The effect of antifungal oral gel and ozonated water on tensile and compressive strength of two types of denture base materials: *in-vitro* study

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Background/aim

Debris accumulation beneath the dentures initiates countless difficulties such as inflamed oral mucosa and denture stomatitis. Denture stomatitis is a prevalent pathologic illness that is commonly linked to *Candida albicans*. Accordingly, treatment requires applying effective anti-inflammatory and antifungal medicaments that do not negatively influence the properties of denture base materials. Antifungal oral gel and ozonated water have quite an impact on inhibiting *Candida albicans* growth and treating denture stomatitis, so they have been selected in this research. This study aimed to compare the effect of antifungal oral gel and ozonated water on the tensile and compressive strengths of poly methyl metha acrylate (PMMA) and Nylon or polyamide denture base materials.

Patients and methods

This study was carried out for two types of denture base materials; group I PMMA and group II Nylon or polyamide. Total samples for both groups were 160 and fabricated following American Dental Association specifications No.12 for assessing tensile and compressive strengths. For each group (80 samples each group), the compressive strength was measured before (10 samples each) and after (10 samples each) the application of antifungal oral gel (10 samples each), and ozonated water (10 samples each), overnight for 15 days for each. Also, the tensile strength was measured for each group before (10 samples each) and after (10 samples each) the application of antifungal oral gel (10 samples each) and ozonated water (10 samples each) overnight for 15 days for each. Comparison between pre and post measurements was accomplished by Paired *t*-test, while comparison between heat-cure PMMA and nylon was carried out by using an Independent *t*-test.

Results

PMMA was significantly affected by ozonated water regarding compressive (P =0.0001) and tensile (P =0.0001) strength while antifungal oral gel had a significant effect only on the tensile strength (P =0.0001) but not the compressive strength (P =0.57). Both antifungal oral gel (P =0.7) and ozonated water (P =0.75) have insignificant effects on the compressive strength of nylon denture base material and also insignificant effect on tensile strength of nylon denture base material (P =0.16) for ozonated water and (P =0.37) for antifungal oral gel.

Conclusion

Ozonated water could adversely impact both the compressive and tensile strength of PMMA denture base material and the antifungal oral gel could affect only its tensile strength. Ozonated water and antifungal oral did not affect the compressive and tensile strength of the nylon denture base material.

Keywords:
antifungal, compressive, denture base, nylon, ozonated water, tensile

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Introduction

Dental caries, trauma, and pathological disorders are among the many factors that lead to tooth loss. These factors not only affect the patients' psychological well-being but also interfere with their teeth's esthetics, phonetics, and functional occlusion. To repair the defect and regain function as best as possible, replacement of lost teeth is necessary [1].

Heat-cured poly methyl metha acrylate (PMMA) acrylic resin was introduced by Dr. Wright in 1931 and used to make removable dentures. PMMA was a popular choice for denture base material because of its ease of manufacturing, inexpensive cost, lightweight, excellent aesthetic properties, low water sorption and solubility, and ease of repair-ability. However, it is more likely to fail during function, and has low thermal conductivity, poor mechanical strength, brittleness, high coefficient of thermal expansion, and relatively low modulus of elasticity. PMMA dentures are most prone to fracture clinically because of impact forces or fatigue [2].

PMMA may contain unpolymerized residual monomers like methyl-methacrylate (MMA) during the curing phase, which might result in allergic responses. Allergy can affect both patients and dental personnel [3].

Flexible dentures were recently introduced in the dental market aiming to reduce the disadvantage of PMMA. They exhibit elastic behavior, good biocompatibility, and excellent aesthetics and comfort. They improve denture base retention by intimately adapting to the supporting oral tissues and engaging hard and soft tissue available undercuts [4].

Nylon polyamides are lightweight, comfortable, less allergenic, strong, extremely resilient, flexible, unbreakable, and resistant to surface abrasion when compared with PMMA denture base material. However, there are drawbacks to flexible dentures as well. The acrylic teeth are attached to nylon by a mechanical bond, which allows the teeth to come out of the prosthesis. Polyamide does not adhere to acrylic resins in the same way, making it difficult to bead new increments of flexible resin to a finished denture. This typically prevents rebasing and repairs [1].

A full denture may change the array of microorganisms found in the oral cavity and may serve as a risk factor for the proliferation of various oral microbiota such as Candida, non-pathogenic Neisseria, corynebacterium, gram-negative coco bacillus, non-aureus Staphylococci, and alpha hemolytic streptococci, which emphasized the patient' denture care [2].

The natural hygienic effects of saliva and the tongue are weakened as the patient wear the complete denture. This is because biofilms are formed and deposited on the prosthesis and the nearby mucosa. The denture base changes the ecology of the oral cavity and increases the likelihood of bacterial accumulation and candida adherence [3,4].

Denture hygiene and its maintenance is one of the key issues experienced by most denture wearers. Denture hygienic habits should be monitored to ensure its cleanliness and prevent mouth inflammation. Because of this, elderly patients especially those who are disabled have poor oral and denture hygiene, together with the incidence of xerostomia, occlusal stress, and ill-fitting dentures can cause infections, ulcerations, and inflammation of the oral mucosa. Plaque is collected on the sides of dentures by the food that is kept under the dentures. Progressively, forming microbial plaque and growing adaptable species, and thereby, failing to take appropriate sanitary precautions. Therefore, proper oral and denture hygiene is required since denture plaque causes oral soft tissue risks and denture stomatitis (DS) [5–7].

Denture-induced stomatitis is an asymptomatic, benign, chronic mucosal lesion associated with dentures. Candida albicans is well-known for its exceptional capacity to stick to oral surfaces and the surface of prosthesis. As a result, it may effectively colonize and resist the mechanical washing impact of saliva. Consequently, Candida albicans is referred to as the Candida species' most opportunistic pathogen [8–10].

The denture hygiene methods can be classified as mechanical or chemical. The mechanical technique using water and a toothbrush has been thought to be the most appropriate sanitary procedure used. Despite that, it has limited effect in eliminating the microorganisms in biofilms and encourages denture plaque production by changing the surface [9].

Chemical methods using disinfectants and mouthwashes successfully reduced intra-oral biofilm bacteria. The patients and prosthetic components are adversely affected by their side effects. Ozone (O_3) is a naturally occurring tri-oxygen gas that can be produced by O_3 generators or found in the environment at concentrations of 1–10 parts per million. It is an essential component of the earth's self-purification process because of its high density, which drives its downward decrease from heights and integration with surrounding pollutants [6,11].

O_3 therapy is defined as a multifaceted bio-oxidative curative O_3 medication given in the form of gas, oil, or water. Using ozonated water in conjunction with O_3 therapy, a more current and effective form of hygiene, has been shown to reduce biofilm microorganisms with short exposure times and have prominent anti-inflammatory benefits. Topical antifungal drugs including creams, powders, pastilles, tablets, lozenges, and suspensions, gels as well are highly effective in treating oral candidiasis as they alters the permeability of the candida cell membrane, allowing the drug to enter the cell and destroy it [10,11].

The present study aimed to compare the effect of antifungal oral gel and ozonated water on the mechanical properties which are tensile and compressive strengths of PMMA and Nylon or polyamide denture base materials.

Materials and methods

Materials

(a) Conventional heat-cured acrylic resin PMMA (Acrostone; Acrostone dental factory – industrial zone –Salam city A.R.E-WHW Plastic, England)
(b) Nylon polyamide (iFlex by TCS Dental Resins, Equipment and Accessories, USA)
(c) Dental plaster (Elite Rock Stone, Zhermack Clinical, Italy)
(d) Antifungal oral gel (Miconaz, Miconazole 2%), Medical Union Pharmaceuticals, Abu-Sultan, Ismailia, Egypt)

Instruments used

(a) Programmable injection molding machine: Thermopress 400 version 2.4/2.56, Bredent, Germany.
(b) O_3 generator: O_3 generator type N 1888A, China.
(c) Universal testing machine: Shimadzu AUTOGRAPH AG-X PLUS; Shimadzu, Tokyo, Japan.
(d) Instrument's combined software: Trapezium X Testing Software, Shimadzu, Tokyo, Japan.

Study design

This *in-vitro* study, assessment of both tensile and compressive strengths took place by the universal testing machine for specimens of both PMMA and nylon denture base materials before and after application of ozonated water and antifungal oral gel 8 h overnight for 15 days for each sample.

Total samples for both groups were 160, with each material group 80 samples. For each group, the compressive strength was measured before (10 samples each) and after (10 samples each) the application of antifungal oral gel overnight for 15 days, and before (10 samples each) and after (10 samples each) the application of ozonated water overnight for 15 days. Also, the tensile strength was measured for each group before (10 samples each) and after (10 samples each) the application of antifungal oral gel overnight for 15 days, and before (10 samples each) and after (10 samples each) the application of ozonated water overnight for 15 days

Sample size calculation

The sample size was estimated owing to an earlier study as references by Shirkavand and Moslehifard in 2014 [12]; and Abad-Coronel *et al.* in 2023 [13]. Accordingly, the minimal permissible sample size for each test is 10 specimens as the effect size was 1.35 with 80% power and 0.05 type I error probability. The independent *t*-test was accomplished by using P.S. power 3.1.6.

Specimens' grouping

PMMA and Nylon samples were fabricated by American Dental Association (ADA) specifications No.12 for measuring both tensile and compressive strengths. This research was made owing to the material's type used into two groups; group I (PMMA) and group II (Nylon) 80 samples per group. For each group, the compressive strength was measured (10 samples) before and (10 samples) after the application of Antifungal oral gel and (10 samples) before and (10 samples) after ozonated water 8 h overnight for 15 days for each. Also, the tensile strength was measured for each group (10 samples) before and (10 samples) after the application of Antifungal oral gel and (10 samples) before and (10 samples) after ozonated water 8 h overnight for 15 days for each.

Methods

Specimen fabrication

A commercially available PMMA and nylon were employed for samples preparation subsequent to ADA specifications number 12. A cylindrical metal model with definite measures (12 mm length × 6 mm diameter) was utilized to prepare specimens for assessing the compressive strength. Whereas tensile strength test required the fabrication of dumbbell-shaped specimens by utilizing a metal pattern model having definite measures (65 mm length × 12.5 mm width × 2.5 mm thickness). tested samples must be free from any voids, cracks, bubbles, or dirtiness together with being appropriately smoothed, well-finished, and polished

The two metal patterns used were initially layered with the separating medium then followed by a plaster mix coat. The plaster let to set (for 30 min) giving a plaster pattern. Both patterns; plaster and metal were covered with a separating medium and an additional coat of plaster was placed into the flask's superior half and vibrated through a mold vibrator. The plaster was left to set for 60 min, the flask was unfastened, the metal pattern was separated, and finally, the mold was ready.

PMMA samples were fabricated by attaining molds via utilizing the classic metal flask. Dental plaster was mixed following the industrialist's guidelines and packed into the dental flask's inferior surface. Nylon ones were processed by utilizing the mold, special metal flask form, and the injection-able thermoplastic resin via a programmable injection molding machine (Programmable injection molding machine: Thermopress 400 version 2.4/2.56, Bredent, Germany) with a temperature 290â °C and pressure 6 bars for 17 min following the manufacturer's directions. Subsequently, both flasks were isolated and left till reaching room temperature before deflasking, and then specimens' finishing and polishing were carried out.

Application of antifungal oral gel and ozonated water to the specimens

Antifungal oral gel and ozonated water were applied for specimens of both groups 8 h/day for a period of 15 days. Specimens of both groups were immersed in ozonated water. This water requires (2–4 mg/l) O_3 concentration for 1 min. in 25 mg of double distilled water with a temperature of 37°C using an O_3 generator [b] (O_3 generator type N 1888A, China) [14]· While antifungal oral gel was applied, for 8 h/day then removed and the surface was dried for the next application.

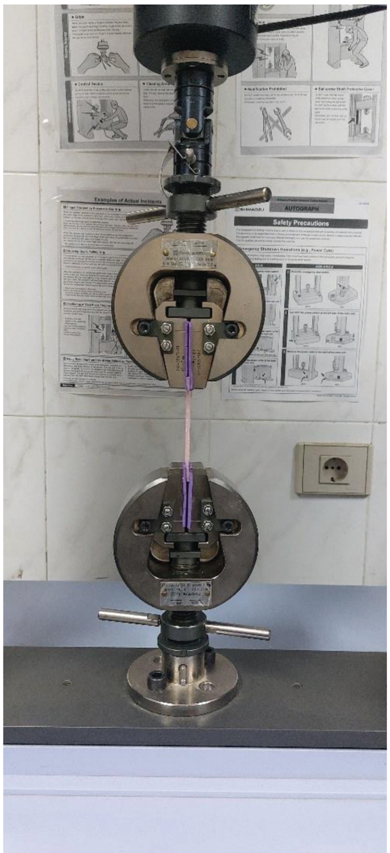
Assessment of tensile strength

The tensile strength test was conducted with the universal testing machine (Shimadzu AUTOGRAPH AG-X PLUS; Shimadzu, Tokyo, Japan) at a crosshead speed of 5 mm/min under a load cell capacity of 10 kN to obtain stress-strain curves for each specimen. This test was carried out for (10 samples) before and (10 samples) after the application of ozonated water and antifungal oral gel for 8 h/day for a period of 15 days for both groups, Fig. 1.

Assessment of compressive strength

Specimens were exposed to a quasi-static load test at a speed of 0.5 mm/min in a path parallel to the specimen's major axis with an initial preload of 10 N via the universal testing machine (Shimadzu AUTOGRAPH AG-X PLUS; Shimadzu, Tokyo, Japan) prepared with a 5kN load cell. Load was applied to the specimen's center by a hardened steel pilot punch with 3 mm radius. The specimens' force/displacement was defined by employing the instrument's combined software (Trapezium X Testing Software, Shimadzu, Tokyo, Japan). All specimens were loaded till fracture whose force was recorded in Newtons (N). This was carried out for (10 samples) before and (10 samples) after application of ozonated water and antifungal oral gel 8 h/day for a period 15 days for both groups, Fig. 2.

Figure 1



Poly methyl metha acrylate specimen positioned on universal testing machine measuring the tensile strength.

Statistical analysis

All data were coded and entered using the statistical package for the Social Sciences (SPSS) version 28 (IBM Corp., Armonk, NY, USA). Pairing data was summarized using mean±SD, and checking for normality distribution by Shapiro–Wilk and Kolmogorov–Smirnov tests. Accordingly, Comparison between pre and post (Intragroup) measurements was accomplished by utilizing Paired t-test, while comparison between PMMA and nylon (Intergroup) was achieved by using independent t-test. P values less than 0.05 were considered statistically significant.

Results

Comparison between pre and post-measurements for nylon and PMMA groups regarding compressive and tensile strength using paired t-test.

Figure 2

Measuring the compressive strength for poly methyl metha acrylate specimen positioned on the universal testing machine.

Compressive strength

Regarding nylon, comparing compressive strength pre and post application of ozonated water, revealed that there was no significant difference as P =0.75, and the mean difference was 0.68±6.58, with antifungal oral gel there was an insignificant difference as P =0.7, and the mean difference was −0.97±7.66. Regarding PMMA, comparing compressive strength pre and post application of ozonated water, revealed that there was a significant decrease with (−19.32±11.28) as P =0.0001, while with antifungal oral gel there was insignificant difference as P =0.57, and the mean difference was −2.28±12.15 (Table 1).

Tensile strength

Regarding nylon, comparing the tensile strength pre and postapplication of ozonated water, there was insignificant difference as P =0.16, and the mean difference was 4.56±9.37, with antifungal oral gel there was an insignificant difference as P =0.37, and the mean difference was 2.51±8.38. Regarding PMMA comparing the tensile strength pre and post application of ozonated water, there was a significant decrease with (−6.3±5.19) as P less than 0.0001, with antifungal oral gel there was a significant decrease with (−9.7±7.47) as P =0.0001 (Table 1).

Comparison between nylon and PMMA regarding compressive and tensile strength, using independent *t*-test.

Compressive strength

Regarding ozonated water, a comparison between nylon and PMMA compressive strength revealed that there was a significant difference between them as P less than 0.05 in pre, and post, and the difference

Table 1 Comparison between pre and post measurements for nylon and poly methyl metha acrylate groups regarding compressive and tensile strength using paired *t*-test

	Pre	Post	Paired *t*-test		
			95% Confidence interval of the difference		
Intragroup comparison	mean±SD	mean±SD	Lower	Upper	*P* value
Compressive (Newton)					
Nylon					
Ozone	22.24±4.99	22.92±4.45	−4.03	5.38	0.750
Antifungal	22.47±4.02	21.50±4.46	−6.45	4.51	0.700
PMMA					
Ozone	49.02±7.10	29.70±7.01	−27.39	−11.26	0.0001*
Antifungal	48.06±7.12	45.78±9.61	−10.98	6.41	0.570
Tensile (Newton)					
Nylon					
Ozone	21.25±4.89	25.81±7.85	−2.14	11.26	0.160
Antifungal	21.59±5.40	24.11±8.69	−3.46	8.49	0.370
PMMA					
Ozone	33.88±2.98	27.57±4.60	−10.01	−2.59	0.0001*
Antifungal	32.96±3.65	23.26±6.09	−15.04	−4.36	0.0001*

*Significant difference as P value less than 0.05.

between pre and post as PMMA was significantly higher than nylon. Regarding antifungal oral gel, comparison between nylon and PMMA compressive strength revealed that there was a significant difference between them as *P* less than 0.05 in pre, and post as PMMA was significantly higher than nylon (Table 2).

Tensile strength

Regarding ozonated water, a comparison between nylon and PMMA tensile strength revealed that there was a significant difference between them as *P* less than 0.05 in pre and a difference between pre and post as PMMA was significantly higher than nylon.

Regarding antifungal oral gel, a comparison between nylon and PMMA tensile strength revealed that there was significant difference between them as *P* less than 0.05 in pre and difference between pre and post as PMMA was significantly higher than nylon (Table 2).

Discussion

Dental prostheses must meet mechanical, biocompatible, and aesthetic requirements. The properties assessed in this research are important for the appropriate performance of dental prostheses, as denture bases are subjected to medicaments that treat DS and oral candidiasis, subsequently, fracture is the most common clinical failure of denture bases. The prostheses must not undergo fractures or plastic deformations during its use in the patient's mouth after the application of medicaments that treat DS and oral candidiasis [15].

Candidal infection occurs frequently in complete denture wearers especially in reduced oral hygiene measures and/or compromised immune response. The antifungal oral gel is commonly used for treatment of oral candidiasis [16].

Oral candidiasis is caused by a yeast-like fungus or candida that infects the oral cavity. Treating oral candidiasis requires proper oral hygiene measures and topical application of antifungal drugs. Antifungal drugs bind to the sterols inside the cell membrane of candida and altering the permeability of cell membrane. After binding of antifungal with ergosterol inside the candida cell membranes they form complexes and lead to the death of candida cells after intracellular leakage [17].

The impact of ozonated water on dental plaque and oral bacteria was evaluated after exposure of the denture base to flowing ozonated water (2 or 4 mg/l) after 1 min, oral microorganisms and dead Candida albicans cells were detected. This result indicate that the use of ozonated water may help to lower the amount of Candida albicans on denture bases [18].

The results of this study revealed that both compressive and tensile strength were significantly reduced after the application of ozonated water to PMMA. This may be attributed to the micro porosity in the acrylic resin surface. Micro porosity is an inherent property in PMMA, it occurs during denture construction even with the best finishing & polishing procedures. Ozonated water may be absorbed into these micro

Table 2 Comparison between nylon and poly methyl metha acrylate regarding compressive and tensile strength, using independent *t*-test

	Nylon	PMMA	Independent *t*-test		
			95% Confidence interval of the difference		
Intergroup comparison	Mean±SD	Mean±SD	Lower	Upper	*P* value
Compressive (Newton)					
Ozone					
Pre	22.24±4.99	49.02±7.10	−32.54	−21.02	0.0001*
Post	22.92±4.45	29.70±7.01	−12.29	−1.27	0.019*
Antifungal					
Pre	22.47±4.02	48.06±7.12	−31.03	−20.16	0.0001*
Post	21.50±4.46	45.78±9.61	−31.32	−17.24	0.0001*
Tensile (Newton)					
Ozone.					
Pre	21.25±4.89	33.88±2.98	−16.43	−8.82	0.0001*
Post	25.81±7.85	27.57±4.60	−7.81	4.28	0.548
Antifungal					
Pre	21.59±5.40	32.96±3.65	−15.69	−7.03	0.0001*
Post	24.11±8.69	23.26±6.09	−6.20	7.91	0.803

*Significant difference as *P* value less than 0.05.

pores & compromising the mechanical properties of PMMA. The reduced compressive and tensile strength also may be due to increased surface roughness which may cause a very small surface defects, which under tension and compression may end by fracture [19].

Polymerization of PMMA occurs by free addition and ends by cross-linked polymer chain and free radicals and containing large amounts of residual monomer. Application of ozonated water to PMMA decreases both tensile and compressive strength due to flow of residual monomer from PMMA and flow of ozonated water into the resin. Also, the plasticizing effect decreases the attraction forces between polymer chains and leading to massive distortion of the polymer chain [20].

On the other hand, the application of ozonated water had an insignificant effect on tensile and compressive strength of nylon denture base material. Nylon has a significantly less porosity than PMMA. This might be attributed to differences in curing techniques. Nylon curing is based on raising in temperature rapidly with nearly equal heating temperature both outside and inside the material. The curing of PMMA depends on a hot water bath (100.3°C) which is nearly equal to the monomer methyl meth acrylate boiling temperature. Gas bubbles might be entrapped inside a polymer. Also, the exothermic polymerization reaction could increase the PMMA porosity, which is not occurring in nylon [21].

There was no statistically significant difference regarding both tensile and compressive strength of the nylon denture base after the application of Antifungal oral gel and for compressive strength only of PMMA denture base material. Many issues are involved in early candida adhesion to the denture surface such as surface charge, free surface energy, hydrophobicity, and irregularity. Candida adhesion to the denture base is based on electrostatic attraction and hydrophobic properties. The negatively charged candida has a repulsive response to the negatively charged denture base. The hydrophobic interaction between candida and denture base helps the growth of candida. Despite the repulsive forces present, adhesion occurs. Introducing antifungal drugs to the denture base weakens the adhesion of candida to the denture base and consequently, does not affect its mechanical properties [22].

The tensile strength of PMMA was significantly reduced after application of Antifungal oral gel. The surface of PMMA was examined by SEM and it showed candida penetrated the PMMA and large number of blastospores was found in the inner surface of the material due to its porosity. This indicates the problem with removal of candida from PMMA over time and their rapid colonization even after disinfection. Also, the surface of PMMA may show micro-cracks due to continuous cleaning and disinfection, thereby compromising the material tensile strength [23,24].

Conclusion

The present study concluded that the antifungal oral gel and ozonated water did not affect both the compressive and tensile strength of the nylon denture base material. The tensile strength of PMMA was negatively impacted by antifungal oral gel and ozonated water. However, the compressive strength of PMMA was adversely affected by ozonated water. Moreover, Further studies are recommended for longer follow-up periods and using different concentrations.

Authors' contributions: Noha T. Alloush performed interpretation of results and statistical analysis and writing the manuscript, Eman M. Ibraheem was responsible for writing the discussion, reviewing all manuscripts, reviewing the plagiarism, and submission of the manuscript to the journal, Wessam M. Dehis was responsible for the laboratory work, writing the detailed methodology, and editing the whole manuscript. All authors write, read, and accept the final manuscript.

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Conflicts of interest

There are no conflicts of interest.

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