THE EVOLUTION OF DENTAL COMPOSITES:

A PREVENTATIVE APPROACH TO RESTORATION FAILURE

An Undergraduate Research Scholars Thesis

by

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ABSTRACT

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This study investigates the problem of restoration failure using research data from primary and secondary sources. The failure of dental composites due to secondary caries is very common, so the creation of a restorative material that will serve as a multifactorial solution will be a significant advancement. An enhanced composite material with antibacterial properties and remineralization properties could be the solution to restoration failure. This composite contains dimethylaminododecyl methacrylate (DMADDM) which has antibacterial properties and the remineralizing effect of amorphous calcium phosphate (NACP). Studies have shown that the combination of NACP and DMADDM is a promising new technology that could increase the longevity of dental restorations and provides several potential benefits for both clinicians and patients. Along with its inhibitory properties, the new composite material is also aesthetically pleasing and could potentially be used in all areas and surfaces of the clinical dentition. Composite failure is a prevalent issue and having a longer lasting dental material would certainly be in the patient's best interest. Our project intends to take a step forward by not only recognizing a problem (primary and secondary caries) and seeking a better solution (enhanced

composite fillings), but to plan for the future by incorporating a preventive strategy where dental hygienists could inform and advocate for their patients.

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KEY WORDS

DM	Dental Materials
DRF	Dental Restoration Failure
SC	Secondary Caries
Di/M	Dimethylaminododecyl metacrylate
ACaP	Amorphous Calcium Phosphate

INTRODUCTION

The second most prevalent chronic disease in the United States is dental caries, with the number one reason for dental restoration failure being secondary caries.[1,2] A new generation of restorative material enhanced with dimethylaminododecyl methacrylate (DMADDM) and nanoparticles of amorphous calcium phosphate (NACP) could potentially be the future of dental restorations. The composition of this restorative material allows for the inhibition of recurrent decay and remineralization of weakened tooth structure, all while maintaining the integrity of the natural dentition.[3]

The intent of this research is to conduct studies centered around a new generation of dental restorative materials. This study is significant to all populations that have experienced any form of dental caries, whether it be primary or secondary. The combination of antimicrobial and remineralizing properties within the initial restoration discourages the process of recurrent decay.[3,4] The use of a new generation dental restorative material containing DMADDM+NACP could potentially extend the life of the initial treatment, which in turn could prevent the need for re-treatment or more invasive procedures. The option for a restoration with remineralizing and antimicrobial properties will maintain the tooth's natural integrity and vital structure. The current NDHRA priority area of oral health care includes New Therapies and Prevention Modalities and Health Promotion: Treatments, Behaviors, Products.

Implementation of this preventative and remineralizing method and/or material into the patient's standard routine care is of contemporary significance because dental professionals are trusted to recommend the best care possible to patients. DMADDM + NACP is an evidence-based treatment that has shown a decrease in secondary dental caries. The advantages of

incorporating restorative materials incorporated with DMADDM and NACP in the dental office include not only restoring a tooth back to its original function, but also interrupting the growth of biofilm and lactic acid build up in the oral cavity.[5]

SECTION I

SECONDARY CARIES AND BENEFITS OF NEW GENERATION RESTORATIVE MATERIAL

Objective 1

Research studies suggest different reasons for the failure of restorative materials, which in turn may lead to secondary caries.[1,3,4,6] Restorative materials (e.g. resin-based composite materials) were suggested as one of the important factors in the restorative failures.[4,3] In 2017, Li et al. also demonstrated that in the United States 50-70% of the 166 million restorations are placed annually due to secondary decay.[5] In an attempt to reduce the occurrence of secondary caries, researchers examined different restorative materials such as DMADDM and NACP.[6] This is an indication of the importance of the selection of restorative materials.

Xu et al. in 2011, developed NACP composite material for the first time as a new restorative material to combat dental caries.[7] They demonstrated that nanoparticles of NACP were more effective in releasing ions at a pH of 4, as compared to non NACP containing dental composites.[7] For example, by using 20% NACP at a pH of 4, they achieved 4.5 mmol/L release of Ca, which is higher than 0.3 mmol/L for 10% NACP at the same pH level.[7] In a similar case, for NACP of 20%, 2mmol/L of PO4 was produced in comparison to 0.2 mmol/L for 10% NACP.[7] Therefore, NACP resulted in a 2-fold increase in strength of composite materials such as calcium phosphate composites and resin-modified glass ionomer control.[7] In addition, NACP exhibited an effective ability to neutralize the acidic environment of the oral cavity and helped in the inhibition of primary and secondary caries.[7]

In 2013, Melo et al. investigated the caries inhibition feature of NACP for the first time in a human *in situ* model.[1] In this study, researchers extracted four bovine teeth, from which two were restored with composite containing NACP and two with placebo composite. These four samples were then placed in a palatal tray and fitted to 25 study participants' maxillary arches for a period of 14 days. Although the pH and salivary flow of these 25 volunteers were different, the composite material impregnated with NACP was able to achieve a 2 to 3-fold higher strength than the traditional composite materials ($p<0.05$). Therefore, it was concluded that NACP composite was more beneficial for reducing secondary caries than the traditional composite materials. These results are aligned with the finding by Xu et al. that were previously mentioned.[1]

Another factor to prevent secondary caries is by adding an antibacterial agent into a bonding agent.[2] In 2014, Wang et al. investigated the effect of DMADDM as a new antibacterial adhesive on *S. mutans*. In this study, they examined 24 plates containing 0%, 2.5%, and 5% of DMADDM and *S. mutans*. They also used Exopolysaccharides (EPS) as the staining agent to analyze the effect of DMADDM. In this research, they demonstrated that all concentrations of DMADDM decreased the growth of *S. mutans* bacteria. However, the higher concentration of DMADDM had a stronger antibacterial effect on the reduction of *S. mutans* biofilm.[2]

In 2014, Li et al. investigated remineralization and antibacterial features of NACP and DMADDM to prevent secondary caries, as an exploratory *in-vivo* study. They placed 48 restorations of differing concentrations of DMADDM and NACP onto rat teeth.[5] They demonstrated that DMADDM with antibacterial properties can reduce the activity of microorganisms, especially *S. mutans* significantly, which led to a reduction of lactic acid ($p<0.05$).[5] This study suggested that the combination of the NACP and DMADDM in bonding

agents helped to form a stronger adhesion to tertiary dentin, which is described as the reformation of a microscopic layer of tooth structure by the body's healing mechanism after trauma.[5,8] This resulted in the decrease of pulpal inflammation, when compared to usage of bonding material without DMADDM and NACP.[5] Lei et al. found that the combination of DMADDM and NACP may reduce the bacterial load, inhibit tooth decay, increase restoration longevity, and reduce secondary caries.[5]

In addition to its clinical benefits, the combination of NACP and DMADDM could potentially provide an option that saves both time and expense for the dentist and patient.[2] As a result, a therapeutic combination of NACP and DMADDM should be considered as a useful restorative material to combat secondary caries.

SECTION II

THE LONG-TERM BENEFITS

Objective 2

When investigating a possible solution to restoration failure another problem arises - the dental population does not yet know about the possible benefits. This could be due to the lack of progression with studies of this material, since studies have not yet advanced on to the primary research trials beyond *in-vivo* or *in-situ* studies. A prevalent and inevitable challenge in dentistry is restoration failure.[9] The increase in demand of aesthetically pleasing dental restorations places polymeric tooth-colored restorations as a preferred method of treatment.[10] The number one reason for failure is due to secondary decay.[1,3,4,6] The replacement of failed restorations accounts for around 60% of all restorations placed.[8,10] These treatments have little comparison when another material can prevent the secondary carious process from initiating. This novel material possesses a positive impact by preventing the need for re-treatment. DMADDM+NACP composite treatments should be implemented into today's standard of care.

Replacing previous restorations accounts for over 50% of operative work in the dental chair.[5] The long-term benefits for dental personnel include less time spent redoing original work. Using these new composite materials intends to decrease, not eliminate, the frequency of the retreatment cycle. To advance beyond this cycle will be a step towards the future of dentistry by helping preserve/increase the potential life of the treatment. Considering the patient's financial burdens incurred from missing work and paying for a service that has already been performed, completed, and considered restored will directly affect the preference for a restoration that inhibits decay and strengthens the tooth. In the United States, it is estimated that $46 billion is

spent annually by restoring carious lesions.[9,10] DMADDM+NACP composite treatments will help remineralize the tooth's surface while inhibiting the destruction from accumulated biofilms. This technique is considered a preventative and therapeutic measure that preserves the remaining natural tooth structure, which makes this product a new generation of restorative dental materials.[5,10]

Polymeric composite materials tend to create an environment for biofilm accumulation when compared to metal restorations; however, amalgam contains properties of expansion and shrinkage, creating potential for microfractures and microleakage.[5] The accumulation of biofilm at the margin of a restoration is the main predisposition for the frequent occurrence of secondary decay which leads to the replacement of the existing restoration.[1,10] When evaluating data associated with bacterial inhibition and remineralization processes used in current composites, there was really no good comparison since there is not one product on the market that accomplishes the potential benefits of this new generation of restorative material. In 2017, Liang et al. researched a material with similar properties by incorporating poly(amino amide) with NACP and showed promise in protecting tooth structures. The limitation to this study is that researchers only measured the dentin hardness after 21 days of immersion in acidic solutions. In comparison to traditional dental materials, a bonding agent with antibacterial properties aids in two ways: to suppress any microorganisms left within the dentin tubules to avoid secondary caries formation and to avoid primary caries at the margin of the restoration due to microleakage.[10] In addition to the antimicrobial properties, a composite with remineralizing properties to restore natural dentin structures resolves the problem of secondary caries.[10]

Recognizing the long-term benefits of a restorative material enhanced with DMADDM and NACP could present as a great advancement towards the future of dentistry. It is of key

importance to spread the knowledge to practitioners since the present treatments for carious lesions seem more harmful than beneficial when compared to DMADDM+ NACP restoration materials. The benefits of DMADDM+ NACP in composite material is what constitutes this product as the future of dental restorations. The ethical duty in dentistry is to provide patients with the best treatment and up to date health care regimens.

SECTION III

RELEVANCE TO THE DENTAL HYGIENIST

Objective 3

In addition to future studies and evolution, revealing the benefits of restorative materials with antibacterial and re-mineralizing properties can be achieved by support and promotion from the dental hygienist. Hygienist's vital roles as prevention specialists includes engaging their patients in educational services and providing them with trusted recommendations. This instrumental restorative material falls under the strategy of prevention, with its abilities to not only replace tooth loss from decay, but inhibit secondary caries from occurring.[3] Hygienists also hold an opportunity to exercise fundamentals of ethics, establish trust with patients, advocate within their realm of prevention, and promote new advancements in oral health to the public..

As previously mentioned, a critical role maintained by the dental hygienist is exercising the fundamentals of ethical decision making within the dental setting. An ethical principle and obligation for dental professionals to consider is the principle of beneficence. According to the Core Values of the ADHA, beneficence can be defined as "withholding the primary role in promoting the well-being of individuals and the public by engaging in health promotion and disease prevention".[11] Taking into consideration that secondary caries is a common prevalence, it would be in the patient's best interest to have dental fillings placed with material that could not only inhibit the recurrent caries process, but simultaneously re-mineralize the natural tooth structure. In addition, the efforts of placing this particular restorative composite material would allow for the hygienist to exercise his or her ethical duties, and allow for the patient's benefits to be maximized, therefore opening up a newly founded opportunity for trust.

Furthermore, patient initial rapport with a dental professional commonly occurs with the dental hygienist, they are typically the first provider to introduce the patient to the practice. This initial encounter allows for a healthy foundation to be established between the patient and hygienist that is centered on trust, especially during the treatment plan and decision-making phase. It is expected that patients will inquire with the dental hygienist regarding treatment options before or even after they are presented with the treatment options, revealing the patients trust in the hygienist's ethical consciousness and professional judgment. In addition, not only could filling material containing DMADDM and NACP be clinically beneficial to patients, but also beneficial to the dental hygienist from a personal aspect. Given the opportunity to better improve a patient's oral and overall health, a sense of reward and fulfillment is obtained, placing both the patient and clinician at a conclusive advantage. In summary, when patients have reached the treatment planning phase, their decision could be influenced by the dental hygienist, due to the development of trust and rapport.

In the ADHA code of ethics, it is recommended that dental hygienists not only participate in the development and advancement of the dental profession, but also seek to increase the public's awareness and understanding of oral health practices.[11] Hygienist's roles include completing required continuing education courses and stressing the importance of prevention strategies to their patients, thus providing patients with new suitable treatment options.[11] With a hopeful pursuit of support and clinical trials, health professionals could better acknowledge and expose the potential for restorative filling material containing DMADDM and NACP.

CONCLUSION

The prevalence of restoration failure can be constituted by the accumulation of undisturbed biofilm, requiring the need for further, more invasive dental treatment. Development of restorative materials containing properties of antibacterial DMADDM along with re-mineralizer NACP, possesses the ability to inhibit the formation of bacteria while simultaneously encouraging the formation of tooth structure.[3] Moreover, restorative material containing DMADDM and NACP has the ability to enhance the longevity of dental restorations, resulting in a decreased need for procedural dental visits and an increase in the patient's overall well-being. An important advocate for this material includes the dental hygienist, or properly known as the prevention specialists. With this dental material's ability to prevent decay, it validates the need of support from all members of the dental field, especially the dental hygienist, in hopes of further maximizing the patient's benefits. In conclusion, this secondary study has not only revealed the multifactorial properties of restorative material impregnated with anti-bacterial and remineralizing properties, but also recognized its promising potential for future dental restorations.

New recommendations for further research and practices include obtaining FDA approval to signify that the benefits outweigh the risks. [11] Scientific research can then advance on towards primary clinical trials in order to support the significance as an effective restorative material and determine long-term safety considerations of this product. This research reflected on studies performed to provide a broad review of information and associated statistics, including limitations found. This research's primary limitation is the fact that there has yet to be any type of human conducted trials. This particular materials' method has gone through rat trials, and has

even been tested on a bovine's tooth in a human's mouth to see if the material weakens with a constant pH fluctuation.[1,5] To disseminate this information to the public, product manufacturers, or into the dental field itself will require a successfully conducted and published primary randomly selected human trial with enough participants to become representative of the population as a whole.

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