Effectiveness Additional Silicon Dioxide Nanoparticles on Flexural Strength and Surface Hardness Heat Polymerization Acrylic Resin Denture Bases: A Systematic Literature Review

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ABSTRACT

Introduction: The objective of this systematic review was to determine the effectiveness of the addition of silicon dioxide nanoparticles on the flexural strength and surface hardness of the denture base of heat polymerization acrylic resin. **Methods:** Two electronic databases were searched through 2012-2022. The terms "(*nanoparticles* AND *SiO2* AND *Silicon dioxide* AND *Silica* AND *flexural strength* AND *surface hardness* AND *heat cured resin acrylic* OR *denture*) was chosen. Articles meeting the inclusion and exclusion criteria were selected. The database search resulted in a total of 587 potential studies. **Results:** After screening titles and abstracts and applying inclusion and exclusion criteria, 5 studies were collected for a full text assessment. Full text assessment resulted in 5 studies that were eligible of qualitative synthesis. Checklist Critical Appraisal (CEBM) with scoring method resulted that there was 3 studies with 10 scores and 2 studies with 9 scores. **Conclusion:** The quantity of concentration used in 5 studies was 1%, 3%, 5% and 7% concentration of silicon dioxide nanoparticles and additional with 5% concentration of silicon dioxide nanoparticles shows the best result in increasing the flexural strength and surface hardness of heat polymerization acrylic resin of denture base.

Keywords: Heat cured resin acrylic, flexural strength, surface hardness, nanoparticles, SiO^2, denture base.

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INTRODUCTION

Medical Dictionary Farlex (MDF) stated the complete denture is a denture that replaces natural teeth that can provide good support or retention in the upper and lower jaw.[1] Main component of denture is the base. The denture base can be defined as the part of the denture that rests on the soft tissues of the oral mucosa and also as attachment site for denture elements.[2] The function of denture base is to improve the contour of the tissue so that it can redistribute into the original oral mucosal tissue and can accept the functional load from occlusion and prevent migration of natural teeth and can stimulate residual ridge tissue.[3]

Basic requirements for denture bases are non-toxic and irritant, low porosity so that there is no bacterial growth, excellent dimensional stability, high strength and resistance, low water absorption and good thermal conductivity.[4] Heat cured acrylic resin is a thermoset material that is often used in the manufacture of denture bases because it has advantages such as biocompatibility to oral tissues, easy finishing and polishing, good dimensional stability, low economical price and good aesthetics.[4,5] Heat cured acrylic resin is an acrylic resin with polymerization that carried out by heating techniques. Heat cured acrylic resin also easily damaged when used due to unintentional negligence on the part of the wearer due to low flexural fatigue strength and low surface hardness.[6] This is a weakness of heat cured acrylic resin materials.[7] Previous literatures have mentioned that 68% of dentures fracture after several years of use and generally caused by fatigue due to occlusal loads and strong impaction during use. Fractures often occur in the midline, especially the maxillary denture.[8] The load imposed on the denture base also often exceeds the maximum flexural fatigue limit of the denture base which causes fractures to occur frequently in the oral cavity.[4]

The ability of the denture base to resist fracture was influenced by high flexural strength and high surface hardness. According to Ajaj-Alkordy, et al (2013) flexural strength is a combination of tensile strength and compressive strength which is directly related to denture base fracture when used in the oral cavity due to flexural fatigue by the denture base that receives repeated masticatory loads which in turn causes alveolar bone resorption so that the denture support becomes unbalanced.[10,11] The minimum standard value for the flexural strength of heat cured acrylic resin base is 65 MPa.[19] According to Sheng T.J et al. (2018), surface hardness is the resistance of the material to deformation when a compressive force is applied and durometer hardness tester (shore D) is used to measure the surface hardness of heat cured acrylic resin denture base.[4,12] Efforts have been made to solve the problem of denture fracture by adding reinforcing materials.[10] The type of reinforcing material added to the denture base of heat cured acrylic resin consists of metal, fiber, and chemical modification.[12] Main focus of chemical industry research is the addition of nanoparticles into heat cured acrylic resin to produce maximum nano-oxide strength with good flexibility in heat cured acrylic resins.[9,14] Nanoparticles that widely used are silicon dioxide (SiO_2) or silica nanoparticles.[15] Currently, silicon dioxide nanoparticles are often used in dental materials because of their advantages such as biocompatible with oral tissues, providing good esthetics and having small particle sizes that are able to form strong interfacial surfaces with heat cured acrylic resin polymers.[14,15] There are many hydroxide radicals bound to the surface of the silicon dioxide nanoparticles that make a strong bond with the heat cured acrylic resin to create good absorption. The absorption and bonding aids in the distribution of stresses can withstand loads by increasing the flexural strength and surface hardness of the heat cured acrylic resin base.[15]

The study of Song, et al (2011) stated that silicon dioxide nanoparticles modified with heat cured acrylic resin are considered to have excellent hydrophobic properties due to their low water absorption which will protect the surface of the heat cured acrylic resin base from fracture.[16] The addition of silicon dioxide nanoparticles will reduce water absorption in heat cured acrylic resins. This causes the surface of the heat cured acrylic resin remain dense and smooth because the silicon dioxide nanoparticles on the surface of the heat cured acrylic resin absorb few water molecules[15,16] The study by Tahiri N, et al (2014) also stated that the strength and durability of silicon dioxide nanoparticles depend on the heating reaction temperature and the time and speed for maximum evaporation of silicon dioxide nanoparticles.[17] Chemical reinforcing materials from silicon dioxide nanoparticles are the main choice for strengthening denture base polymer heat cured acrylic resin resulting to increase flexural strength, hardness and fracture resistance.[14,15] Research by Alnamel HA, et al (2014) stated that the addition of 3% and 5% concentration of silicon dioxide nanoparticles increased flexural strength but decreased at 7% concentration of silicon dioxide nanoparticles and 3%, 5% and 7% concentration of silicon dioxide nanoparticles increased surface hardness.[14] Meanwhile, the research study by Fatihallah AA, et al (2015) stated that the addition of 5% concentration of silicon dioxide nanoparticles increased the flexural strength and surface hardness of the denture base of heat cured acrylic resin compared to the control group without the addition of silicon dioxide nanoparticles.[13] The research study of Cevik P, et al (2016) stated that the addition of 5% concentration of silicon dioxide nanoparticles on the denture base of heat cured acrylic resin has higher flexural strength and surface hardness compared to 1% concentration of silicon dioxide nanoparticles.[9] The study of Salman A, et al (2017) showed that the addition with crystalline sand-type of silicon dioxide nanoparticles with 3%, 5% and 7% concentrations of silicon dioxide nanoparticles increased the flexural strength and surface hardness of the denture base of heat cured acrylic resin.[18] The research of Akhlas Z, et al (2019) stated that the addition of 1% concentration of silicon dioxide nanoparticles increased the flexural strength and surface hardness of heat cured acrylic resin denture base compared to the control group without the addition of silicon dioxide nanoparticles.[20]

Based on the research that has been done previously, it can be concluded that 5% concentration of silicon dioxide nanoparticles showed the highest flexural strength and surface hardness in heat cured acrylic resin denture bases. Therefore, this systematic literature review was done as an updated reference in discussing.

METHODS

Study Selection

The selection process began with filtering identified articles by reading the abstracts. Full texts of the relevant articles were then evaluated. Evaluation was done with inclusion and exclusion criteria based on PICOS (Table 1).[25]

Quality assessment

Quality assessment was done using checklist Critical Appraisal (CEBM) to the study design of the assessed journals. Randomized controlled trial (RCT) used Critical Appraisal (CEBM). Checklist Critical Appraisal is the criteria using scoring method and consist of 12 questions that can be given -1, 0 or 1 point. Quality assessment was done using 1 criteria according to the study design of the assessed journals. Randomized controlled trial (RCT) used Critical Appraisal (CEBM) criteria consist of 12 questions that can be given -1, 0 or 1 point and the total points then were added up, journals with 4-8 points were considered as high quality and 0-3 points were considered as low quality. (Table 2).

Search Strategy and Data Extraction

An online literature search was conducted using the PubMed and Google Scholar. The search was done with Boolean system with the keyword " (*nanoparticles* AND *SiO2* AND *Silicon dioxide* AND *Silica* AND *flexural strength* AND *surface hardness* AND *heat cured resin acrylic* OR *denture*) " PRISMA (Preferred Reporting Items for Systematic Reviews and Meta – Analysis) was suitable articles for analysis PICOS (Population, Intervention, Comparison, Outcome, Study) was used to narrow the scope of the articles search (Table 1).

Criteria	Inclusion	Exclusion
Database	PubMed, Google Scholar	Other database
Publishing year	2012-2022	Other publishing year
Language	English	Other language
Publication type	Journal	Other publication type
Journal quality	High and medium quality	Low quality
Populations	Heat cured acrylic resin denture base	Other materials denture base
Intervention	Addition silicon dioxide nanoparticles	Other reinforcement materials
Comparison	Difference concentration of silicon dioxide nanoparticles in heat cured acrylic resin denture base	Other materials
Outcome	Effectiveness of additional silicon dioxide nanoparticles on flexural strength and surface hardness heat cured acrylic resin denture base	No significant changes
Study	RCT (Randomized controlled trials)	Other studies

Table 1. Inclusion and Exclusion of PICOS

Author & Year	Point	Quality
Alnamel HA, et al (2014)[14]	10	High
Fatihallah AA, et al (2015)[13]	9	High
Cevik P, et al (2016)[9]	10	High
Salman A, et al (2017)[18]	10	High
Akhlas Z, et al (2019)[20]	9	High

Table 2. Critical Appraisal (CEBM)

Data Analysis

Data analysis was done qualitatively using the scoring method checklist Critical Appraisal (CEBM).[26]

RESULTS

Five hundred eighty seven articles were obtained from PubMed and Google Scholar databases. The articles were checked for duplicates which were then deleted, leaving 585 articles. The remaining articles were then checked for the titles and abstracts according to the inclusion and exclusion criteria based on PICOS, leaving 10 articles. Furthermore, the full texts of these articles were analyzed resulted in 5 articles that could be used in this systematic literature review (Figure 1).

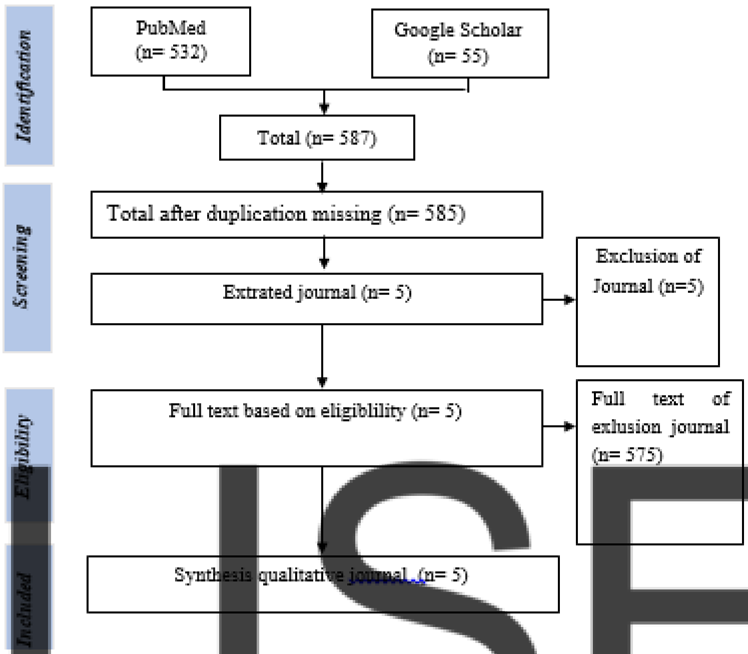

Figure 1. Study workflow and finding.

Study of Alnamel HA, et al (2014) 3%, 5% and 7% concentrations of silicon dioxide nanoparticles were used on heat cured acrylic resin denture base with a size of 100 nm silicon dioxide nanoparticles. The polymerization technique of silicon dioxide nanoparticles and heat cured acrylic resin was carried out by mixing silicon dioxide nanoparticles into polymer and monomer of heat cured acrylic resin and polymerization curing using a water bath for 1 hour 30 minutes at a temperature of 74°C. At 3% concentration of silicon dioxide nanoparticles, the flexural strength value shows 120.14 MPa and surface hardness value shows 84,81 g/mm^2. At 5% concentration of silicon dioxide nanoparticles, the flexural strength value showed 124.56 MPa and surface hardness value shows 85,15 g/mm^2. At 7% concentration of silicon dioxide nanoparticles, it showed a flexural strength value of 111.60 MPa and surface hardness value shows 85,33 g/mm^2. [14].

Study of Fatihallah AA, et al (2015) 5% concentration of silicon dioxide nanoparticles was used on the denture base of heat cured acrylic resin. The polymerization technique of silicon dioxide nanoparticles and heat cured acrylic resin is by mixing silicon dioxide nanoparticles into polymer and monomers heat cured acrylic resin and polymerization curing using a water bath for 3 hours at 100°C. At the addition of 5% concentration of silicon dioxide nanoparticles, the flexural strength value showed 119.21 MPa and surface hardness value shows 85,93 g/mm^2. [13]

Study of Salman A, et al (2017) the silicon dioxide nanoparticles used in his research were crystalline nanosilicon sand (NSS) nanoparticles with a size of 70 nm crystalline nanosilicon sand (NSS) on heat cured acrylic resin denture base. At 3%, 5% and 7% concentrations of silicon dioxide nanoparticles were used on heat cured acrylic resin denture base. The polymerization technique of silicon dioxide nanoparticles and heat cured acrylic resin was carried out by mixing silicon dioxide nanoparticles into polymer and monomer heat cured acrylic resin and polymerization curing using a water bath for 8 hours at 70°C. At 3% concentration of silicon dioxide nanoparticles, the flexural strength value showed 41.25 MPa and surface hardness value shows 80.43 g/mm^2. At

5% concentration of silicon dioxide nanoparticles, the flexural strength value showed 42.20 MPa and surface hardness value shows 81.43 g/mm^2. The addition of 7% concentration of silicon dioxide nanoparticles showed a flexural strength value of 45.70 MPa and surface hardness value shows 81.70 g/mm^2.[18]

Study of Cevik P, et al (2016) 1% and 5% concentrations of silicon dioxide nanoparticles were used on a heat cured acrylic resin denture base with a size of 12 nm silicon dioxide nanoparticles. The polymerization technique of silicon dioxide nanoparticles and heat cured acrylic resin is by mixing silicon dioxide nanoparticles into polymer and monomers of heat cured acrylic resin and polymerization curing using a water bath for 2 hours at a temperature of 120°C. At 1% concentration of silicon dioxide nanoparticles, the flexural strength value showed 100.80 MPa and surface hardness value shows 78.25 g/mm^2. At the addition of 5% concentration of silicon dioxide nanoparticles, the flexural strength value showed 103.30 MPa and surface hardness value shows 87.25 g/mm^2.[9]

In the research of Akhlas Z, et al (2019) 1% concentration of silicon dioxide nanoparticles was used in the denture base of heat cured acrylic resin. The polymerization technique of silicon dioxide nanoparticles and heat cured acrylic resin was carried out by mixing silicon dioxide nanoparticles into polymer and monomer heat cured acrylic resin and curing polymerization using a water bath for 1 hour 30 minutes at 70°C. At the addition of 1% concentration of silicon dioxide nanoparticles, the flexural strength value showed 75.02 MPa and surface hardness value shows 78.66 g/mm^2. [20]

All articles were analyzed and data were extracted. The data and conclusions needed from the study was tabulate in table. (Table 3-7).

Author & year	Title	Journal Ranking (Quartile)	Shape of nanoparticles SiO_2	Size of nanoparticles SiO_2	Concentration nanoparticles SiO_2	Type of Acrylic	Curing Cycle Heat cured acrylic resin + nanoparticles SiO_2	Effectiveness nanoparticles SiO_2 on flexural strength	Effectiveness nanoparticles SiO_2 on surface hardness	Conclusion of Effectiveness nanoparticles SiO_2 on flexural strength	Conclusion of Effectiveness nanoparticles SiO_2 on surface hardness
Alnamel HA, et al (2014)[14]	The Effect of Silicon Dioxide Nano-Fillers Reinforcement on Some Properties of Heat Cure Polymethyl Methacrylate Denture Base Material	Q1	synthetics SiO_2	100 nm	3%, 5%, 7%	Heat cured acrylic resin	Curing cycle waterbath 1hours 30 minutes, 74°C	120,14 MPa of 3% nanoparticles SiO_2 124,56 MPa of 5% nanoparticles SiO_2 111,60 MPa of 7% nanoparticles SiO_2	84,81 g/mm^2 of 3% nanoparticles SiO_2 85,15 g/mm^2 of 5% nanoparticles SiO_2 85,33 g/mm^2 of 7% nanoparticles SiO_2	3% nanoparticles SiO_2 effective 5% nanoparticles SiO_2 effective 7% nanoparticles SiO_2 non-effective	3% nanoparticles SiO_2 effective 5% nanoparticles SiO_2 effective 7% nanoparticles SiO_2 effective

Table 3. Alnamel HA,et al (2014)[14]

Author & year	Title	Journal Ranking (Quartile)	Shape of nanoparticles SiO_2	Size of nanoparticles SiO_2	Concentration nanoparticles SiO_2	Type of Acrylic	Curing Cycle Heat cured acrylic resin + nanoparticles SiO_2	Effectiveness nanoparticles SiO_2 on flexural strength	Effectiveness nanoparticles SiO_2 on surface hardness	Conclusion of Effectiveness nanoparticles SiO_2 on flexural strength	Conclusion of Effectiveness nanoparticles SiO_2 on surface hardness
Fatihallah AA, et al (2015)[13]	Comparison of Some Mechanical Properties of Silanated SiO_2 and Polyester Fiber Composite Incorporation into Heat Cured Acrylic Resin	Q1	synthetics SiO_2	-	5%	Heat cured acrylic resin	Curing cycle waterbath 3hours, 100°C	119,21 MPa of 5% nanoparticles SiO_2	85,93 g/mm^2 of 5% nanoparticles SiO_2	5% nanoparticles SiO_2 effective	5% nanoparticles SiO_2 effective

Table 4. Fatihallah AA, et al (2015)[13]

Author & year	Title	Journal Ranking (Quartile)	Shape of nanoparticles SiO_2	Size of nanoparticles SiO_2	Concentration nanoparticles SiO_2	Type of Acrylic	Curing Cycle Heat cured acrylic resin + nanoparticles SiO_2	Effectiveness nanoparticles SiO_2 on flexural strength	Effectiveness nanoparticles SiO_2 on surface hardness	Conclusion of Effectiveness nanoparticles SiO_2 on flexural strength	Conclusion of Effectiveness nanoparticles SiO_2 on surface hardness
Cevik P, et al (2016)[9]	The Effect of Silica and Prepolymer Nanoparticles on The Mechanical Properties of Denture Base Acrylic Resin	Q1	synthetics SiO_2	12 nm	1%, 5%	Heat cured acrylic resin	Curing cycle waterbath 2hours, 120°C	100,80 MPa of 1% nanoparticles SiO_2 103,30 MPa of 5% nanoparticles SiO_2	78,25 g/mm^2 of 1% nanoparticles SiO_2 87,25 g/mm^2 of 5% nanoparticles SiO_2	1% nanoparticles SiO_2 effective 5% nanoparticles SiO_2 effective	1% nanoparticles SiO_2 effective 5% nanoparticles SiO_2 effective

Table 5. Cevik P, (2016)[9]

Author & year	Title	Journal Ranking (Quartile)	Shape of nanoparticles SiO_2	Size of nanoparticles SiO_2	Concentration nanoparticles SiO_2	Type of Acrylic	Curing Cycle Heat cured acrylic resin + nanoparticles SiO_2	Effectiveness nanoparticles SiO_2 on flexural strength	Effectiveness nanoparticles SiO_2 on surface hardness	Conclusion of Effectiveness nanoparticles SiO_2 on flexural strength	Conclusion of Effectiveness nanoparticles SiO_2 on surface hardness
Salman A, et al (2017)[18]	Comparative Study of the Effect of Incorporating SiO_2 Nano-Particles on Properties of Poly Methyl Methacrylate Denture Bases	Q1	synthetics SiO_2	70 nm	3%, 5%, 7%	Heat cured acrylic resin	Curing cycle waterbath 8hours, 70°C	41,25 MPa of 3% nanoparticles SiO_2 42,20 MPa of 5% nanoparticles SiO_2 45,70 MPa of 7% nanoparticles SiO_2	80,43 g/mm^2 of 3% nanoparticles SiO_2 81,43 g/mm^2 of 5% nanoparticles SiO_2 81,70 g/mm^2 of 7% nanoparticles SiO_2	3% nanoparticles SiO_2 effective 5% nanoparticles SiO_2 effective 7% nanoparticles SiO_2 effective	3% nanoparticles SiO_2 effective 5% nanoparticles SiO_2 effective 7% nanoparticles SiO_2 effective

Table 6. Salman A, et al (2017)[18]

Author & Year	Title	Journal Ranking (Quartile)	Shape of nanoparticles SiO_2	Size of nanoparticles SiO_2	Concentration nanoparticles SiO_2	Type of Acrylic	Curing Cycle Heat cured acrylic resin + nanoparticles SiO_2	Effectiveness nanoparticles SiO_2 on flexural strength	Effectiveness nanoparticles SiO_2 on surface hardness	Conclusion of Effectiveness nanoparticles SiO_2 on flexural strength	Conclusion of Effectiveness nanoparticles SiO_2 on surface hardness
Akhlas Z, dkk (2019)[20]	The Effect of Silica Addition on Hardness and Flexural Strength of Relined Acrylic Denture Base	Q1	synthetics SiO_2	-	1%	Heat cured acrylic resin	Curing cycle waterbath 1hour 30 minutes, 70°C	75,02 MPa of 1% nanoparticles SiO_2	78,66 g/mm^2 of 1% nanoparticles SiO_2	1% nanoparticles SiO_2 effective	1% nanoparticles SiO_2 effective

Table 7. Akhlas Z, et al (2019)[20]

DISCUSSION

This systematic review aimed to identify published articles comparing the effectiveness of adding different concentration of silicon dioxide nanoparticles in heat cured acrylic resin denture base. A total of 5 articles were obtained after going through the identification process to quality assessment and were eligible to be analyzed in this systematic review. Five articles with RCT design were published in 2012-2022. In RCT studies, the checklist Critical Appraisal (CEBM) were used to determine the quality of each articles with method of scoring. All articles in these studies were asked a 12 questions to show the validity of articles used in this systematic literature review. All studies were conducted in Arabia countries.[9,13,14,18,20]

Of the 5 studies that assessed in random controlled trials (RCT) by using scoring method of Critical Appraisal (CEBM) checklist, there are 2 questions with a score of 0 for all studies. The first question is "Could it be that the way the sample was obtained (selection) was biased?" and the second question is "Could the questionnaire measurement valid and reliable?" so that it can be stated that all of these studies do not provide clear details based on these two questions. At the Critical Appraisal (CEBM) checklist stage, there were also 8 questions that resulted in a score of 1 for all studies. The first question is "Does the research address a clear question/problem focus?", the second question is "Could the research method / research design appropriate to answer the research question?", the third question is "Could the method of selecting research subjects clearly explained?", the question the fourth is "Could a representative sample of subjects related to the population to be used as a reference?", the fifth question is "Are the statistics comparing groups clearly explained?", the sixth question is "Are the results for each group and the estimated effect size and accuracy explained?" , the seventh question is "Could the confidence interval in the study clearly explained?", the eighth question is "Can the results be applied to your research?". So it can be stated that all of these studies generally discuss or describe these 8 questions. Based on the scores obtained, the 3 studies have passed the journal quality review stage with a total score of 10 and 2 studies with a total score of 9. [9,13,14,18,20]

The results of data extraction in table 3-6 of the 5 studies discuss the effectiveness of the addition of silicon dioxide nanoparticles on the flexural strength and surface hardness of the denture base of heat cured acrylic resin and conclusions about their effectiveness. The data needed in this research is the concentration of silicon dioxide nanoparticles that can be added to the denture base of heat cured acrylic resin and their effectiveness on flexural strength and surface hardness. In this study, there were 2 studies that used 3%, 5% and 7% concentrations of silicon dioxide nanoparticles on the flexural strength and surface hardness of the heat cured acrylic resin denture base, 1 studies that used 1% and 5% concentrations of silicon dioxide nanoparticles on flexural strength and surface hardness of heat cured acrylic resin denture bases, 1 studies used 1% concentration of silicon dioxide nanoparticles on the flexural strength and surface hardness of heat cured acrylic resin denture bases and 1 studies used 5% concentration of silicon dioxide nanoparticles on flexural strength and surface hardness of heat cured acrylic resin denture base.

Based on research on these 5 studies, the additional of 1%, 3%, 5%, and 7% concentrations of silicon dioxide nanoparticles on the flexural strength and surface hardness of the denture base heat cured acrylic resin showed different results on the flexural strength and surface hardness values compared to the control group without the addition of silicon dioxide nanoparticles, however, 3% and 5% concentration of silicon dioxide nanoparticles had a positive effect in increasing the flexural strength and surface hardness values of the heat cured acrylic resin denture base. This is because, the high value of flexural strength (MPa) and surface hardness (g/mm2) can be influenced by variations in sample size, test method, nanoparticle size, nanoparticle concentration, silanization process, type of resin, polymerization cycle of silicon dioxide nanoparticles with heat cured acrylic resin and specimen conditioning.[9,13,14,18,20]

Incorporation of silicon dioxide nanoparticles into heat cured acrylic resin can improve mechanical properties.[64] In addition, the value of flexural strength of heat cured acrylic resin depends on the concentration value of silicon dioxide nanoparticles used. However, increasing the concentration of silicon dioxide nanoparticles that are too high can decreasing the mechanical properties of the heat cured acrylic resin.[65] Several investigators included in this review also demonstrated a similar effect on flexural strength which increased at low concentrations of silicon dioxide nanoparticles and decreased at high concentrations. [9,13,14,18,20]

This can be attributed to the fact that the addition of silicon dioxide nanoparticles with low concentrations developed the homogeneous distribution of silicon dioxide nanoparticles in the space of the polymer matrix of the heat cured acrylic resin and developed the creation of strong interfacial bonds between the nanoparticles. silicon dioxide and heat cured acrylic resin polymer matrix which can cause deviation from cracking and increase the flexural strength.[9] One method to inhibit excessive accumulation of silicon dioxide nanoparticles is through the silanization technique, silicon dioxide nanoparticles can also form functional groups in their chemical structure as well as a linking agent that forms a strong bond between silicon dioxide nanoparticles and the polymer matrix of heat cured acrylic resin that can improve its mechanical properties.[27] According to ISO 20795-1:2013, specimens should be immersed in water for 50 ± 2 hours at 37°C prior to flexural strength testing. Based on these 5 studies, the study of Alnamel HA, et al (2014) and Fatihallah AA, et al (2015) followed the ISO standard, while the study of Cevik, et al (2018) and Akhlas Z, et al (2019) did not state the procedure for the condition of the specimen, and the study from Salman, et al (2017) exceed ISO standards.[9,13,14,18,20]

In the studies involved in this review, considerable variation was found in the polymerization time and temperature used for the specimen. Based on research from all these studies, all of these studies used time and temperature that followed ISO standards at different concentration levels. This time and temperature difference can affect the flexural strength of the heat cured acrylic resin denture base. Polymerization of acrylic resin at 73°C for 90 minutes and then at 100°C as boiling temperature for 30 minutes increased the flexural strength compared to polymerization at 71°C for 9 hours.[28]

In addition, the polymerization technique of heat cured acrylic resin and silicon dioxide nanoparticles that too long can have an effect on residual monomer where in the residual monomer content is likely to be higher at high temperatures than at low temperatures and consequently affects the flexural strength of the denture base heat cured acrylic resin.[29]

The increase in surface hardness is influenced by the distribution of silicon dioxide nanoparticles which are homogeneously incorporated into the heat cured acrylic resin polymer. The distribution of the silicon dioxide nanoparticles fills the space between the linear macromolecular chains of the heat cured acrylic resin polymer and the segmental movement of the macromolecular chains becomes limited so the distribution of silicon dioxide nanoparticles becomes more effective. The well-distributed particles facilitate the transfer of pressure between the silicon dioxide nanoparticles and the heat cured polymerized acrylic resin polymer.[14,22] This also causes the transfer of pressure between the two causing the heat cured acrylic resin denture base to withstand a stronger masticatory load by increasing the surface hardness of the heat cured acrylic resin denture base.

The size of the silicon dioxide nanoparticles also affects the mechanical properties of the heat cured acrylic resin denture base. Small size of silicon dioxide nanoparticles facilitates a pressure distribution mechanisme between silicon dioxide nanoparticles and the polymer matrix of heat cured acrylic resin.[58] The addition of silicon dioxide nanoparticles to the denture base of heat cured acrylic resin is important in giving effect to increase the hardness of heat cured acrylic resin denture base. The addition of silicon dioxide nanoparticles in an excessive quantity can reduce the hardness of the heat cured acrylic resin denture base. Several investigators included in this review also demonstrated a similar effect on surface hardness which increases at low concentrations of silicon dioxide nanoparticles and decreases at high concentrations. [9,13,14,18,20]

This is due to the agglomeration of silicon dioxide nanoparticles when combined with heat cured acrylic resin polymers. Agglomeration causes the accumulation of silicon dioxide particles on the surface and the distribution of less homogeneous particles in the polymer matrix of heat cured acrylic resin.[21,22] The agglomeration that occurs can interfere with the polymerization process between silicon dioxide nanoparticles and the polymer matrix of heat cured acrylic resin.[24]

CONCLUSION

Within the limitations of this systematic review, based on research from all these studies, it can be concluded that the results showed that silicon dioxide nanoparticles with a concentration of 5% were most effective in increasing the flexural strength and surface hardness of the heat cured acrylic resin denture base.

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