INDONESIAN JOURNAL OF PROSTHODONTICS

REVIEW

The benefit of chitosan adding as a reinforcement material for polymethyl methacrylate provisional fixed dentures

Dara Aidilla, Ricca Chairunnisa, Syafrinani

Keywords: Chitosan, Provisional fixed partial denture, Self-cure PMMA

ABSTRACT

Backgrounds: Provisional fixed partial denture (FPD) is an important procedure in prosthetic treatment such as crown or bridge. In particular cases, like crown lengthening as preliminary treatment, implant procedure until osseointegration process, and temporomandibular disorder as an occlusal therapy, the use of provisional FPD will take 3-6 months until the insertion of definitive restoration. Therefore, materials used in making a provisional FPD should be able to preserve the prepared tooth, maintain the periodontal conditions, and have superior esthetic for a long time. Self-cure polymethyl methacrylate (PMMA) is a most commonly used material due to its biocompatibility, high wear resistance, ease of application, and superior esthetic. Nonetheless, unmodified self-curing PMMA has weaknesses due to its degradation process in the oral cavity, which affects its mechanical and physical properties. To overcome this, addition of reinforcement material, namely chitosan, in provisional FPD is necessary. Chitosan is polymer compound obtain through partial deacetylation of acetyl glucosamine through deacetylation of chitin base and modified into magnetic nanoparticles with size 100-400 nm to increase absorption power. The addition of nanotechnology to polymeric materials has shown significant appeal and improved mechanical and physical properties. (IJP 2024;5(2):89-91)

Introduction

Provisional restoration is an important stage of prosthetic treatments withcrowns and bridges. The periodontal tissue usually requires 6 months to heal after certain procedures, such as crown lengthening. A provisional restoration is therefore required to maintain the periodontal's shape and tissue after crown lengthening.[1,2] The same holds true for implant installation, which requires a 3-6 months osseointegration period.[3]

Provisional restoration serves to protect and maintain patient comfort when definitive restoration is made. The success of the treatment phase using provisional restoration , the dentist can gain the patient's trust and favorably influence the final success of the restoration.[1,4] The types of materials that can be used in temporary retortation are PMMA, PEMA, Urethane Dimethacrylat Resin, and Bicacryl Composite. The material that until now has been used is PMMA (polymethyl methacrylate). PMMA is often used because of its easy application and because its price is not too expensive when compared to other materials. PMMA comes in several types, namely heat-cure and self-cure.[5,6]

The most commonly used material for producing provisional restoration s is PMMA. This material has a reduced molecular weight and doesn't require heat for polymerization. A tertiary amine niciator, such as dimethyl-p-toluidin, activated benzyl peroxide, which subsequently creates free radicals chemically, in a self-cure PMMA. Better dimensional stability and adaptation are the primary advantages of PMMA self-cure, and there is minimal shrinkage after polymerization.[6] However, since PMMA self-cure polymerizes to a lower degree than heat-cure PMMA, there are many unreacted monomers, or so-called residual monomers, that could irritate tissues and decrease their mechanical and physical properties. To overcome this, a reinforcing material was added to the self-cure PMMA, increasing its resistance to fractures caused by masticatory loads, discoloration, and long-term use. Chemical substances, metals, or fibers can be utilized as reinforcing materials. However, because natural ingredients are biocompatible and safe for the body, several researchers have created the method of adding them as reinforcement.[7,8]

A naturally existing material called chitosan is derived from the shells of crustaceans like crabs, shrimp, and lobsters. Other microbes, including yeast and fungus, also contain chitosan. Research on chitosan keeps on being established because it has many benefits in biomedical and dental applications. Chitin bases are deacetylated to produce chitosan, a polymeric compound of glucosamine and N-acetyl glucosamine. Chitosan has many advantageous properties, including good biocompatibility, mucoadhesion, non-toxicity, lack of allergic reactions, and lack of carcinogenicity.(9–11) In addition, chitosan also has a high resistance to heat due to its intramolecular hydrogen bonds. Chitosan can be modified both chemically and physically during development to increase its adsorption capacity,

Specialist Program in Prosthodontics, Faculty of Dentistry, Universitas Sumatera Utara, Medan, Indonesia
*Corresponding author: ricca@usu.ac.id

DOI 10.46934/ijp.v5i2.205

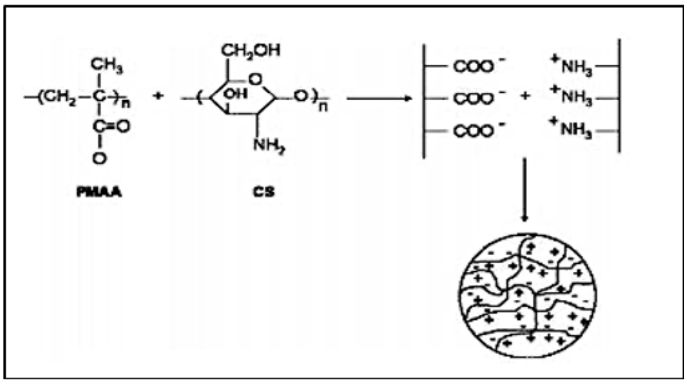

Figure 1. Bond between PMMA and chitosan compounds

selectivity, and use. Such chitosan modifications can be accomplished by combining chitosan with a variety of polymers, both natural and synthetic.[12-14]

Research has shown that nanoparticles are significantly attracted to prosthodontic polymeric materials because of the materials' improved mechanical and physical properties. However, a number of variables, including particle size, polymer particle interface, fabrication method, and particle distribution in the polymer matrix, influence how much of an impact nanoparticles have on the physical and mechanical properties of polymers.[8,9] Chitosan development research is still being explored. The scientists researched further special qualities in chitosan that may be applied in a variety of industries, such as medical, biology, and pharmaceuticals. Many studies use chitosan as an absorbent and modify it chemically and physically by combining it with other polymers.[13] Based on this, the author wants to describe how PMMA is self-curing while chitosan material is being added to the provisional fixed denture material in an attempt to improve its physical and mechanical properties.

Provisional Fixed Dentures

A provisional restoration, according to The Glossary of Prosthodontics, is a fixed or removable dental prosthesis or maxillofacial prosthesis created to improve aesthetics, stability, and/or function for a brief period of time before being replaced by a final dental or maxillofacial prosthesis.[15] Until the insertion of a definitive restoration, provisional restorations perform an important function in dental preparation. Although the final restoration will be done a few weeks after the tooth is restored, provisional restorations should nevertheless satisfy the patients' and dentists' essential needs.[3]

Provisional restoration may be required for a prolonged period of time due to periodontal diseases or the etiology of TMJ problems. Therefore, a provisional restoration must be adequate for maintaining the patient's health. The ideal interim restoration must take into account a number of interrelated factors, which can be classified as biological, mechanical, and aesthetic considerations. The condition of a provisional restoration must be able to protect the pulp, prevent supraeruption and the presence of tipping on the teeth, produce good occlusal function in the patient, easily maintain the patient's OH, the material used must be resistant to occlusal and retentive loads, aesthetically pleasing and can be policed to prevent plaque accumulation.[2,16]

Some materials that can be used for provisional restoration are Polymethyl Methacrylate Resins (PMMA), Polyethyl Methacrylate Resins (PEMA), vinyl ethyl methacrylate resins, butyl methacrylate, epimine, metal, polycarbonate materials, bis-acryl composites, bis-GMA composites, and Urethane Di Methacrylate Resins (UDMA). However, a commonly used material for provisional restoration is PMMA acrylic resin.[5]

Polymethyl Metachrylate (PMMA)

In 1843, Redtenbacher published the first description of PMMA, an odorless acrylate acid polymer. However, PMMA's development in biomedicine occurred gradually over a period of time. In 1937, PMMA was first introduced in powder form for the fabrication of denture bases. Later, in the 1940s, PMMA became an important biomaterial for dental laboratories and clinics.[17]

The properties obtained by PMMA, such as easy to process, acceptable mechanical properties, aesthetics, cost-effectiveness, and relatively lower toxicity, have replaced the basic materials of artificial teeth used previously, namely, gold, porcelain, aluminum, and others. In the late 20th century, PMMA gained popularity for the fabrication of a variety of dental and maxillofacial prostheses, including obturators, dentures, provisional crowns and bridges, in addition to being the base material for dentures. However, this material has gluttons, such as exothermic polymerization, high polymerization shrinkage, and low wear resistance.[5]

According to Anusavice (2013), the types of akrilik resins are:[18] Hot polymerized acrylic resin (Heat-Activated Denture Base Resin); This material is used by almost all denture base manufacturers. This material is available in powder and liquid form and requires thermal energy (heating) for polymerization. A water bath or microwave can be used to heat the material; Chemical-Activated Denture Base Resin. The terms self-cure, cold-cure, autopolymerization, swapolimerizing resins are frequently used to describe acrylic resins that require chemical activation. This material polymerizes by chemical activation. In self-cure PMMA, tertiary initiator amines such as dimethyl-p-toluidine are added, which after polymerization activates benzyl peroxide and produces free radicals. Activation is chemical and does not require the application of thermal energy. Therefore, it can be done at room temperature. This material is frequently utilized today because the quick and simple manufacturing process makes it simpler for dentists to do provisional restorations.

PMMA self-cure

Self-curing PMMA was first introduced in 1945 in Germany. The advantages of using this type of material over other types of PMMA polymers include easy application; a fast manufacturing process; biocompatibility with oral tissue; allergy-freeness; low density and molecular weight; stable color for acceptable aesthetics; minimal depreciation; a stable polymerization cycle with an acceptable end result; and long-term functionality.[17,19]

This material consists of powder and liquid, where acrylic resin powder, benzoyl peroxide, fibers, and colorants are contained in the powder. And the self-cure PMMA liquid contains methyl metacrylate, hydroquinone, ethylene glycole, and what distinguishes

DOI 10.46934/ijp.v5i2.205

it from pmma heat-cure is the addition of a tertiary amine activator. Before this material polymerizes, there are multiple phases that occur when powder and liquid are mixed. At the initial stage, physical changes occur. The mixture of this material will feel grainy or sandy. Then the monomer will mix with the polymer. Part of the polymer chain will be dispersed in the monomer liquid so that the viscosity increases. The number of polymer chains increases during the dough stage. The dough is plastic and easy to mold during this stage.[17] Benzoyl peroxide and tertiary amines react to generate free radicals as the powder and liquid are mixed. When a substance transitions from the grainy stage to the dough stage, free radicals are created. Inhibitors in liquids eliminate these free radicals. The polymerization reaction occurs as a result of chemical changes that take place when the inhibitor is depleted during the dough stage. The dough material stiffens and thickens. The material warms up as a result of this reaction, which also produces heat. As the polymerization process is finished, the material solidifies and becomes rigid.[17,20]

PMMA self-cure has a limitation in that its degree of polymerization is less than that of PMMA heat-cure, resulting in a higher proportion of monomers that do not react or are termed monomers, while the remaining monomers will irritate tissue. This weakness results in a drop in mechanical and physical qualities. Self-cure PMMA resins have various physical and mechanical properties, such as an elastic modulus of 1.63–3 MPa, impact resistance of 8.3 KJ/m2, flexural strength of 79 MPa, water absorption of 2.5%, and a density of 1.19 g/cm3.[19,21]

Chitosan

One of the biomaterials currently under research is chitosan, which has been found to be safe for usage in humans as well as to offer a number of medical benefits. Chitosan is frequently used in biomedical applications due to its distinct properties, which include good biocompatibility, biodegradability, mucoadhesion, non-toxicity, does not cause immunological reactions, and does not cause cancer. In dentistry, chitosan is widely used for bone and tissue regeneration, as an antimicrobial in toothpaste, and as an antifungal in denture bases. In vitro studies established significant results of chitosan denture base composites in antifungal, antioxidant, antimicrobial, and some mechanical properties.[22]

Chitosan is composed of three elements: carbon, hydrogen, and nitrogen. Acidic solvents, including acetic acid, formic acid, lactic acid, citric acid, and hydrochloric acid, can dissolve chitosan. A number of acidic solvents must be included in order for chitosan to dissolve in water, methanol, acetone, and other mixtures. Chitosan is insoluble in water, alkalis, and dilute mineral acids except under specific circumstances. Chitosan's solubility is influenced by the molecule's weight and degree of deacetylation.[10]

In its development, chitosan is modified in the magnetic form of chitosan nanoparticles with a particle size of 100-400 nm to increase its absorbency. The distribution of nanoparticles inside the polymer matrix, the matrix's relative crystalline or amorphous properties, the interaction of the fillers with the polymeric matrix, and other factors all affect how nanoparticles affect the physiomechanical properties of nanocomposites. Chitosan is a polycationic polymer with the functional groups "amino" and "hydroxyl" as its active components. In addition, due to its intramolecular hydrogen bond, chitosan has a high resistance to heat. Chitosan can be modified both chemically and physically to increase its adsorption capacity, selectivity, and applicability. Such chitosan modifications can be accomplished by combining chitosan with a number of different polymers, both natural and synthetic.[10,18]

Chitosan-PMMA self-cure

In the polymerization process, a reaction between methyl methacrylate, glycol dimethacrylate, and heat produces a cross-link into poly (methyl methacrylate). Chitosan, which has basic characteristics and has NH2, forms the first chain in this intermediate bond. While acrylic resin, or PMMA, contains COOH and has acidic characteristics. The final result of the COO (-) + NH3 bond can be NH3 because NH2 from chitosan captures (H) from COOH in PPMA. This bond can occur because, in general, chitosan is alkaline and has the ability to absorb components from PMMA, which is acidic and more likely to readily release them.[12,22]

Discussion

PMMA has been altered to improve its mechanical (impact strength, cyclic fatigue, flexural strength, and wear resistance), physical (thermal conductivity, water absorption, solubility, and dimensional stability), and biological properties. These modifications have involved chemical or mechanical reinforcement using additives (fibers, nanofillers, nanotubes, and hybrid materials) (antimicrobial activity, biocompatibility).[18]

In 2021, Felycia analyzed the effect of chitosan coating on the transverse strength and water absorption of hot polymerized acrylic resin dentures. Hot polymerized acrylic resin dentures' bases' transverse strength and water absorption are both affected by chitosan coating. Chitosan coating can prevent water absorption and prevent hot polymerized acrylic resins from decreasing its transverse strength.[10]

Chitosan nanoparticles (Cs/NPs) were investigated by Abdillah M. et al. in 2020 to see how these would affect thermoplastic resin materials' flexural strength, impact strength, fracture toughness, water absorption, and solubility. The flexural strength, impact strength, and fracture toughness of thermoplastic resins are all decreased by the incorporation of Cs/NPs. Meanwhile, the modified thermoplastic resin's solubility and water absorption were increased.[9]

Investigated the effectiveness of a mixture of acrylic resins, chitosan, and acrylic acid as an anti-Candida albicans denture material. The results showed that the chitosan and acrylic resin combination significantly inhibited the growth of Candida albicans.[11]

The addition of high-molecular chitosan in the form of nanogels has an effect on the acrylic resin's base material's mechanical strength and color stability. The values of impact strength, transverse strength, and discoloration of the acrylic resin's base material after the addition of chitosan nano gel at different percentages of 0.25 percent, 0.50 percent, 0.75 percent, 1.0 percent, and 1.5 percent can be seen to significantly vary. The best consistency that can be used as a strengthening material is the addition of chitosan nanogel at 1%.[18]

A comprehensive overview of the preparation, application, and major breakthroughs of chitosan biomaterials. GIC material modified with the addition of chitosan results in an increase in GIC bonding strength. In this case, chitosan has the advantage of having the highest antibacterial activity and the highest compressive and

DOI 10.46934/ijp.v5i2.205

flexural strength.[12]

In order to significantly improve biocompatibility without affecting other implant properties, Tanikonda et al. discussed several applications of chitosan in the field of chitosan electrodeposition dentistry in combination with calcium phosphate in Ti6Al4V implants. It has been reported that electrolytically precipitated calcium phosphate is initially octacalcium phosphate, which is then transferred to apatite carbonate. This is due to chitosan being present, which affects how calcium phosphate forms and crystallizes, preventing octacalcium phosphate from converting to carbonate apatite and causing a drop in crystallinity. Chitosan concentration increases have a detrimental effect on coating thickness and surface roughness.[13]

The effect of differences in Ch concentrations on flexural strength (FS), fracture toughness (FT), impact strength (IS), and surface roughness (Ra) on hot polymerization DBR. The addition of chitosan to the acrylic resin of the denture base increases the flexural strength, fracture toughness, and impact strength of the denture base resin. The flexural strength, toughness of the fracture, and the highest impact strength are obtained at the addition of 5% of the chitosan weight to the resin of the denture base. Surface roughness decreases with chitosan concentrations and increased surface roughness is observed at the addition of chitosan 5% to the resin of the denture base.[14]

Conclusion and Suggestion

The effect of differences in Ch concentrations on flexural strength (FS), fracture toughness (FT), impact strength (IS), and surface roughness (Ra) on hot polymerization DBR. The addition of chitosan to the acrylic resin of the denture base increases the flexural strength, fracture toughness, and impact strength of the denture base resin. The flexural strength, toughness of the fracture, and the highest impact strength are obtained at the addition of 5% of the chitosan weight to the resin of the denture base. Surface roughness decreases with chitosan concentrations and increased surface roughness is observed at the addition of chitosan 5% to the resin of the denture base.[14]

References

1. Wassell RW, St George G, Ingledew RP, Steele JG. Crowns and other extra-coronal restorations: Provisional restorations. Vol. 192, BRITISH DENTAL JOURNAL VOLUME. 2002.
2. Heboyan A, Movsisyan N, Khachatryan VA. Provisional Restorations in Restorative Dentistry. WORLD SCIENCE. 2019 Jun 30;3(6):11–7.
3. Santosa RE. Provisional restoration options in implant dentistry. Vol. 52, Australian Dental Journal. 2007.
4. Trevor Burke F. Use of a Novel Resin Composite Crown as a Long-Term Provisional Indications for crowns. Vol. 36, Dent Update. 2009.
5. Singh A, Garg S. Comparative Evaluation of Flexural Strength of Provisional Crown and Bridge Materials-An In-vitro Study [Internet]. Vol. 10, Journal of Clinical and Diagnostic Research. 2016. Available from: www.jcdr.net
6. Zafar MS. Prosthodontic applications of polymethyl methacrylate (PMMA): An update. Vol. 12, Polymers. MDPI AG; 2020. p. 1–35.
7. Rateb Al-Hallak K, Zakaria Nassani M, Mourshed B, Kinan Seirawan M. Influence of Acrylic Resin Polymerization Methods on Residual Monomer Release and Porosity. 2019;4(1). Available from: http://scholarsmepub.com/sjodr/
8. Mahalaxmi S. Materials Used in Dentistry. 1st ed. Vol. 1. New Delhi: Wolters Kluwer; 2013.
9. Ahmed Refaei M, Abdelrahim R, Ali M. Evaluation of some physical and mechanical properties of chitosan modified thermoplastic denture base resin. Al-Azhar Journal of Dental Science. 2020 Jul 1;23(3):247–53.
10. Tarigan S. The effect of chitosan coating on the base of hot polymerized acrylic resin dentures on water absorption and transverse strength. Journal of Dental Researchers and Students. 2021;5(1):57–63.
11. Ismiyati T, Siswomihardjo W, Soesatyo MHNE, Rochmadi R. A mixture of chitosan with acrylic resin as an inhibitory denture material Candida albicans. Indonesian Dentistry Magazine. 2017 Dec 29;3(3):21.
12. Zhang C, Hui D, Du C, Sun H, Peng W, Pu X, et al. Preparation and application of chitosan biomaterials in dentistry. Vol. 167, International Journal of Biological Macromolecules. Elsevier B.V.; 2021. p. 1198–210.
13. Tanikonda R, Ravi R, Kantheti S, Divella S. Chitosan: Applications in dentistry. Trends Biomater [Internet]. 2014;28(2):74–8. Available from: https://www.researchgate.net/publication/311628439
14. Chander NG, Venkatraman J. Mechanical properties and surface roughness of chitosan reinforced heat polymerized denture base resin. Journal of Prosthodontic Research. 2022;66(1):101–8.
15. Ferro K, Morgano S. The Glossary of Prosthodontic Terms: Ninth Edition. J Prosthet Dent. 2017 May 1;117(5):e1–105.
16. Davis S, O'Connell P. The provisional crown. Journal of The Irish Dental Association [Internet]. 2004;50(4):160–71. Available from: https://www.researchgate.net/publication/8113969
17. Adnan Hamad Q. Investigation some mechanical properties of self-cured PMMA resin reinforced by different T types of nano particles. The Iraqi Journal For Mechanical And Material Engineering. 2017;17:2016–27.
18. Adiana I. Effect Of Chitosan Nano Gel Addition On Mechanical Properties And Color Stability Of Tooth Base Material Imitation Hot Polymerized Acrylic Resin. [Medan]: University of North Sumatra; 2016.
19. Mumcu E, Cilingir A, Gencel B, Sülün T. Flexural properties of a light-cure and a self-cure denture base materials compared to conventional alternatives. Journal of Advanced Prosthodontics. 2011;3(3):136–9.
20. Walczak K, Thiele J, Geisler D, Boening K, Wieckiewicz M. Effect of chemical disinfection on chitosan coated PMMA and PETG surfaces-An in vitro study. Polymers (Basel). 2018 May 16;10(5).
21. Fonseca RB, Kasuya AVB, Favarão IN, Naves LZ, Hoeppner MG. The influence of polymerization type and reinforcement method on flexural strength of acrylic resin. Scientific World Journal. 2015;2015.
22. Tiyaboonchai W. Chitosan Nanoparticles : A Promising System for Drug Delivery. Vol. 11, Naresuan University Journal. 2003.

DOI 10.46934/ijp.v5i2.205