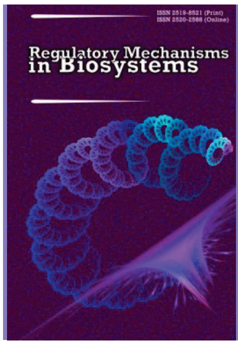

Regulatory Mechanisms in Biosystems

ISSN 2519-8521 (Print)
ISSN 2520-2588 (Online)
Regul. Mech. Biosyst.,
2024, 15(4), 657–660
doi: 10.15421/022494

Comparative analysis of effect of eco-friendly and conventional disinfectants on the durability of dental heat cured acrylic resin and GC-soft liner

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Article info

Received 05.10.2024
Received in revised form 10.11.2024
Accepted 16.12.2024

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Aziz, R. R., Al-Kateb, H. M., Sadoon, M. M., & Almashhadne, F. A. M. (2024). Comparative analysis of effect of eco-friendly and conventional disinfectants on the durability of dental heat cured acrylic resin and GC-soft liner. Regulatory Mechanisms in Biosystems, 15(4), 657–660. doi:10.15421/022494

Excessive use of chemical and pharmaceutical disinfectants harms both the environment and human health, in addition to having a deleterious effect on acrylic resin and soft liners. The aim of this article is evaluate the effect of eco-friendly disinfectant oils related to their PH value (*Nigella sativa*, sesame, olive, thymol, and ginger oil) compared to nystatin suspension on the hardness of heat cured acrylic resin and GC-Soft Liner throughout three months. Seventy samples were prepared: thirty-five from heat-cured acrylic resin (rectangular shaped 30 × 15 × 3 mm) and thirty-five from GC-extra soft lining material (circular shaped 20 × 4 mm, diameter and thickness, respectively). The samples were immersed in oils for three months for 8 hours daily. The hardness of the samples was examined using a Shore-D hardness durometer for acrylic resin and Shore-A hardness durometer for soft liner. The results demonstrated that there were no significant differences between all tested oils compared to nystatin suspension and distilled water in relation to hardness of heat cured acrylic resin and GC-soft liner except for the effect of thymol oil on acrylic samples, which still remained within clinically accepted hardness values. pH values ranged 5.9–7.0. Thymol is a weakly acidic oil, whereas other oils are of neutral to weakly acidic nature. All tested natural disinfectants would be safe and clinically accepted in relation to hardness of heat cured acrylic resin and GC-soft liner and could be used with minimum cost and optimum safety.

Keywords: eco-friendly dentistry; hardness; heat cured acrylic resin; soft liner; antifungal activity.

Introduction

Eco-friendly dentistry is a rapidly developing practice discipline of dentistry that encompasses a simultaneous devotion to renewability, sustainability, energy efficiency, nontoxicity, and minimal invasiveness. Eco-friendly dentistry offers the potential to minimize future destruction of our world by merging human and environmental health (Mittal et al., 2020; Raut et al., 2022). Currently the medical and dental fields are being revolutionized by eco-friendly dentistry with the aim of limiting their impact on the ecosystem and the amount of waste created and risk to humans. This encourages dentists to implement innovative methods to decrease the waste produced by the industry. Many acceptable, practical, and simple solutions exist for fulfilling this mission (Jaouhar et al., 2024; Hamzah & Al-Mashhadane, 2022).

Soft denture liners are widely used in denture treatment in addition to hard denture base resin, but the difficulty in cleaning resilient denture liners is still a material disadvantage (Kreve & Dos Reis, 2019; Sameeh et al., 2021; Procópio et al., 2022). The selection of denture cleanser is important to avoid or decrease changes to properties of resilient materials (Abuhajar et al., 2023). As they undergo chemical changes over time. choosing a soft liner for clinical uses should be based on the biocompatibility of materials, durability and mechanical properties in the oral environment (Chladek et al., 2014; Sameeh et al., 2021). Many studies aim to evaluate the effect of different denture cleansers on soft liner properties such as hardness, surface roughness, bond strength, color and others (Mese & Guzel, 2008; Chladek et al., 2014; Sameeh et al., 2021; Abuhajar et al., 2023; Al-Sumaidae, 2023).

Eco-friendly products that are not harmful to the environment encourage the use of natural products newly introduced for denture cleaning such as curcumin, tea oil, cinnamon, nigella (*Nigella sativa* L.), sesame (*Sesamum indicum* L.), flax (*Linum usitatissimum* L.) and ginger oil (*Zingiber officinale* Roscoe) (Hamzah & Al-Mashhadane, 2022; Bencze et al., 2023; Noori & Al-Khafaji, 2024), and these are safe and biocompatible materials (Garcia et al., 2020; Iyer et al., 2022).

Though nystatin is a widely used, an efficient antifungal drug for treating oral candidiasis and cleansing soft denture liners and acrylic resin, it is important to be aware of its potential side effects. Local discomfort, hypersensitivity reactions, and the risk of microbial resistance are important aspects (Procópio et al., 2022; Abuhajar et al., 2023).

The null hypothesis is that these eco-friendly disinfectants (*Nigella sativa*, sesame, olive oil, thymol, and ginger oil) have no deleterious effect on the hardness values of heat-cured acrylic resin and GC-Soft Liner as compared to nystatin suspension.

Materials and methods

Surface hardness test for heat cured acrylic resin. Thirty-five heat cured acrylic resin samples were prepared (rectangular shaped 30 × 15 × 3 ± 0.03 mm) according to ADA Specification No. 12 (ADA No. 12, 2006), the specimens were finished and polished by pumice, the hardness of samples were tested by Shore-D hardness durometer (Show, China) five readings were made for each specimen, then the mean was taken (Aziz & Sadoon, 2024).

Surface hardness test for GC-soft lining material. Thirty-five sample were prepared from GC-soft lining material (Japan), they were circular shaped (20 × 4 mm, diameter and thickness, respectively) (Gonçalves et al., 2023). The soft lining samples were prepared inside an auto cured acrylic resin base. The acrylic base was prepared by aluminum mould (Sameeh et al., 2021), the cold cured acrylic resin was mixed according to the manufacturer's instructions. When the mixture reached dough stage it was placed in the mould. After setting, the acrylic base was removed, and the acrylic slashes was removed with an acrylic bur using a hand piece. A sheet of wax with 4 mm thickness was placed over the prepared acrylic resin base then a hole of 20 × 4 mm was made in the middle of the wax sheet by using a sharp wax knife, this hole was for flasking of the soft liner. Flasking was done in the conventional method, packing of GC Extra soft liner [auto polymerized material] where the material was supplied as two pastes and a special gun used, which allows mixing and injection of the material into the created mould, according to the manufacture's instruction. A glass slab was placed over the mould After setting, the glass slab was removed and any excess resin material removed from the specimens with a sharp scalpel. The samples were immersed for 8 hour per day in these products (oils) throughout three months.

Hardness for the GC-soft liner was measured using Shore-A-hardness durometer (Loyka, Turkey). The specimens were placed on a bench, the Shore – A-durometer was held in a vertical position with point of indenter 5 mm from the periphery of the specimen. Readings were taken after 1 second from the firm contact that was achieved between the durometer foot and the material under test. Five measurements were taken and the mean was calculated for each specimen (Sameeh et al., 2021).

Natural disinfectants pH measurements. The pH values for the investigated eco-oil disinfectants (Emad factory, Mosul, Iraq) were measured using a pH meter (PH7110) Xylem analytics Gmbh, Germany), after cleaning the electrode with distilled water (the electrode was immersed in the solution for 30 seconds). The natural disinfectant was removed daily at the end of the soaking trial (8 hours), the beakers were cleaned, and the specimens were immersed in distilled water until the next day, and so on for 90 days. The measurements were repeated five times for each measure, and the average of the replicated readings was calculated (Goudie et al., 2023).

Results

Surface hardness of heat-cured acrylic resin and GC-soft liner. Evaluating the effect of several natural oils that had already been studied as antifungal agents (Al-Sumaidae, 2012; Al-Sumaidae, 2023) on the hardness of heat-cured acrylic resin and GC-soft liner material.

For heat cured acrylic resin hardness; the mean, number of samples, standard deviation, and Duncan's multiple range test are demonstrated in Table 1, with the highest Shore D value for tested natural disinfectants shown for the ginger oil group (86.40), while the lowest shore D value was shown for the thymol oil group (74.80). The one-way analysis of variance showed that at P = 0.05 there were significant differences between tested groups expressed in Table 2, while Duncan's Multiple Range Test of Shore D hardness of heat cured acrylic resin disinfected by natural oils revealed that there were no significant differences between all groups and the control group except for thymol oil but, this was still within acceptable hardness value.

While for hardness of GC-soft liner the mean, number of samples, standard deviation, and Duncan's multiple range test were demonstrated in Table 3, with the highest Shore A value for tested natural disinfectants shown for the ginger oil group (36.22), while the lowest Shore A value was shown for the thymol oil group (34.66). The one-way analysis of variance demonstrated that at P = 0.05 there were no significant differences between all groups and the control group (Table 4).

Table 1
Descriptive statistics and Duncan's Multiple Range Test of Shore D hardness of heat cured acrylic resin disinfected by natural oils (x ± SD, n = 5)

Variant of experiment	Mean ± standard deviation	Duncan's Multiple Range Test
Distilled water	87.20 ± 1.92	A
Nystatin	87.00 ± 1.58	A
Thymol oil	74.80 ± 2.39	B
Ginger oil	86.40 ± 2.07	A
Nigella oil	85.00 ± 1.58	A
Sesame oil	85.40 ± 2.07	A
Olive oil	86.20 ± 2.49	A

Natural disinfectants pH activity. The pH values during the study ranged between 5.89–7.00. Thymol was a weakly acidic oil, whereas other oils like *Nigella sativa*, olive oil, and ginger oil were neutral to weakly acidic, as shown in Table 5.

Table 2
One-way analysis of variance of shore D hardness of heat cured acrylic resin disinfected by natural oils

Source of variance	DF	SS	MS	F	P
Between groups	6	575.77	95.96	23.00	<0.001
Within groups	28	116.80	4.17	–	–
Total	34	692.57	–	–	-

Table 3
Descriptive statistics and Duncan's multiple range test of shore A hardness of GC soft liner material disinfected by natural oils (x ± SD, n = 5)

Variant of experiment	Mean ± standard deviation	Duncan's multiple range test
Distilled water	35.50 ± 1.58	ABC
Nystatin	35.30 ± 1.72	ABC
Thymol oil	34.66 ± 1.17	AB
Ginger oil	36.22 ± 1.09	BC
Nigella oil	36.00 ± 1.23	BC
Sesame oil	35.58 ± 0.43	ABC
Olive oil	36.20 ± 0.45	BC

Table 4
One-way analysis of variance of shore A hardness of GC soft liner material disinfected by natural oils

Source of variance	DF	SS	MS	F	P
Between groups	6	9.28	1.55	1.09	0.391
Within groups	28	39.64	1.42	–	–
Total	34	48.92	–	–	–

Table 5
Natural disinfectants pH activity (n = 5)

Source of variance	Mean pH
Distilled water	7.00
Nystatin	6.74
Thymol oil	5.89
Ginger oil	6.91
Nigella oil	6.79
Sesame oil	6.83
Olive oil	6.85

Discussion

Antibiotic resistance to commonly used antifungal agents is a major issue in antifungal pharmacotherapy. As a result, it is critical to seek out new compounds, especially those of natural origin, which can be utilized to combat infections (Raut et al., 2022; Shineh et al., 2023). Overuse of chemical and pharmaceutical disinfectants jeopardizes environmental integrity and human health. Therefore, it is recommended to use natural and eco-friendly disinfectants as safer alternatives (Kowalczyk et al., 2020; Mittal et al., 2020; Al-Sumaidae, 2023; Jaouhar et al., 2024).

Currently there is an active search for novel fungal natural plant oil compounds with well-known structures and bioactivity, such as *Nigella sativa*, sesame, olive oil, thymol, and ginger oil. Novel research has shown that they have antibiofilm, antifungal, antileishmanial, antiviral, and anticancer effects. Furthermore, their innovative therapeutic formulations, such as nanocapsules containing these elements, can benefit medical practice and open up new avenues for their widespread use. The widespread use of these immersion oils in healthcare is highly promising, but more in vivo study is needed because the molecular mechanism of action for the majority of them is unknown, and their therapeutic potential in infectious disorders should be explored. Bacteria such as *Escherichia coli*, *Listeria monocytogenes*, *Pseudomonas putida*, *Staphylococcus aureus*, and methicillin-resistant *S. aureus* (MRSA) exhibit a wide range of biological and therapeutic activity. Antifungal capabilities have been proven for *Fusarium* spp., *Aspergillus* spp., *Candida* spp., as well as *Cryptococcus neoformans* and *C. laurentii*, which are differentiated by their ability to form biofilms and hence resist normal antifungal therapy. Efficacy against parasites such as *Leishmania infantum* has also been discovered, as has antiviral efficacy against viruses such as influenza, HSV-1, HSV-2, and HIV-1. Plant extracts also show promising anti-tumor action through multiple mechanisms, such as the induction of apoptosis and suppression of proliferation (Li et al., 2019; Kowalczyk et al., 2020; Jaouhar et al., 2024; Noori & Al-Khafaji, 2024). Other new forms of medicines with such natural substances, such as nanocapsules, nanosphere, and nanotubes, can be very helpful in therapeutic applications, and seem to be promising, but require further research (Kowalczyk et al., 2020; Aziz & Sadoon, 2024). All these natural disinfectants have US Environmental Protection Agency registration approval that meet its safety and efficacy standards and are even edible oils with no hazards whatever.

Surface hardness of heat-cured acrylic resin and GC-soft liner. Hardness property is very important for resilient material and should remain stable for a long period to fulfill its function. Therefore, hardness is effectively used to investigate factors influencing mechanical properties of the polymers (Azevedo et al., 2005a). Hardness of complete denture liners is one of the most challenging factors for their use, since most of them are affected by the moist environment of the mouth (Kreve & Dos Reis, 2019).

Denture cleaning is one of the factors that can change the surface characteristics of the liners (Sameeh et al., 2021). The prosthesis is immersed in a cleansing solution to remove the biofilm from the liner's surface, which increases the possibility of instability of the resilient materials (Azevedo et al., 2005b; Rabee Al-Sumaidae, 2023; Noori & Al-Khafaji, 2024). Recently many researchers use a natural disinfectant (Jaouhar et al., 2024; Noori & Al-Khafaji, 2024; Ribeiro et al., 2024). These natural disinfectants were tested expressing effective antifungal agents and would be accepted and safe in relation to the physical properties of acrylic and soft liner (Al-Sumaidae, 2012; Noori & Al-Khafaji, 2024).

The results show that the tested natural products would be accepted, causing minimum changes in relation to their effect on hardness of heat cured acrylic resin after immersion in them for 8 hours per day throughout three months, but the thymol oil group shows the least hardness value, though this still lies within acceptable hardness value. This was in agreement with Noori & Al-Khafaji who found no changes in hardness of acrylic immersed in natural oils (Noori & Al-Khafaji, 2024). This could be attributed to the PH effect on acrylic resin caused by the acidic character of thymol oil; polymethyl methacrylate hydrolyzes under acidic conditions. The acidic environment can cause cleavage of ester bonds in the polymer chain, resulting in a decrease in the resin's molecular weight and mechanical strength. This degradation might show increased brittleness and reduced elasticity, threatening the structural integrity of dental prostheses (Li et al., 2019; Kowalczyk et al., 2020). The results agree with other research on acceptability of hardness changes with acrylic treated with thyme, *Nigella sativa* and other oils (Albarrag et al., 2017; Sameeh et al., 2021; Shahasvari & Golshan Ebrahimi, 2022) while it disagrees with other research showing great decrease in hardness of heat cured acrylic resin after immersion in water and other solutions (Neppelenbroek et al., 2005; Kreve & Dos Reis, 2019).

The results showed that there are no significant differences between all tested oils and distilled water in relation to hardness of GC-soft lining material at $P = 0.05$. So, all the tested natural antifungal solutions would be accepted and safe in relation to the hardness of GC-soft liner. The favourable results found in the study of the use of natural disinfectants may be attributed to their having no chemical component that causes dissolution of the tested materials. These results agree with research that showed that immersion disinfection did not change the hardness of soft liners (Mante et al., 2008), while they disagree with other studies showing that immersion disinfection caused a significant increase in the hardness of soft liner (Chladek et al., 2014; Sameeh et al., 2021), which was clearly observed during a 60-day period (Mancuso et al., 2009). Resilient liners immersed in water showed high hardness values over time (Mese & Guzel, 2008). Our study lasted for 90-days of immersion and does not show a significant increase in hardness of GC-soft liner (Bueno et al., 2017; Carvalho et al., 2020). Other studies reveal increased hardness in all tested materials at first immersion month, after which the materials had a stabilization of hardness values (Bueno et al., 2017; Carvalho et al., 2020).

Liners should evenly distribute functional stresses on residual ridges during mastication thus reducing the transmitted loads to the mucosa (Awad et al., 2023). During clinical use, the hardness of the soft lining materials altered (Wilson & Tomlin, 1969; Safari et al., 2013). In some investigations immersion in different solutions enhanced the hardness of the soft liners (Mante et al., 2008; Hong et al., 2020; Goudie et al., 2023; Mutahar et al., 2023). It can be assumed that the plasticizer leaches out and the liquid is absorbed and these procedures would be responsible for the increased hardness values (Mante et al., 2008; Safari et al., 2013; Hong et al., 2020). Nevertheless, depending on the formulation of the material and the time of immersion, an increase or decrease in the hardness can be noticed (Wilson & Tomlin, 1969).

However, in clinical conditions, these materials are prone to further changes in hardness, which could be related to temperature fluctuations and pH shifts (Wilson & Tomlin, 1969; Goudie et al., 2023).

Natural disinfectants' pH activity. A low pH reduces hardness of acrylic resins and soft liner in relation to the pH value of each natural disinfectant oil. Thymol, a weakly acidic oil, may have a measurable effect on the pH of acrylic resins and GC soft liner material, while other oils like *Nigella sativa*, and olive oil had minor effects due to their neutral to weakly acidic nature. Ginger oil showed the weakest effect on heat cured acrylic resin and GC soft liner material due to its almost neutral nature, which concurred with other studies (Albarrag et al., 2017; Li et al., 2019; Kowalczyk et al., 2020).

The pH values of these oils correspond to their chemical compositeons and functional groups. Oils with a high triglyceride content, such as sesame and olive oil, are often neutral. Thymol, on the other hand, has a low acidity due to its phenolic composition, which may affect its antibacterial capabilities. Thymol's moderate acidity can increase its solubility and antimicrobial activity, making it a desirable molecule in a variety of applications (Goudie et al., 2023). Thymol has a lower pH than other oils because of its chemical structure and characteristics. Thymol's lower pH can be due to its phenolic structure, which permits it to donate protons in solution. This contrasts with the other oils, which are largely neutral and made up of chemicals that do not substantially change pH (Li et al., 2019; Kowalczyk et al., 2020). In comparison to other oils, neutral oils such as sesame and olive oil are predominantly made up of triglycerides and fatty acids, which are normally neutral and do not significantly affect pH. They lack functional groups that can donate protons. While other oils, such as *Nigella sativa* and ginger oil, may have some mildly acidic qualities due to their bioactive constituents, they do not exhibit the same amount of acidity as thymol since they lack a strong phenolic structure (Nicodemo et al., 2013; Tuna et al., 2013; Albarrag et al., 2017; Sá et al., 2020; Hamzah & Al-Mashhadane, 2022; Goudie et al., 2023).

Exposure to a low pH medium reduces acrylic hardness due to resin disintegration, resulting in decreased microhardness, increased release of residual monomer, and reduced hardness. As a result, dental prostheses exposed to acidic pH values are likely to be weaker and susceptible to fracture (Nicodemo et al., 2013; Tuna et al., 2013; Sá et al., 2020; Goudie et al., 2023). Another study identified that acidic saliva conditions cause more residual monomer release than neutral saliva conditions, which reduces the strength of acrylic resin (Tuna et al., 2013; Sá et al., 2020).

Thymol's pH, on the other hand, has the potential to radically boost its antibacterial effects via a variety of methods. Thymol's lower pH increases its antibacterial activity by damaging microbial cell membranes, slowing growth, and modifying metabolic processes. This makes thymol a useful compound in antibacterial and antifungal applications, especially in formulations that benefit from its acidic nature (Albarrag et al., 2017; Kowalczyk et al., 2020; Al-Sumaidae, 2023).

Conclusions

All of the tested natural disinfectants were found to be safe and clinically acceptable in terms of their influence on the hardness of heat-cured acrylic resin and GC-Soft Liner after three months of immersion in these products for eight hours per day. The use of such disinfectants in clinical settings not only follows safety guidelines but also encourages a comprehensive approach to infection management, improving overall healthcare outcomes. providing a cost-effective alternative that improves patient and environmental safety.

The authors lack conflicts of interest to disclose.

RRA and HM participated with the study's design, methodology, statistical analysis, findings interpretation, and creation of the original draft article, as well as writing, MMS and FAM participated with reviewing, and editing it. All authors reviewed the results and approved the final version of the text for publication.

This study did not get any grant or financial assistance from governmental or commercial sectors.

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