A Probiotic Approach to Caries Management

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Abstract

The surgical approach has been the predominate mode of caries management for the past 150 years. Dentistry has, however, in recent years moved toward an antibiotic/antimicrobial model of disease management. This approach, however, raises serious questions: (1) do the antibiotic/antimicrobial agents (chlorhexidine, povidone iodine, fluoride, etc) kill all offending organisms?; (2) if so, do the agents preclude the re-entry of the same organisms from external sources?; and (3) if the agents do kill all the offending organisms, do any remaining pathogenic organisms have selective advantage in repopulating the tooth surfaces? To overcome the problems inherent in an antibiotic/antimicrobial approach, probiotic methods are currently under study as means of caries management. This paper discusses probiotic approaches, such as genetically modified Streptococcus mutans and targeted antimicrobials in the management of dental caries. Implications for this approach in the management of other diseases are also presented. (Pediatr Dent 2006;28:151-153)

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Review of caries

W.D. Miller and his contemporaries gave us our first real understanding of the dental caries process more than 100 years ago.[1] Miller, an American-educated dentist working in Germany, demonstrated that dental caries was a bacterially-mediated process.

Over the past 115 years, the scientific study of dental caries has further refined the processes. Today we know that dental caries is a multifaceted disease process. Several models have been useful to elucidate the mechanisms in play. One of the earlier models that is familiar to most dentists was put forth by Fitzgerald and Keyes.[2] They used three overlapping circles describing the host, bacteria, and nutrients required to foment the production of organic acids and the subsequent demineralization activity.

The beauty of this model is that all three elements must be present for the disease to progress. Since all three are required for disease initiation and progression, removal of any one element ostensibly leads to the interception of the disease process.

This work and the work of numerous others helped the research and practice communities with emerging disease management models.

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Traditional approaches to disease management

Surgical model

For the past 150 or so years, a surgical treatment model has evolved. The model predates our current understanding of dental caries and is consistent with the original concept that dental caries was a gangrenous process. Gangrene was treated by amputation and as such, carious teeth were originally extracted (the final surgical insult for a tooth). Later just the demineralized portions (gangrenous portions) of the tooth were removed. This missing tooth structure was then replaced with an inert restorative material.

The evolutionary descendent of this practice is still employed today and is one of the primary elements of our dental practice. We teach the removal of diseased tooth structure or failed/failing restorations prior to placement of materials to restore form and function.

In some dental offices this is where the treatment of caries ends. The underlying thought must be that surgical removal of the nidus of infection will stop the disease processes. If the removal of the causative organisms were actually accomplished in this surgical process, then it would fit the Fitzgerald/Keyes model and we should expect a "cure."

The flaw in this model is that the removal of the demineralized/diseased tooth structure has repeatedly been shown to not remove the causative infection.[3]

Antibiotic model

Since the surgical model did not remove the causative bacteria from the Fitzgerald/Keyes model, the next logical

progression is to treat the remaining infection with antimicrobials or antibiotics. For the purposes of this discussion, "antibiotic" is defined classically wherein these molecules are generated by other cells, like penicillin. "Antimicrobials" are other chemical agents that kill or debilitate the infection of interest, like iodine. Both antibiotics and antimicrobials have been used to treat the dental caries infections.

Whether we choose chlorhexidine, povidone iodine, fluoride, penicillin, or other antimicrobials/antibiotics, these agents kill a broad spectrum of organisms. They may be semiselective in that we can prescribe medicaments that preferentially affect either Gram(+), Gram(-), anaerobic, or aerobic organisms, but they still kill an array of like organisms.

There are serious questions about this model:

- Does the medicament kill all the offending organisms?
- If so, does it preclude the re-entry of the same organism from external sources?
- If it does not kill all the offending organisms (odontopathogens in our case), do any remaining pathogenic organisms have selective advantage in repopulating the ecosystem (tooth surface)?

To answer these questions in order, we know that none of our current treatments sterilize the oral cavity, nor do they come close. The oral cavity is exposed to an external environment that is full of microbes and is not a sterile space. If we apply broad spectrum agents to treat the caries infection, we can suppress the infection but never totally eliminate it.[4] Monoclonal antibody diagnostics show that selected odontopathogens are still present.[5-7] Therefore the pathogen is available for repopulation of the oral cavity.

While a number of medicaments can suppress the infection, none to date have been able to successfully preclude the regrowth of residual pathogens or reinfection from external sources.

The repopulation of the microbial flora with the pathogen(s) of concern is a critical question. To answer the question, it is helpful to examine which organisms have a selective advantage in the ecosystem. If refined carbohydrates are available as a nutrient (one of the three circles), then the mutans streptococci (MS) group have a selective advantage in the oral ecosystem. This is the reason we tell our patients to limit their sugar intake. The advantage they possess is their production of glucans and fructans.[8,9] These extracellular polysaccharides are very "sticky" and aid the organism's adherence. The organisms elute these materials on all surfaces and recruit other organisms to help form the oral biofilm popularly known as "plaque."

Thus, we must conclude that broad spectrum antibiotics or antimicrobials are not effective long-term unless their application is periodically repeated. We can use this information and the information on how soon the infection re-appears to repeatedly dose our patients. This repeated suppression can be effective as long as resistant strains of the bacterial pathogens do not develop and no yeast infections develop because of suppression of the normal flora.

The probiotic approach

To overcome the limitations of the traditional disease management strategies, a number of researchers are developing "probiotic" methods to treat the caries causing infection. "Probiotic," as used here, means that mechanisms are employed to selectively remove only the (odonto) pathogen while leaving the remainder of the oral ecosystem intact.

The most well-publicized of these efforts is a substitution strategy developed by Hillman and colleagues.[10] They have genetically modified a *Streptococcus mutans* organism so that it no longer produces acid while competing aggressively for the ecologic niche where the wild type *S mutans* is found. In theory and in laboratory animals, once this substitute organism is introduced, it entirely displaces the disease-causing wild type *S mutans*. Not only does this stop the disease process, it also precludes the re-emergence of the disease-causing organism and eliminates re-infection because the ecologic "inn is full." Hillman is conducting limited human trials at the time of this writing.

A different way of accomplishing the removal of the pathogens is to develop "targeted antimicrobials." Shi and his colleagues are working on such targeted antimicrobials.[11] The basic idea is to develop an inexpensive targeting molecule that will reliably attach to only the organism of interest, in this case *S mutans*, *S sobrinus*, or other chosen pathogen. Once the targeting molecule is perfected, then a "killer" molecule is optimized and chained to the targeting molecule. The combined unit then selectively eliminates the infection of interest. In the case of the oral cavity and dental caries, this system is attractive from the perspective of eliminating all the pathogens thereby precluding the regrowth of the original infection. There is also compelling evidence from clinical trials and laboratory efforts demonstrating that once the bacterial ecosystem is free of *S mutans*, it is difficult to reintroduce the organisms (another competitive inhibition situation).[12,13]

One criticism of probiotic approaches is that they do not address the other pathogens that may be involved in a disease process like dental caries. Using the targeted approach outlined above, the development of diagnostic screening tools (targeting molecule with a diagnostic marker) that tell the practitioner which organisms are in play and their attendant therapeutics (targeting molecule with an attached killer molecule) is straightforward.

Conclusions

These and other probiotic strategies are part of the continuing evolution of the treatment of oral infection that produces the clinical manifestations of dental caries. As a profession, we are slowly moving away from the purely surgical approach to treating this disease. Science is providing us the tools to diagnose and treat the infection before it causes damage. The application of probiotic strategies may, in the not-distant future, provide the end of new cavities in treated populations.

Regardless of which of these or other strategies emerges as a winner in the war on caries, it is most interesting that

these technologies will serve whole other areas of health care as well. If you can solve the problems of this specific infection in the heavy bioburden of the oral cavity, you can solve it on virtually all mucous membranes. Given appropriate release mechanisms, some of these technologies may be parenterally administered to treat life-threatening infections and emerging drug-resistant organisms.

While the expression of this work is current, the groundwork for these probiotic approaches was laid by Loesche in the 1970s and 1980s.[14] It is a tribute to his foresight that these applications of his "Specific Plaque Hypothesis" are now appearing 20 and 30 years after he envisioned their development.

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