a germicidal cement is needed. “ (7) The mistaken concept of the maintenance of a sterile field and the damage done with the use of cements, such as Ames 97% copper, lead to the abandonment of copper cements by most dentists. Therapeutically, copper increases local and general immunity and prohibits chronic inflammation and infection in tissues associated with local dental procedures. Copper supports tissue metabolism and detoxification. (6) Copper is a toxin only when used at toxic levels. Newer copper cement formulations have been proven to be anti-microbial, therapeutic and biocompatible.

The Role of Copper-Containing Cements in the Eradication of Biofilms

The Center for Biofilm Engineering (CBE), Bozeman, Montana, under the direction of William Costerton, PhD, began searching for biofilm resistant surfaces for medical prosthesis and devices. Many anti-microbial agents, including copper and silver were considered. Used alone, none of these materials were able to penetrate the biofilm slime layer and destroy associated microbes. It was then discovered that when copper and silver ions were placed in solution together, the cations due to mutual repulsion, became highly activated allowing them to penetrate the slime layer and disrupt the metabolism of biofilms. (11)From earlier research, Dr. Marcus Ward concluded that the anti-microbial effectiveness of copper-containing cements depended on the germicidal quality of the copper salt used as well as the infinitesimal solubility of the cement in its phosphate form.

Ward rightly stated, “Our chief interest is in what may happen beneath fillings”. (5) The dentin tubules beneath any restoration will become a microbial breeding ground unless the microbes are continually destroyed. Infintesimal solubility is the key to constant availability of the germicidal agent. Cooley & Cooley Ltd, Houston, TX, working with the author, improved the older formulas of copper-containing cements. A new line of low concentration copper-containing cements was produced, based on the interaction of copper with the cations- silver and iron. Combining these materials with a mineral phosphate base provides the necessary infinitesimal solubility of minerals to impart anti-biofilm/anti-microbial action in the tissues and dentin tubules beneath restorations. A pulp canal sealer based on the same principals was also developed. The product line was named Doc’s Best after Doc Holliday who was noted for his use of red copper cement, among his other well-known activities. Doc’s Best™ cements underwent testing at CBE. All of Doc’s Best™ products were found to be 100% resistant to the biofilms of Staphylococcus aureus, Lactobacillus paracasei and Streptococcus mutans. All other cements tested proved nonresistant. (12)

Clinical Studies and Biocompatibility of Copper-Containing Cements

The author has used these cements clinically for sixteen years with only minor modifications. Many documented case studies reflect the ability of the cements to render decay inactive with pulpal health remaining positive. (14) Root calcification, an indicator of chronic inflammation, was not evident in any of these cases. Many of the minerals found in Doc's Best™ cements are restorative to the health of pulpal tissues, including odontoblasts.

According to Dr. Ralph Steinman's findings, the inflammation process coincides with the loss of magnesium, copper, iron, manganese, zinc, phosphorus, ATP, ADP, sulf-hydro groups and acetylcholine from the pulp chamber and dentin. (4) Clinical evidence now suggests that Doc's Best cements contribute to the formation of secondary dentin beneath restorations. (14)According to a recent study performed by Yiming Li DDS, MSC, PhD at Loma Linda University Dental School, the combination of the cement powder mixed with COPALITE® varnish is not cytotoxic and is well accepted at the cellular level. (15) Clinical Applications Using Doc's Best Products Doc's Best Products serve in multiple applications as previously described, acting as anti-microbial and anti-biofilm agents, therapeutic agents and mechanically as cements.

They should be considered an anti-biofilm, therapeutic cementation system, rather than typical cement. Current products include: a red formulation used to cement gold work, posts and non-visible restorations, including composites and resins; a white formulation designed for use with porcelain margins or in areas where esthetics are a primary concern; a pulp canal sealer designed to prevent bacterial infestation within stagnant dentin tubules of non-vital teeth. The cement systems consist of the red or white powders, dilute phosphoric acid and COPALITE cavity varnish. The powder is mixed with the dilute phosphoric acid on a glass or tile slab to desired consistency forming the copper-containing, activated mineral, phosphate cement. Cooley & Cooley Ltd's COPALITE® dental varnish is always used before placing phosphate cements; it protects dentin tubules from sucking back phosphoric acid prior to complete set, thus protecting living tissues.

COPALITE® varnish is both highly biocompatible and anti-microbial. Additional successful applications have been developed and used by many dental professionals (16), (17), (18). Red or white powder can be mixed with composite resin for build-ups, which are resistant to biofilm infestation. The red cement is recommended for cementation of root canal posts and for use with post failures where softening has occurred around a previous post. Applying a slurry mixture of the varnish and the powder prior to cementation can inactivate existing decay making total decay removal unnecessary. The activated minerals are carried quickly into the tissue and dentin tubules. Pulpal exposure should be avoided as it causes tissue trauma and the destruction of odontoblasts, which are critical for secondary dentin formation and the thorough healing of a vital tooth. The previous application techniques are meant as an overview and are not to be taken as complete. Complete and precise instructions are available through Cooley & Cooley, Ltd. and should be studied before attempting any of these procedures or techniques. Conclusion There exists a two way street between the oral cavity and the rest of the human body. The oral cavity is an extension of the overall body and its physiological functions are directly linked with the body through the dentinal fluid transport system.

The presence of biofilms in oral decay and their link to systemic infection necessitate a prudent approach to caries prevention. For more than a century, zinc phosphate, copper-containing cements were the solution to decay prevention, but they fell into disfavor due to the toxicity of cements with high copper concentrations. The mistaken concept of the sterile field in dentistry further negated the need for anti-microbial cements. Today, high rates of recurrent decay and restorative failures indicate the current use of dental materials that function poorly in vivo. A return to the concept of anti-microbial cements has lead to the development of new, activated copper-containing cements with the following attributes: anti-cariogenic, anti-biofilm, biocompatible, therapeutic, multi-functional and mechanically effective. The use of Doc's Best Copper System, including the activated cements, promotes caries prevention, lasting restorations and optimal oral health.

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