Evaluating the Fracture Resistance of Different Reinforcement Methods of Repaired Maxillary Complete Denture

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Abstract

Complete dentures are made of acrylic material, though its main downside is the midline fracture. Throughout years, many reinforcement methods were advocated to repair the midline fracture. Hence, this study aims to evaluated different reinforcement methods used to overcome fracture problem. And to asses which technique of repair can provide better strength for complete denture repair.

Methods: The present study included a sample of 50 identical maxillary complete dentures. The midline fracture was reproduced on center of the dentures, then repaired with five different reinforcement methods (n = 10). The reinforcements were placed 1 mm away from the tissue surface. First method; was repaired without reinforcing materials (as a control group). Second method; repaired with 3% of Magnesium oxide nanoparticles impregnated into auto-polymerizing resin. Third method; dentures reinforced with orthodontic wire soldered as meshwork. Forth method; reinforcement with the fiber, fifth method; reinforcement with the chrome metal meshwork. The fracture strength of maxillary complete denture was tested using universal testing machine and load was applied to the tissue surface of the denture with a 10-mm diameter ball at a crosshead speed of 5 mm/min. The results were analyzed using stat graph version 5.1, one-way ANOVA ($p<0.05$).

Results: The denture fracture resistance was significantly decreased when denture was repaired with 3% of magnesium oxide nanoparticles compared with control group, ($p< 0.05$). However, the highest value of fracture strength was when the denture was reinforced with fiber followed by orthodontic wire and chrome meshwork ($p< 0.05$).

Conclusion: Within the limitations of the present study, it can be concluded that:There is statistically significant difference present in the mean fracture resistance values in all groups. The weakest denture was when acrylic reinforced with 3% of nanoparticles. Followed by control, chrome, orthodontic and the highest fracture resistance was when the denture repaired with fiber reinforce.

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Introduction

Dentures are one of the oldest dental devices that used for replacement of missing teeth. [1] Complete denture materials are made of acrylic, however, it has drawbacks such as fracture, specially the midline fracture which is the most common in complete dentures. Furthermore, patients with upper complete denture and with natural lower teeth are more susceptible to midline fracture of the upper denture. Numerous causes have been documented for the midline fracture including, flexural weakness due to distortion during laboratory processes. [2] Thus many researchers attempted to improve the acrylic material (poly methyl methacrylate)

towards ideal properties, like better strength, dimensional stability, scratch resistance. The midline fractures can be minimized if conventional prosthodontics principles were used during fabricating the denture.[3] Through out years many research were done to develop new techniques to improve denture. Several methods like mechanical and chemical were used. One of the methods used to increase the strength of acrylic is by increasing the thickness of the denture base. [4,5] Furthermore, Nanoparticles has been used to improve mechanical properties of the denture. Recently nanotechnology has opened up new avenues of research and offers many applications in human health, such as improving mechanical, biological and physical properties of the materials. Nanotechnology can be defined as using materials and structures with nano scale dimensions usually in the range 1-100 nm.[6] For instance, zirconium oxide nanoparticles, silver nanoparticles have been used to improve the denture strength. Nevertheless, there are several factors that affect nanoparticles properties. Such as, concentration and the size of nanoparticles. Because it will cause agglomerations of the particles and cluster formations that will weaken the material rather than strengthening it. Furthermore, metal nanoparticles such as Magnesium oxide nanoparticles could also be used to improve the strength of the denture.[7,8] Another method of reinforcement is the use of orthodontic wire. The strength power will be produced by the adding the stainless steel wire.[9] Another method is by adding of the fibers to acrylic resin to improve the mechanical properties of the material. Effective fiber reinforcement depends on several variables including the material used, the ratio and the size of fibers in the matrix and their modulus and supply, fiber location and fiber shapes. [10,11] Another method is the use of metal to reinforce the acrylic. Many studies were conducted to improve the strength of the denture with the use of the chromium-cobalt reinforcement.[12]

Till now there is no ideal procedure that can be used to minimize the midline fracture of upper denture. Thus, this study aims to evaluated different clinical methods used to overcome fracture problem of the upper complete denture. And to asses which technique of repair can provide better strength for complete denture. In this study the midline fracture of upper complete dentures was repaired with the use of different reinforcement methods. First method: Conventional repair with the use of cold cure acrylic, which considered as control group. Second method: Reinforcement with the use of nanoparticles- magnesium oxide nanoparticle size 15nm at 3%. Third method: Reinforcement with the use of orthodontic wire diameter 0.9 soldered as network. Forth method: Reinforcement with use of fiber. Fifth method: Reinforcement of the fracture site with the use of chrome metal meshwork.

Methods

Fabrication of maxillary dentures

Maxillary edentulous identical casts were prepared by pouring dental stone in the maxillary edentulous commercial molds (U-402; Nissin Dental Products Inc). All the maxillary casts were trimmed and polished. A 2-mm modelling wax sheet was adapted over the maxillary edentulous cast and occlusal rims with ideal measurements, and teeth sets of similar size were selected (Biotone; Dentsply Intl).Teeth arrangement was done following the principles of teeth setting followed by carving and finishing of the waxed denture. Flasking and dewaxing of the dentures was done. In the similar manner 50 dentures were prepared. Denture fracture was reproduced on center of maxillary complete dentures between two central incisors with the use of diamond disc bur. The fracture pieces were re aliened with the use of sticky wax (wax name of company). Later the fractured denture was coated with Vaseline as separating medium. Afterward, the plaster (MG Crystal Rock; Maruishi Gypsu) was poured on the tissue side of the denture to make a cast upon which the relining will take place. Subsequently, all fractured dentures were repaired with different reinforcement methods with the use of auto-polymerizing resin (JET, Clássico, São Paulo, Brazil). The reinforcements were placed 1 mm away from the tissue surface. Each reinforcement method 10 replicas (n=10). Reinforcement methods The reinforcements methods were as fol-

low:
First method: Conventional repair with the use of cold cure acrylic placed on the fracture site and after curing the dentures were polished. This method was considered as control group.
Second method: Reinforcement with the use of magnesium oxide nanoparticles size 15nm at 3%. Acrylic were weighted and then nanoparticles were added into the acrylic and mixed carefully to ensure homogenous distribution of the nanoparticles within the acrylic. Then acrylic impregnated with nanoparticles were placed on top of the fracture site. After cuing the dentures were polished.
Third method: Reinforcement with the use of orthodontic wire, three horizontal wire and two vertical wires with 20 mm length and diameter 0.9 were soldered as a meshwork. Then the meshwork was placed on the fracture site. Then cold cure acrylic was mixed and placed on top of the orthodontic wire meshwork. After cuing the dentures were polished.
Forth method: Reinforcement with use of fiber lined horizontally at the fracture site. The fiber was made of polyethylene fiber 2 mm thick. At the fracture site five horizontally lined fiber were placed, each with 20 mm length and 4 mm width. Then cold cure acrylic was mixed and placed on top of the fibers. After cuing the dentures were polished.
Fifth method: Reinforcement with the use of metal meshwork- chromium-cobalt. First the meshwork was made of wax then converted into the chrome mesh. After finishing and polishing it was placed at the fracture site. Then cold cure acrylic was mixed and placed on top of the chrome meshwork. After cuing the dentures were polished.
Before testing, the specimens were immersed in distilled water at 37 C for 50 hours as described by Tokgoz, et al., (2019). To measure the fracture resistance, complete dentures were placed with the artificial teeth downward on a universal testing machine, and load was applied to the tissue surface of the denture with a 10-mm diameter ball at a crosshead speed of 5 mm/min. The maximum force that resisted fracture was recorded as fracture resistance in newton. The compressive test data were evaluated with statistical software one way ANOVA, (mean ± SE), stat graph version 5.1. ($p<0.05$) is counted as a statistically significant. The fracture lines of all specimens were observed with the naked eye. After analyzing the failure aspects of all specimens, the failure mode was classified into 1 of 3 patterns according to the fracture line. In Pattern A, the complete denture was completely fractured into 2 parts. In Pattern B, the denture was not fractured completely, with fractures only in the anterior or posterior midline area. In Pattern C, the fracture occurred only at the loaded area.

Result

Evaluation of fracture resistance of the repaired dentures

Fracture resistance of all the five groups were evaluated using the Universal testing machine. To measure the compressive properties, complete dentures were placed on a Universal testing machine and load was applied to the tissue surface of the denture with a rod until the dentures were fractured. The means, standard error of compressive properties of all methods and the Intergroup comparison of fracture resistance are listed in table 1. (One-way ANOVA, $p< 0.05$, $n=10$).
The dentures that were repaired with only acrylic (control), was compared with dentures that were repaired with acrylic impregnated nanoparticles. The result showed there was a significant difference, Since, the dentures were fractured earlier with lowest load when were repaired with nanoparticles see (Figure 1 A, B). Furthermore, the dentures that were repaired with orthodontic wire, was also compared with (control) samples. The result showed the denture were deferred in fracture and greater load were required to cause the fracture as in (Figure 1 A, C). Similarly, the dentures that were fiber reinforced, was also compared with (control) samples. The result showed that there was a significant difference (table 1). Moreover, the dentures that were repaired with chrome, was compared with (control) samples and was significantly different. As, the dentures required greater load to cause the fracture when was repaired with chrome (Figure 1

A,D). Lastly, Intergroup comparison of fracture resistance of all tested groups were also evaluated. There was statistically significant difference present in the mean fracture resistance values in all groups. The weakest denture was when acrylic reinforced with 3% of nanoparticles. Followed by control, chrome, orthodontic and the highest fracture resistance was when the denture repaired with fiber reinforcement.
The failure modes of all specimens are listed in Figure 2, The control group, acrylic impregnated nanoparticles and dentures reinforced with orthodontic wire all showed pattern A complete fracture (Figure 2 A, B, C). While pattern B was observed when denture reinforced with fiber as incomplete fractures at the anterior midline was seen (Figure 2, D). Furthermore, pattern III was observed when denture was reinforced with chrome metal as fracture was only seen at the loaded area (Figure 2, E).

Table 1: Intergroup comparison of fracture resistance of all tested groups. (One-way ANOVA, p< 0.05, n=10). all data (Mean ± S. E). Numbers with different letters and symbol are statistically different from each other (Unit Newton).

Tested samples	Load in Newton (N)
Control	(270.5 ± 0.957)*
Nanoparticles	(245.3 ± 3.033) # a
Orthodontic wire	(416.8 ± 1.123) # b
Fiber reinforcement	(1057.8 ± 5.863) # c
Chrome mesh	(403.2 ± 2.624) # b

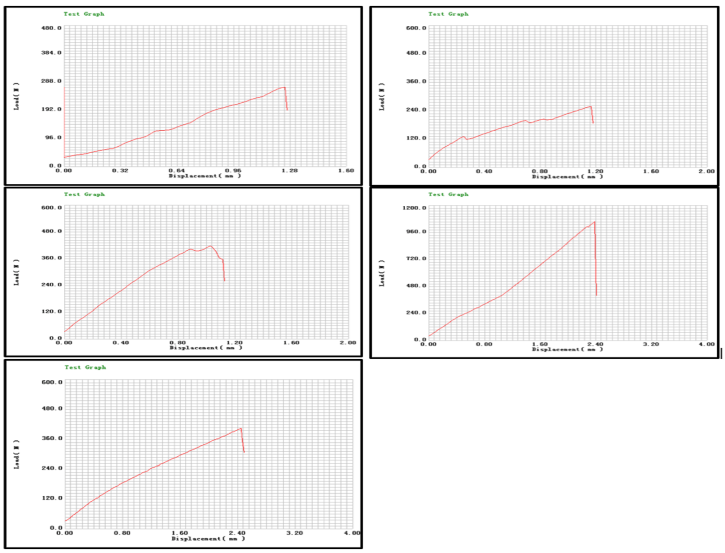

Figure 1: Load and displacement curve of the fractured denture. (Unit Newton). A)Denture repaired with only acrylic, B). Denture repaired with acrylic impregnated with nanoparticle. C) Denture repaired with orthodontic wire. D) Denture repaired with fiber reinforcement. E) Denture repaired with chrome mesh.

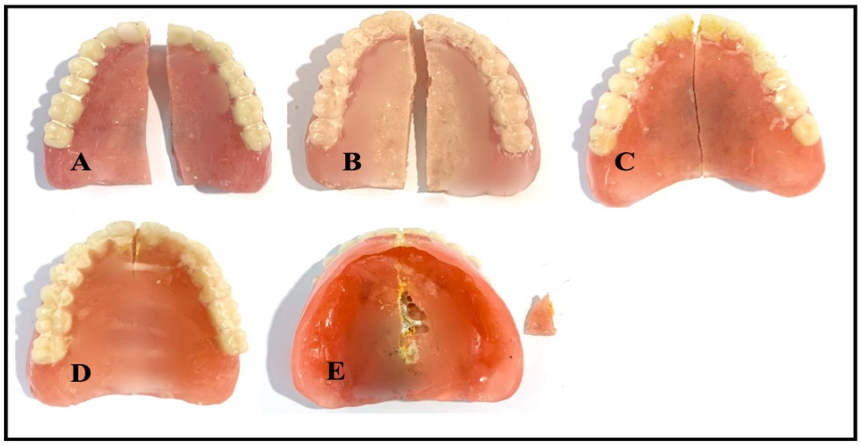

Figure 2: Failure mode of complete dentures after compressive test. A) Class I Denture fracture repaired with acrylic, B) Class I Denture fracture repaired with acrylic impregnated with nanoparticles. C) Class I Denture fracture repaired with orthodontic wire. D) Class P Denture fracture repaired with fiber. E) Class III denture fracture repaired with chrome meshwork.

Discussion

Throughout years' various methods have been proposed to improve the strength of the acrylic denture material, like chemical modification of PMMA by the addition of rubber, fibers or metal into the denture bases.[13] Metal have been inserted in to dentures in the form of wires, meshes, and plates. Furthermore, different fibers include carbon, aramid, glass, and polyethylene fibers also has been used to improve strength of the denture.[14] This study, evaluated the fracture resistance of five different methods used to repair the midline fracture of complete dentures. The results showed that using nanoparticles at 3% corporate in acrylic to repair denture caused decrease in fracture resistance. This result was in coincide with a study conducted by (15). As they revealed that the use of nanoparticle incorporation into acrylic resin adversely affected the mechanical properties. However, another study conducted by [16], demonstrated that the acrylic resin reinforced with 1% TiO2 showed significantly higher impact strength compared to the conventional acrylic resin with no adverse effect on other properties. This could be du to the fact that nano-sized oxide particles can reinforce the matrix if the filler content were maintained at a proper level, because of their higher surface energy and chemical reactivity [17] otherwise, the nano-sized oxide particles may agglomerate. Moreover, a study pointed that the higher concentrations of nanoparticles will decrease the strength of acrylic due to high chance of aggregation and separation from the polymer; this of course will not contribute to the reinforcement of the material. additionally, there is correlation between increasing the concentration and decrease in strength of acrylic du to the stress in the area of agglomerated particles.[18] In this study, when the dentures were repaired with orthodontic wire, results showed superior fracture resistance when compared with control dentures. Similarly, a study by (19) demonstrated that the metal wires used to reinforce acrylic resin denture material increased the fracture resistance of the test specimens. This could be du to the fact that wire mechanically stronger than the acrylic matrix. Additionally, wire diameter is a primary considering factor to reinforce the acrylic resin effectively also larger diameter gives better strength as reveled by(20) They demonstrated that diameter 0.7-1.0 increased the strength of denture. Moreover, similar results were observed when denture was repaired with chrome mesh. This result was in coincide with a study conducted by(21) as they showed that chrome metal reinforcement increased the fracture resistance and toughness of complete dentures.

This could be due to the fact that perforated metal mesh combined well with acrylic offering high strength to the denture. Regarding the dentures that are reinforced with fiber showed the highest fracture resistance. This result was similar to a study done by (22) demonstrating that an increase in the amount of fibers enhanced the fracture resistance of the test specimens. Furthermore, the fiber -reinforced complete denture largely maintained its original structure even after fracturing because of the unbroken fibers.

For the failure mode, the first three groups showed complete fracture, since fracture of dentures occurs in the area of stress concentration. In the test mode of this study, the load was applied to the mid-palatal area of the internal side of the denture. However, if the load had been applied on both axes of the posterior teeth, a different failure mode would have occurred. Furthermore, various dental studies revealed that acrylic resin are prone to fracture under impact force and will fatigue after period of time as a result of decreased flexural strength. [23] This results were similar to a study conducted by (24) they reinforced complete dentures with with metal at the ridge lap region and middle region and they demonstrated complete midline fracture. From the results of this study the first three groups showed no improvement in the strength of the denture. However, fiber reinforcement was more effective than metal mesh in reinforcing the fracture resistance and toughness of complete dentures. The content of the glass fiber was more flexible compared to metal thus more resistance to fracture was observed and this was slimier to study conducted by (25).

Conclusion

Within the limitations of the present study, it can be concluded that:There is statistically significant difference present in the fracture resistance values in all tested groups. The weakest denture was when acrylic reinforced with 3% of nanoparticles. Followed by control denture group, denture reinforced with chrome meshwork, orthodontic wire and the highest fracture resistance was when the denture reinforced with fiber. Thus the fracture of acrylic maxillary complete dentures can be improved by reinforcing the denture with fiber to withstand midline fracture, heavy occlusal force and accidental damage.

Conflict of interest

The author reported no conflict of interests**.**

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