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Degradation of Nitrile Gloves and Rubber Based Impression Materials by Pseudomonas aeruginosa- Comparative Study

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ABSTRACT :

Objective: This study investigates the comparative degradation of nitrile gloves and rubber-based dental impression materials by P*seudomonas aeruginosa, a bacterium known for its robust biodegradation capabilities.*

Methods: Samples of Nitrile gloves and Rubber-based impression materials were exposed to *Pseudomonas aeruginosa* cultures under controlled laboratory conditions. The degradation process was monitored over a specified duration using microscopic analysis for surface analysis, Fourier-transform infrared spectroscopy (FTIR) for chemical characterization and mass proportions.

Results: The study revealed significant differences in the rate and extent of degradation between the two materials. Nitrile gloves exhibited surface pitting and loss of tensile strength within 7 days of exposure, while rubber-based impression materials showed slower degradation, with minimal structural changes after the same period. FTIR analysis indicated breakdown of nitrile polymers into simpler compounds, whereas the rubber material demonstrated oxidative degradation, scission of polymeric chains and accumulation of inorganic additives indicating degradation likely occurring.

Conclusion: Pseudomonas aeruginosa has a notable degradative effect on nitrile gloves whereas, Rubber-based impression materials exhibit higher resistance, making them more suitable for prolonged use under similar conditions. These findings emphasize the importance of understanding material durability in microbial environments for enhanced infection control, material longevity and the exploration of biodegradation as a potential recycling method for dental wastes.

Keywords: Nitrile gloves, Rubber-based impression materials, Pseudomonas aeruginosa, microbial degradation, infection control, material durability

INTRODUCTION :

The extensive use of synthetic polymers such as nitrile gloves and rubber-based impression materials in dentistry has raised concerns about their environmental impact due to their non-biodegradable nature. These materials, while essential for clinical applications, contribute significantly to the accumulation of medical and dental waste. Exploring their interaction with microbial agents capable of biodegradation offers potential insights into addressing this challenge.

Pseudomonas aeruginosa is a versatile bacterium known for its ability to degrade a wide range of organic materials, including synthetic polymers. Its metabolic adaptability, facilitated by enzymatic mechanisms, makes it a suitable model organism for studying microbial degradation of commonly used dental materials. Nitrile gloves, composed of synthetic rubber, and rubber-based impression materials, including polysulfide, polyether, and silicones, differ in their chemical compositions and mechanical properties. These variations may influence their susceptibility to microbial degradation, offering a unique opportunity to investigate the comparative effects of P. aeruginosa on these materials.

This study aims to evaluate the degradation patterns of nitrile gloves and rubber-based impression materials when exposed to P. aeruginosa. The focus is on understanding the extent of material breakdown, changes in physical and chemical properties, and identifying material-specific susceptibilities. The findings can provide insights into the potential for developing eco-friendly alternatives or recycling strategies for dental polymers, contributing to sustainability in dental practice and material science.

AIM :

The aim of this study is to evaluate the microbial degradation of rubber-based dental impression materials by *Pseudomonas aeruginosa*, leveraging its established ability to degrade synthetic polymers such as nitrile gloves. By examining the interaction between *P. aeruginosa* and different types of rubber-based impression materials, the study seeks to identify variations in susceptibility to microbial degradation, assess changes in material properties, and provide evidence for potential environmental implications and biodegradation pathways.

MATERIALS AND METHODS :

Selection of rubber based impression material sample

The impression material ,which were commercially sourced, were cut into pieces to increase the substrate's contact surface with bacteria .The material prices were washed and dried until obtaining a constant weight.

P. aeruginosa cultivation

Isolated colonies of P.aeruginosa grown on Muller Hinton agar and the colonies were isolated and inoculated in a Muller Hinton broth . This was inoculated at 37 degree Celsius for 24 hrs, after 24hrs colonies were grown in the broth.

Adaptation of P.aeruginosa with rubber based impression material

The fresh broth culture were inoculated the polymers for 24hrs and 72hrs.

Weight measurement of rubber-based impression materials

To confirm the colonization of bacteria on rubber-based impression materials, the piece of samples were collected from the broth after 24hrs and 72hrs and their weights were measured.

Microscopic analysis

To observe surface modifications in rubber based impression material, samples were taken from the broth and were observed under microscope with 40× objective .

Fourier transform Infrared spectroscopy (FT-IR)

FT-IR were used to analyze chemical structural changes in the rubber-based impression materials following degradation by Pseudomonas aeruginosa. The absorption bands of the unknown compounds were correlated with the known absorption frequencies.

RESULTS :

Weight measurement of rubber-based impression material

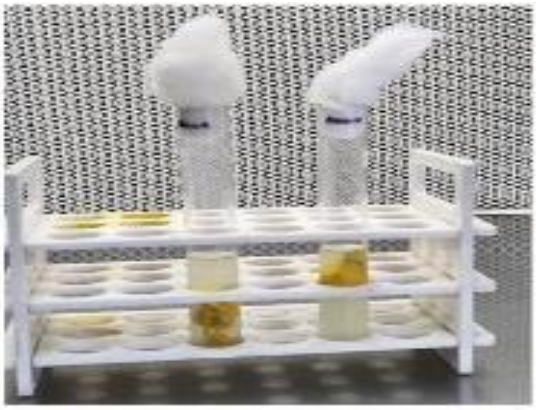
Weight of piece of rubber based impression materials collected from broth after 24hrs and 72 hrs were noted increased which indicating biofilm formation

POLYMERS

Initial stage - weighing of polymer before inoculation of Pseudomonas sp.

PREPARATION OF BROTH

Isolated colonies of *Pseudomonas sp.* Grown on Muller Hinton agar and the colonies were isolated and inoculated in a Muller hinton broth. This was incubated at 37 degree Celsius for 24 hrs, after 24 hrs colonies were grown in the broth.



Fresh broth culture were inoculated the polymers for 24 hrs

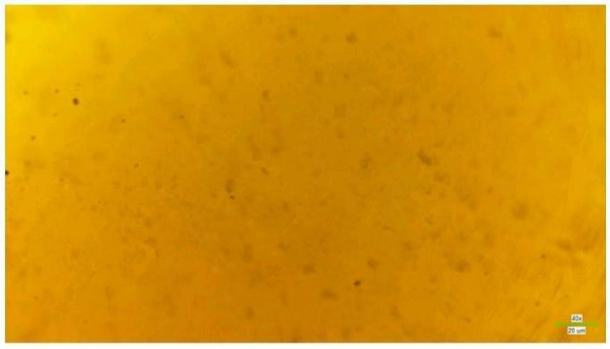
Weighing of inoculated after 24 hrs

Fresh broth culture were inoculated the polymers for 72 hrs

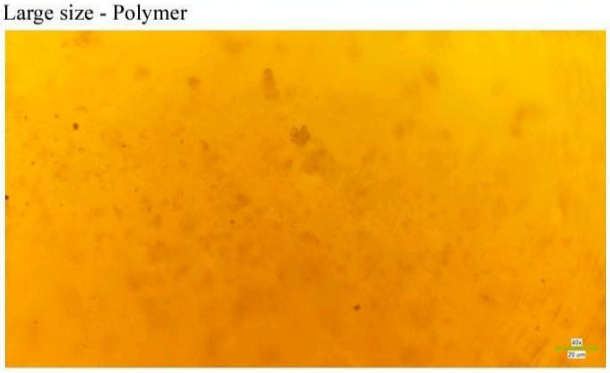
Weighing of inoculated after 72 hrs

Microscopic analysis

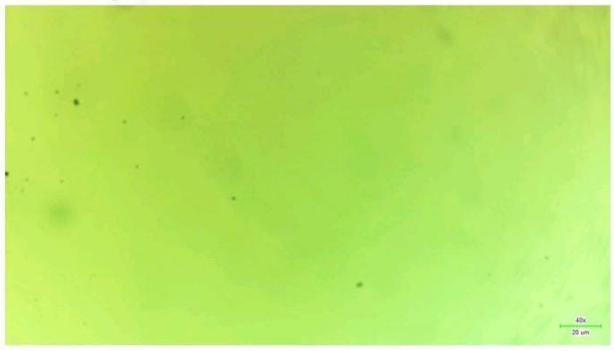
Cha**nges** were observed over the surface of the rubber based impression material during microscopic analysis, we detected surface irregularities and adaptation of bacteria has been seen on the surface of the materials.



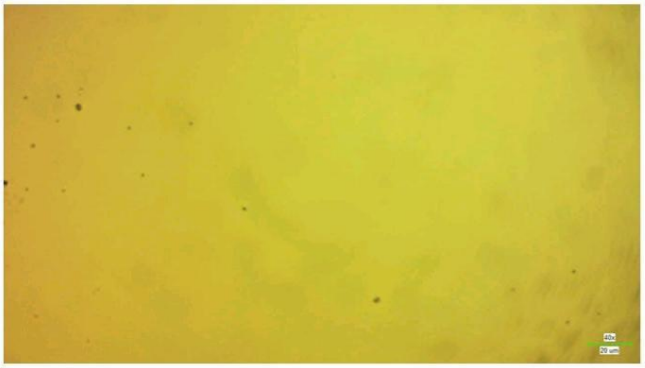
Large size - Polymer



Small size - polymer



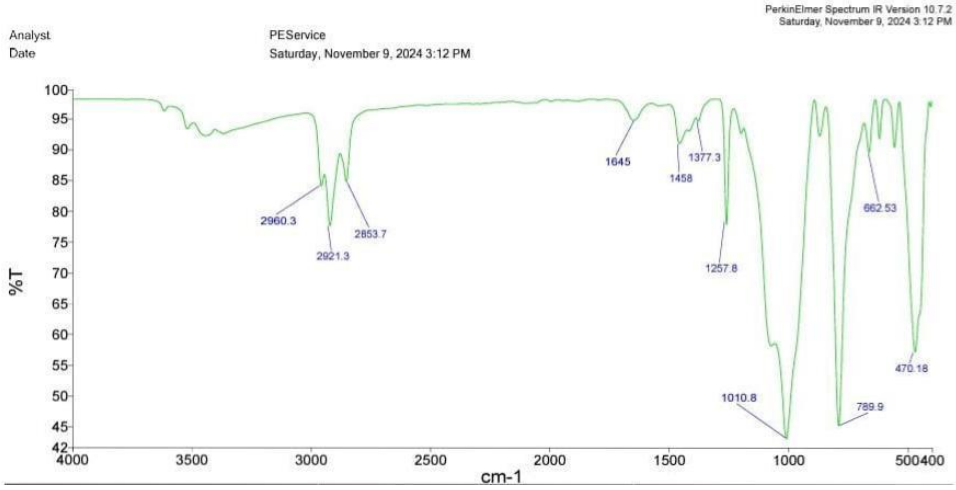
Small size - polymer (control)



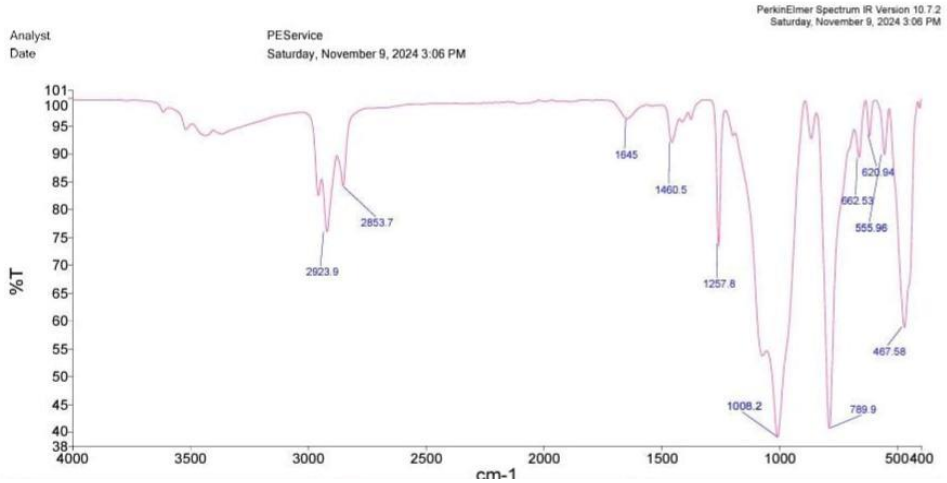
Large size - Polymer (control)

Fourier transform Infrared spectroscopy (FT-IR)

Coated polymer



Uncoated polymer(control)



***2921 cm⁻¹ (C-H Stretching)*:**

- This is typically the *asymmetric stretching* of *methylene groups (–CH₂–)* and is found in *alkyl chains*. In *saturated hydrocarbons* like *polyethylene* or *polypropylene*, this peak is common, in this peak intensity decreases, and it indicates *chain scission* or breakdown of the polymer backbone during degradation.

***1645 cm⁻¹ (C=C Stretch or Carbonyl Stretch)*:**

- This peak suggests the presence of *C=C double bonds* (from *alkenes* or *conjugated systems*). If the polymer is *oxidized* or undergoing *hydrolysis*, the formation of *carbonyl groups (C=O)* is common, and this peak may become more pronounced. This is an indicator that *degradation* has likely occurred, especially in *unsaturated polymers*.

***1458cm⁻¹ (C-H Bending)*:**

- This is associated with *C-H bending* vibrations of *methylene (–CH₂–)* or *methyl (–CH₃)* groups. In the context of degradation, the peak intensity decreased due to *alkyl chains* are breaking down or becoming oxidized.

***1257 cm⁻¹ (C-O Stretch or C-H Bending)*:**

- This peak can indicate *C-O stretching* in *ether* or *ester* linkages, or *C-H bending* in *alkyl groups*. If the polymer contains *ether* or *ester linkages*, this could suggest some changes in the structure, particularly if degradation is hydrolytic in nature (e.g., *polyesters* or *polyurethanes*).

***1010cm⁻¹ (C-O Stretch)*:**

- This is typically the *C-O stretching* vibration, indicative of *ether* or *ester linkages*. If *hydrolysis* or *oxidative degradation* is occurring, the intensity of this peak increased due to the polymer breaks down.

470 *cm⁻¹*

- This is related to inorganic additives, an increase in the intensity of this peak indicates microbial activity, enzymatic degradation could lead to accumulation of inorganic by- Products.

INTEPRETATION OF DEGRADATION

1. *Degradation likely occurring*: since there is a *reduction in the intensity* of the *C-H stretching bands* (2923, 2853 cm^{-1}), along with the appearance or *increase in the intensity* of *carbonyl stretches* (1645 cm^{-1}), it suggests *oxidative degradation* or *scission* of the polymer chains. The appearance of new *functional groups*, such as *carbonyl* or *hydroxyl*, supports this.
2. *Changes c-o stretching vibration* (1010 cm^{-1}) may also indicate *oxidative degradation* or *hydrolysis.*
3. *Increases in peaks related to inorganic additives* (467 cm^{-1}) could indicate that accumulation of inorganic by-products further suggesting degradation.

DISCUSSION :

Nitrile gloves and rubber-based impression materials contribute significantly to plastic pollution due to their single-use nature and extreme resistance to biodegradation. Improper disposal leads to accumulation in landfills and environmental contamination through microplastics and chemical pollutants. Nitrile gloves, composed of nitrile butadiene rubber (NBR), are recognized as environmental pollutants, causing soil acidification and leaching toxic nitrile compounds. Research on the biodegradability of nitrile gloves remains limited, focusing primarily on their polymer constituents rather than the full material.[6] Microorganisms, particularly *Pseudomonas aeruginosa*, exhibit potential in degrading synthetic plastics, including nitrile gloves. *P. aeruginosa* utilizes mechanisms like biofilm formation, enzymatic activity (e.g., nitrilase, depolymerases), and intracellular metabolic pathways to break down polymers. Biofilms mediate adhesion to polymer surfaces, while enzymes reduce molecular weight and convert polymers into harmless by-products like CO2. The bacterium's versatility in degrading other polymers, such as polyethylene and natural rubber, underscores its capability. However, the biodegradation of nitrile gloves is not well-studied, with limited standardized methods for evaluating polymer degradation.[7] Analytical techniques like SEM, FT-IR spectroscopy, bacterial growth studies, and weight loss measurements are crucial for accurate assessment. Further research is needed to understand the mechanisms, optimize degradation processes, and address environmental concerns associated with nitrile glove disposal.[8]*Nitrile gloves degradation by Pseudomonas aeruginosa* demonstrates its capability to utilize nitrile gloves as the sole carbon source, achieving a weight loss of 2.25% through biofilm formation, as evidenced by Scanning Electron Microscopy (SEM) analysis, which revealed surface alterations such as cracks, scales, and protrusions indicative of microbial activity (Delgado-Nungaray et al., 2024). Biofilm formation is a critical mechanism enabling *P. aeruginosa* to adapt and survive under adverse conditions, facilitating adhesion and polymer breakdown through extracellular polymeric substances (EPS).[9] Gradual adaptation played a significant role in the biodegradation process; the bacterium initially exhibited growth with 1% nitrile gloves but experienced inhibited growth at 3% concentration due to nitrile toxicity. However, progressive adaptation allowed *P. aeruginosa* to grow with 5% nitrile gloves, demonstrating optimal metabolic activity and substantial biomass production. Fourier Transform Infrared (FT-IR) analysis further confirmed biodegradation by identifying characteristic changes such as aldehyde and aliphatic amine formation, indicating the bacterium's ability to break down and assimilate nitrile polymers. SEM observations also revealed depolymerization through extensive surface modifications, including the formation of semi-spherical holes and an EPS matrix, underscoring the bacterium's metabolic adaptability.[10]

The degradation capabilities of *Pseudomonas aeruginosa* on nitrile gloves and rubber-based impression materials reveal distinct variations in bacterial colonization, disintegration rate, and long-term effects. Nitrile gloves, composed of nitrile butadiene rubber (NBR), and rubber-based impression materials, typically made from elastomers like polyvinyl siloxane or polysulfide, are both susceptible to microbial degradation due to their polymeric composition. Delgado-Nungaray et al. (2024) demonstrated that *P. aeruginosa* can efficiently colonize nitrile gloves through biofilm formation, enabling adhesion and enzymatic breakdown, with gradual adaptation enhancing the degradation process. Similarly, Gu et al. (2006) explored the bacterial colonization of rubber-based impression materials and highlighted their higher susceptibility to surface modifications and disintegration, particularly in the presence of biofilm-producing bacteria. Comparative findings suggest that Long-term exposure to *P. aeruginosa* consistently revealed significant structural damage, including cracks, scales, and depolymerization, particularly in rubber-based materials.

LIMITATION :

Since the tests are conducted only for 3 days observation period, the biofilm formation and bacterial adaptation is noted, the incubation period should be extended more for complete degradation of rubber based impression material by Pseudomonas aeruginosa.

CONCLUSION :

In comparison with nitrile gloves, which exhibited a more pronounced degradation due to the susceptibility of their synthetic polymer structure, rubber-based impression materials were more prone to microbial attack, similar to nitrile gloves, albeit at a slower rate.

The increased FTIR peaks related to inorganic additives, such as silica and titanium dioxide, in both nitrile gloves and rubber-based impression materials, indicate leaching or exposure of these inorganic components during the degradation process. This suggests that *P. aeruginosa* may break down the organic matrix, leaving behind inorganic residues, thus affecting the integrity and durability of these materials.

Overall, *Pseudomonas aeruginosa* can degrade rubber-based impression materials to a certain extent, albeit less efficiently than nitrile gloves.

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