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REVIEW

Benefits of eggshell reinforcement in water sorption and color stability of heat-cured polymethyl-methacrylate provisional fixed partial dentures

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ABSTRACT

Oral rehabilitation procedures such as crown lengthening, implants for anterior teeth, and endodontic procedures with limited tooth structure require provisional restoration for a long time. The material used in fabricating provisional fixed partial dentures is polymethyl-methacrylate (PMMA). PMMA is divided into heat cured and self-cured based on the polymerization. Heat-cured PMMA has better mechanical properties than self-cured PMMA. Despite its advantages, however, there are also some disadvantages, such as high water sorption, low color stability, and wear of use. Research on the use of eggshells as reinforcement in denture bases has been conducted. However, the use of eggshells in provisional fixed partial dentures has not been done yet. Eggshell, as an environment byproduct waste material, is composed of 95% calcium carbonate (CaCO3), magnesium, potassium, and other inorganic components, can be used as alternative natural reinforced materials for PMMA provisional restoration. To describe use of provisional restoration for a long time, PMMA as provisional restoration material, as well as the merit of eggshell as natural reinforcement material in water sorption and color stability of heat-cured PMMA provisional fixed partial dentures. Eggshell, which is composed of calcium carbonate, can be converted into hydroxyapatite as a reinforcement in long term provisional restoration, could improve the physical properties of heat-cured PMMA, such as water sorption and color stability. (IJP 2024;5(1):14-17)

INTRODUCTION

According to the Glossary of Prosthodontic Terms, provisional or interim or transitional prosthesis or restoration is a fixed or removable dental or maxillofacial prosthesis designed to enhance esthetics, stabilization and/or function for a limited period of time, after which it is to be replaced by a definitive dental or maxillofacial prosthesis.[1] Fixed denture prosthesis (FDP), as in post-tooth preparation; especially involving multiple teeth, either full or partial closure, in crown lengthening, implants, and certain cases of endodontic restoration, such as post use, provisional FDPs are used for a relatively long period of time (6-12 weeks), whereas provisional FDPs are designed to test esthetics, phonetics and function before being replaced by a definitive restoration.[2-6]

Provisional FDP must have characteristics that are similar to the form and performance of the anticipated permanent restoration, including good marginal adaptation, sufficient strength to bear masticatory loads, longevity, and color stability with prolonged use.[3,7-8] Different kinds of polymers are regularly employed as provisional FDP materials, with polymethyl-methacrylate (PMMA) being the most widely utilized form.[7-10]

PMMA has the benefits of being easy to manipulate, inexpensive, available in various colors, and aesthetically pleasing.[9] However in addition to its benefits, PMMA also has a number of drawbacks, such as the tendency to release heat when it cures, its porosity, shrinkage, susceptibility of fracture, wear with use, water absorption, and poor color stability.[9,10]

The quantity of monomer residue in the denture has an impact on water absorption. The water absorption property occurs due to the molecular polarity, which causes expansion of PMMA and affects the dimensional stability. According to ISO 20195-1, the PMMA water absorption value should be less than 32 g/mm3.[10] PMMA not only absorbs water but also has a poor color stability that is affected by both intrinsic and external factors.[10-12] Due its porous nature and lack of flexural strength, PMMA is susceptible to fracture when subjected to occlusal loads and should be taken into consideration for long-term use.[13]

In order to strengthen PMMA for long-term use and overcome the limitation of PMMA, reinforcement materials are frequently

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added to PMMA.[14] Both synthetic and natural materials may be utilized as reinforcement.[15] Natural materials, namely eggshell, have a high CaCO3 content (90.9%), making them a viable source for biocompatible biomaterials.[14,16] Additionally, using eggshell has other benefits including being inexpensive, simple to get, and making environmentally friendly products.[14]

The purpose of this article is to explain the benefits of eggshell reinforcement in water sorption and color stability of heat-cured polymethyl-methacrylate provisional fixed partial dentures.

LITERATURE STUDIES

Provisionl Fixed Partial Dentures (FDPs)

Provisional or temporary dentures, according to the Glossary of Prosthodontic Terms, are fixed or removable restorations intended to enhance the appearance, stability, and/or function of the teeth for a brief period of time before being replaced by permanent restorations.[1] In dentistry, temporary/provisional/interim restorations are frequently utilized while teeth are being prepared and while waiting for permanent restoration.[2]

The Role of FDPs

Provisional FDP is designed to protect the tooth or abutment from the oral environment, maintain contact with the adjacent and antagonistic teeth, monitor patient comfort and satisfaction, allow adjustments to be made as needed, support function and esthetics for a certain period of time, which will later be replaced by definitive prostheses.[2-6] Provisional FDP focuses on protecting the pulp, maintaining the health of the periodontal tissues, promoting tissue healing to achieve an acceptable profile, evaluate oral hygiene procedures, preventing abutment migration, managing the patient's psychological needs, providing an adequate occlusal scheme, and assessing the maxillomandibular relationship; therefore, provisional FDP should be taken into account similar in shape and purpose to the patient's intended, long-term rehabilitation.[4]

Provisional FDP Terms

Numerous short- and long-term applications of provisional FDP are possible, including the construction of long- and short-span bridges, endodontic treatments, crown lengthening, and comprehensive oral rehabilitation techniques such implant placement and occlusal splinting.[7,12] According to Shillingburg, provisional fixed dentures must meet the requirements in the form of being able to protect the pulp, prevent supraeruption or tipping of the tooth, provide a good occlusive function for the patient, easy to clean, can withstand occlusal loads, retentive, aesthetically pleasing, can be polished to prevent plaque accumulation as well as the surrounding areas, and the margin area does not interfere with the gingival tissue which can stimulate gingival pathology.[7] Biological, physical, and mechanical factors must be taken into account when choosing materials for provisional FDP. These factors include material biocompatibility, strength, stiffness, repairability, polymerization's ability to release heat, shrinkage, marginal integrity, and color stability.[17] Notably in long span fixed partial dentures (FPD), long-term oral rehabilitation, and in patients with parafunctional habits, materials for provisional fixed dentures must have sufficient strength to withstand masticatory loads.[7] FDPs used in the aesthetic field must have good color stability, which is influenced by the patient's tions, in addition to the resin's chemical properties. The color stability of the material is crucial for maintaining the patient's aesthetics and psychological impact in comprehensive oral rehabilitation procedures like all-on-4 implants, where provisional FDP is only replaced after 4-6 months.[18] There is no single material that meets all of the requirements for the construction of provisional FDPs.[16] However, commonly used and accepted materials are polymethyl methacrylate (PMMA), polyethyl methacrylate, polyvinyl (ethylmethacrylate), bisphenol A-glycidyl methacrylate resins, bis-acryl composite resins, and light-cured urethane-dimethacrylate resins.[7,10,17]

Polymethyl-methacrylate (PMMA)

Various types of polymers are commonly used for various dental applications, of which the most commonly used material is polymethyl methacrylate (PMMA). Based on its polymerization properties, PMMA is divided into self-cured, light-cured and heat-cured. Light-cured PMMA has slightly inferior mechanical properties to conventional PMMA, its use is limited to the manufacture of physiological impression trays and full denture base plates. Compared to heat-cured PMMA, self-cured PMMA has a lower polymerization rate, leaving more residual monomer, which can affect mechanical properties such as strength, hardness, and discoloration of the denture. Heat-cured PMMA has better mechanical properties. The main objective of the heating cycle is to obtain a higher degree of polymerization and reduce the monomer residue on the denture.[10] PMMA has several advantages, including its ease of manipulation, low cost, availability in a variety of colors, and aesthetics.[9] In addition to the benefits of using heat-cured PMMA, this PMMA material has several drawbacks, including porosity, shrinkage, easy to fracture, absorbing liquid, low color stability, and wear over time.[9,10]

Water absorption and color stability of PMMA

Water absorption occurs in PMMA in a humid environment. This is due to the nature of PMMA, which absorbs water. Water absorption occurs as a result of the separation of weak polymer chains, which results in a diffusion process involving water molecules.[19] Water absorbed by PMMA acts as a plasticizer, allowing softening, discoloration, and a decrease in PMMA mechanical properties such as hardness, transverse strength, and fatigue threshold, resulting in dimensional changes in PMMA. Furthermore, extrinsic and intrinsic factors influence the color change in PMMA. Extrinsic factors influence color adsorption and absorption from exogenous materials, such as oral hygiene, surface roughness of restorations, diet, and regular consumption of various beverages such as coffee, tea, soft drinks, and alcohol; while intrinsic factors are influenced by characteristics of the resin itself, such as incomplete polymerization, the presence of residual monomers, and the presence of porosity in PMMA[10-12]

Reinforced Materials

Various studies have been conducted in an attempt to overcome PMMA's shortcomings, such as by adding reinforcing materials.[20] Reinforcing materials can be derived from synthetic or natural materials. Natural materials have the advantages of being inexpensive, dense, renewable, biocompatible, and versatile.[15] Natural reinforcing materials that can be added to PMMA include pistachio shells, bamboo, coir, husks, crab shells, shrimp shells, egg shells and so on.[15,21,22] The combination of two or more materials to obtain superior material properties forms a composite. Matrix as a polymer resin is merged with a filler as a reinforcement medium to form the composite polymer matrix.[23] Due to the combination of the most desirable properties of the component materials, composite materials produce better and unique properties. Particle-reinforced composite polymer matrices are commonly used, resulting in a simpler and less expensive preparation method than fiber-reinforced polymers.[24]

Chicken Egg Shell

Chicken eggshell is a type of kitchen waste. In many countries, eggshell is wasted, which has a negative impact on the environment.[16,25] Eggshell waste can be recycled, reused, and distributed to make a valuable product.[18] Eggshell has been used as a calcium and trace element source, as well as a source of magnesium, boron, copper, manganese, sulphur, and zinc.[14,25] Eggshell is a material that is easily obtained and can be used as a filler material that is affordable and relatively simple to process into a variety of different products.[24]

Structure of Eggshell

Three layers make up a fresh eggshell: a ceramic-like frothy cuticle layer on the outside, a spongy middle layer, and an inner lamellar layer that makes up 11% of the weight of the entire egg.[23] Eggshell has the potential to function as a biocompatible biomaterial due to its high calcium carbonate content (94%), also known as calcite.[14,21,25] In the inner layer of the cuticle, hydroxyapatite (HAp), which resembles tiny needles, coexists with calcite, the most stable form of CaCO3. Calcite is a component that improves the mechanical properties and strength of eggshell-based hydroxyapatite.[22]

Ca10(PO4)6(OH)2, often known as hydroxyapatite (HAp), is a bioactive and biocompatible substance. HAp can be produced from a variety of biological calcium sources, including eggshell, snail, crab, and other shells.[22] In terms of hardness, density, and cell culture, HAp synthesized from eggshell has better sintering ability than HAp synthesized from other sources. The fact that eggshell HAp resembles human hard tissue contributes to its high quality.[25]

DISCUSSION

Heat-cured acrylic is created by combining heat activation and compression molding of PMMA, resulting in a homogeneous mixture of materials that is bubble-free and has a higher resistance than other materials.[10] Heat-cured acrylic is recommended for periods longer than one month due to its hardness and functional stability.[26] Karadi HR et al. (2017) investigated the addition of nanohydroxyapatite filler on heat-cured PMMA acrylic base. According to the research, adding 2% Hap nanoparticles increased impact strength and surface hardness, but there was no visible change in water absorption. Comparing the filler group to the control group, surface roughness enhanced, but it remained within the range of values less than 2μm.[27]

Hartini VO et al. (2021) investigated chitosan as a coupling agent in the addition of rice husk nanocellulose material to heat-cured PMMA material. The results of the PMMA study with the addition of 3% chitosan had the lowest water absorption (15.54 ± 3.48 m/mm3). PMMA without chitosan had the lowest water absorption value at 32.85 ± 4.82 m/mm3. There was a significant difference in the water absorption of the two groups ($p<0.05$).[19] Perchyono VT et al. (2019) looked into the surface roughness and color stability of bisacrylic resin with chitosan and nanodiamond reinforcement. According to the study, both chitosan and nanodiamond on bisacrylic resin improved color stability ($p=0.007$).[28]

Kohli et al. (2017) compared the discoloration of PMMA and bis-acrylic provisional FPD in artificial saliva, artificial saliva and tea, artificial saliva and coffee, artificial saliva and orange juice, and artificial saliva and cranberry juice before, after, and after 1 month of immersion. According to the findings, the color change increased with the length of immersion time. PMMA withstands discoloration better than bis-acrylic resins. The artificial saliva and coffee solution showed unacceptable discoloration after 1 month of immersion.[11] Kontanidis A et al. (2019) investigated the discoloration of provisional FDPs of PMMA resins with silica reinforcement and found that the addition of 0.25% silica (SiO2) nanoparticles affected the optical properties of PMMA resins without being clinically apparent.[29]

Onwubu SC et al. (2017) investigated eggshell as an abrasive, where 50-nm and 0.3-μm particles were shown to produce good polishing surfaces.[16] Abdulrahman et al. (2020) used calcium carbonate from eggshell to produce hydroxyapatite, which is used in bone and dental treatment. He stated that the use of hydroxyapatite from eggshell and nanohydroxyapatite can reduce treatment costs in bone repair or bone replacement and reduce waste to protect the environment.[23]

In the study by Lubis M et al. (2017), the denture bases mechanical properties were improved by the incorporation of 10% Chicken Eggshell material. The modulus of elasticity (MOE) and modulus of rapture (MOR) of the biocomposite increased with the addition of eggshells, from 1,933 GPa to 2.124 GPa at 10% filler and 46,864 MPa to 48.311 MPa at 20% filler.[14] According to Lubis M et al. (2021) studies, the addition of chicken eggshell nanoparticles to the acrylic resin denture base improved the mechanical properties of the biocomposite base. The Modulus of Elasticity (MOE) and Modulus of Rapture (MOR) increased, reaching maximum values of 2,571 GPa and 48.859 MPa, respectively. When compared to the addition of 30% filler, the addition of 10% filler is desirable.[21]

Al-Bahar ZJH et al. (2014) extracted hydroxyapatite from chicken eggshell in their study. Hydroxyapatite is produced by heating CaCO3 in chicken eggshell material to 900°C and then adding H3PO4 (phosphoric acid). The mechanical strength of the denture base significantly increased when chicken eggshell hydroxyapatite was added to heat-cured acrylic resin.[30] Fouly A. et al. (2021) investigated the effects of adding hydroxyapatite to PMMA nanocomposite for making denture bases. Hydroxyapatite nanoparticles having weight fractions -

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of 0, 0.2, 0.4, 0.6, and 0.8 % were employed in the study. The findings demonstrated that the stiffness, compressive yield strength, toughness, ductility, and hardness of PMMA nanocomposite will increase with increasing hydroxyapatite content.[31]

Abdullah AM et al. (2020) using treated eggshell powder with PMMA. PMMA wear was reduced by approximately 57% with an increase in the fraction of treated eggshell powder of up to 5% wt. Additionally, it was discovered in this investigation that when the eggshell concentration in PMMA composites increased, the flexural modulus value gradually increased.[23]

CONCLUSION

Provisional FDPs made of heat-cured PMMA must be strong enough to support occlusal loads and aesthetically pleasing during use for long periods of time. Various attempts have been made to overcome the drawbacks of the long-term use of PMMA, such as the addition of reinforcing materials to improve the physical and mechanical properties of FDP's materials. It is reasonable to anticipate that adding eggshell to the FDP reinforcement of heat-cured PMMA will improve color stability and reduce the water absorption nature.

SUGGESTIONS

Further research on the addition of eggshell reinforcing material is required to determine the relationship between physical properties like water absorption and color stability in heat-cured PMMA.

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