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Influence of Chemical Disinfection on the Flexural Strength of PETG and PMMA Materials Used in Occlusal Splints

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Abstract:
Background:
Occlusal splints are commonly used for the management of temporomandibular disorders (TMDs), bruxism, and occlusal imbalance. Polymethyl methacrylate (PMMA) and polyethylene terephthalate glycol-modified (PETG) are frequently employed materials for their fabrication. Regular disinfection of these appliances is critical for infection control; however, prolonged exposure to chemical disinfectants may compromise their mechanical properties, particularly flexural strength, which is vital for clinical longevity.
Aim:
To evaluate and compare the effects of three chemical disinfectants—chlorhexidine gluconate (CHX), glutaraldehyde (GA), and sodium hypochlorite (NaOCl)—on the flexural strength of PMMA and PETG materials used in occlusal splints.
Materials and Methods:
An in vitro experimental study was carried out using 120 standardized samples, equally divided between PMMA and PETG (n=60 each). Each material group was further subdivided into four subgroups (n=15): three experimental groups based on disinfectant type (4% CHX, 2.45% GA, 5% NaOCl) and one control group. Samples in the test groups were immersed daily in the assigned disinfectant for 15 minutes over 60 days. Flexural strength was measured using a Universal Testing Machine. Statistical analysis was performed using ANOVA and post-hoc tests.
Results:
All disinfectants caused a reduction in flexural strength for both materials. Sodium hypochlorite (5%) led to the most significant decrease, followed by glutaraldehyde (2.45%). Chlorhexidine gluconate (4%) caused the least reduction. PMMA consistently demonstrated higher flexural strength than PETG across all groups.
Conclusion:
Chemical disinfection impacts the mechanical integrity of PMMA and PETG. Chlorhexidine gluconate caused the least degradation and is recommended for routine disinfection. Sodium hypochlorite significantly compromised flexural strength and should be used cautiously. These results highlight the importance of selecting disinfectants that maintain the structural performance of occlusal splint materials.
Keywords:
Flexural strength, PMMA, PETG, chemical disinfection, chlorhexidine, glutaraldehyde, sodium hypochlorite, occlusal splints.

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I. Introduction

The masticatory system is a highly coordinated unit responsible for chewing, speech, and swallowing, supported by bones, muscles, ligaments, and teeth under neuromuscular control . At the core of its function is the temporomandibular joint (TMJ), a complex joint that allows both hinge and sliding movements essential for mandibular dynamics [1].

Occlusal splints are removable acrylic devices commonly used to manage temporomandibular disorders (TMDs), protect teeth from parafunctional forces, and stabilize occlusion. These appliances help reduce muscle strain, improve joint alignment, and redistribute occlusal loads [1,2]. As defined in the Glossary of Prosthodontic Terms, they serve diagnostic and therapeutic purposes by modifying the relationship between the mandible and maxilla [3].

Two frequently used materials in splint fabrication are polymethyl methacrylate (PMMA) and polyethylene terephthalate glycol (PETG). PMMA is a rigid, biocompatible acrylic resin known for its durability, polishability, and dimensional stability, making it ideal for long-term splints . PETG, in contrast, is a thermoplastic copolyester valued for its flexibility, transparency, and ease of molding, commonly used in short-term or vacuum-formed appliances. Despite its comfort, PETG may respond differently to stress due to its lower rigidity compared to PMMA [4,5,6].

A critical factor in the long-term performance of these materials is flexural strength, which indicates a material's ability to resist deformation under functional loads. Repeated stresses during use, including chewing and bruxism, can challenge the mechanical stability of occlusal splints[6].

To prevent contamination, chemical disinfectants such as chlorhexidine, glutaraldehyde, and sodium hypochlorite are routinely used. However, prolonged or repeated exposure to these agents may alter the material's surface characteristics and internal structure, potentially weakening their mechanical properties [7,8].

This study investigates how routine chemical disinfection affects the flexural strength of PMMA and PETG materials used in occlusal splints, aiming to identify practices that preserve both hygiene and structural reliability.

II. Material And Methods

Study Design

This was an in-vitro comparative study conducted to evaluate the influence of chemical disinfection on the flexural strength of polyethylene terephthalate glycol (PETG) and polymethyl methacrylate (PMMA) materials used in occlusal splints.

Study Location

The present study was carried out in the Department of Prosthodontics and Crown & Bridge, Jaipur Dental College, Jaipur. Flexural strength testing was performed at I.T.S. Engineering College, Greater Noida, Uttar Pradesh.

Study Duration

The duration of the study spanned three months.

Sample Size Calculation

Sample size was calculated using G*Power software version 3.1.9.6 with a significance level of 5%, power of 90%, and large effect size (0.40). A total of 120 samples were prepared:

- PMMA group**:** 60 samples
- PETG group**:** 60 samples

Each material group was further divided into four subgroups based on the disinfection method, with 15 samples in each subgroup.

Materials Used

- PMMA Resin**:** Heat cure polymethyl methacrylate (Pyrax)
- PETG Sheets**:** Erkodur (Erkodent, Germany)
- Disinfectants:
  - 4% Chlorhexidine gluconate
  - 2.45% Glutaraldehyde
  - 5% Sodium hypochlorite
- Other Materials:
  - Type II dental stone
  - Modelling wax
  - Putty silicone
  - Sandpaper (1000-grit), cold mold seal, digital vernier caliper

Inclusion Criteria

- Samples made of PMMA or PETG
- Standardized dimensions: 80 mm × 10 mm × 3 mm
- No visual defects or warpage
- Daily disinfection for 15 minutes over 60 days

Exclusion Criteria

- Incomplete polymerization
- Surface cracks or air bubbles
- Inconsistent disinfection/storage protocol

Methodology

Sample Preparation

PMMA Group:

Wax specimens were created using a standardized mold and invested in Type II gypsum. Heat cure PMMA was

processed using a conventional short curing cycle. The finished specimens are polished and checked for dimensional accuracy.
PETG Group:
PETG sheets (3 mm thick) were trimmed into test dimensions using a diamond disc with water cooling. All specimens were polished and checked with a digital vernier caliper.

Grouping and Disinfection Protocol
Both PMMA and PETG groups are categorized into four subgroups, each consisting of 15 specimens :

Table 1. Division of subgroups

Subgroup	Treatment Protocol	Number of Samples
1	Disinfection with 4% Chlorhexidine	15
2	Disinfection with 2.45% Glutaraldehyde	15
3	Disinfection with 5% Sodium Hypochlorite	15
4	Control (no disinfection)	15

Disinfection was performed by immersing specimens for 15 minutes daily over a 60-day period. Specimens were washed and stored in distilled water between each disinfection cycle. Control group specimens were stored dry and not disinfected.

Flexural Strength Testing
Testing was performed using a Universal Testing Machine (UTM) in a 3-point bending configuration according to ISO 20795-1 standards.

- Support span: 50 mm
- Crosshead speed: 0.5 mm/min
- Maximum load at fracture (N) was recorded

Flexural strength (σ) was calculated using the formula:

$$\sigma = \frac{3FL}{2bd^2}$$

Where:

F = Load at fracture (N)
L = Support span (mm)
b = Width of specimen (mm)
d = Thickness of specimen (mm)

Statistical Analysis
The data obtained from flexural strength testing were entered into Microsoft Excel 2007 and statistically analyzed using IBM SPSS software version 23.0.
Descriptive Statistics

- Mean and standard deviation (SD) were calculated for each subgroup.
- Data normality was tested using the Shapiro–Wilk test.
- To determine variance consistency across groups, Levene's test was performed.

Inferential Statistics

- One-way ANOVA was applied to determine statistically significant differences in mean flexural strength among the subgroups within each material group (PMMA and PETG).
- Post-hoc Tukey test was used for pairwise comparisons if ANOVA results were significant.
- Independent t-test was used to compare the mean values between PMMA and PETG groups for each disinfection method.

A p-value < 0.05 was considered statistically significant.

III. Result

The present in vitro study was carried out to evaluate influence of chemical disinfection on the flexural strength of polyethylene terephthalate glycol (PETG) and poly methyl methacrylate (PMMA). The recorded values were obtained, tabulated and subjected to statistical analysis of variance.

Table –2 Effect Of Various Disinfectants On The Flexural Strength (Mpa) Of The PMMA Group

	Mean	Std Dev	Std Error	95% CI		Minimum	Maximum
Group 1	107.45	3.11	0.80	105.73	109.18	101.36	114.14
Group 2	99.02	6.23	1.61	95.57	102.47	82.40	107.88
Group 3	74.23	3.57	0.92	72.25	76.21	66.84	84.18
Group 4	126.39	2.39	0.62	125.07	127.71	121.31	131.73

Group 1-Disinfection with 4% Chlorhexidine (after 60 days), Group 2-Disinfection with 2.45% glutaraldehyde (after 60 days), Group 3-Disinfection with 5% Sodium Hypochlorite (after 60 days), Group 4-Control Group, No Disinfection

Table 3-Post Hoc Analysis of PMMA group

	Mean	Mean Difference	Std Error	P value	Significance
Group 1	Group 2	8.435	1.494	0.001	Significant
Group 1	Group 3	33.225	1.494	0.001	Significant
Group 1	Group 4	18.937	1.494	0.001	Significant
Group 2	Group 3	24.790	1.494	0.001	Significant
Group 2	Group 4	27.372	1.494	0.001	Significant
Group 3	Group 4	52.162	1.494	0.001	Significant

The study evaluated the effect of various disinfectants on the flexural strength of polymethyl methacrylate (PMMA) specimens. Among the four groups tested, the control group (Group 4), which underwent no disinfection, exhibited the highest mean flexural strength (126.39 MPa), followed by Group 1 (107.45 MPa), which was disinfected with 4% chlorhexidine. Group 2, treated with 2.45% glutaraldehyde, showed a mean strength of 99.02 MPa, while Group 3, exposed to 5% sodium hypochlorite, recorded the lowest mean strength of 74.23 MPa.

Statistical analysis using post hoc LSD tests revealed that all intergroup comparisons were statistically significant ($p \leq 0.001$). Notably, the flexural strength of Group 3 was significantly lower than all other groups, indicating the most detrimental effect on PMMA when disinfected with sodium hypochlorite. In contrast, chlorhexidine (Group 1) and glutaraldehyde (Group 2) also resulted in reduced strength compared to the control, but the impact was less severe. The findings highlight that disinfection protocols, particularly with sodium hypochlorite, can significantly compromise the mechanical integrity of PMMA

GRAPH 1 - Effect Of Various Disinfectants On The Flexural Strength (Mpa) Of The PMMA Group

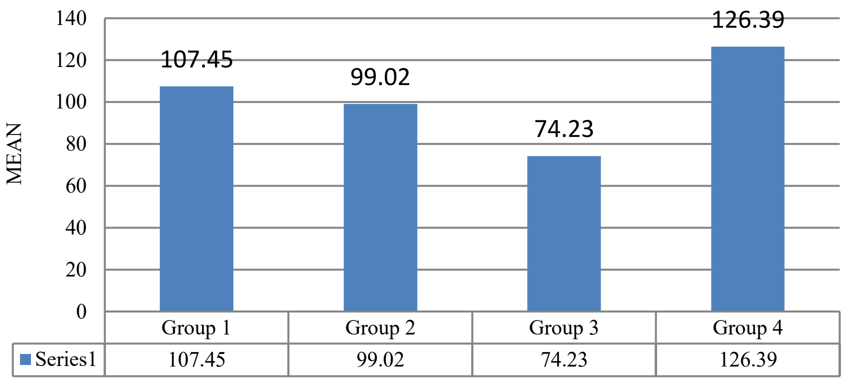


Table –4 Effect Of Various Disinfectants On The Flexural Strength (Mpa) Of The PETG Group

	Mean	Std Dev	Std Error	95% CI		Minimum	Maximum
Group 1	89.14	3.04	0.79	87.46	90.82	84.12	94.73
Group 2	82.25	4.93	1.27	79.52	84.98	68.39	89.54
Group 3	61.61	2.95	0.76	59.98	63.24	55.47	69.86
Group 4	104.62	2.14	0.55	103.43	105.81	100.68	109.33

Group 1-Disinfection with 4% Chlorhexidine (after 60 days), Group 2-Disinfection with 2.45% Glutaraldehyde (after 60 days), Group 3-Disinfection with 5% Sodium Hypochlorite (after 60 days), Group 4-Control Group, No Disinfection

Table- 5 Post Hoc Analysis of PETG Group

Post Hoc Analysis of PETG groups					
	Mean	Mean Difference	Std Error	P value	Significance
Group 1	Group 2	6.893	1.250	0.001	Significant
Group 1	Group 3	27.527	1.250	0.001	Significant
Group 1	Group 4	15.480	1.250	0.001	Significant
Group 2	Group 3	20.634	1.250	0.001	Significant
Group 2	Group 4	22.373	1.250	0.001	Significant
Group 3	Group 4	43.007	1.250	0.001	Significant

The effect of various disinfectants on the flexural strength of polyethylene terephthalate glycol-modified (PETG) specimens was analyzed across four groups. The control group (Group 4), which received no disinfection, exhibited the highest mean flexural strength of 104.62 MPa. Among the disinfected groups, Group 1 (4% chlorhexidine) maintained a relatively high flexural strength of 89.14 MPa, followed by Group 2 (2.45% glutaraldehyde) at 82.25 MPa. Group 3, subjected to 5% sodium hypochlorite, demonstrated the lowest flexural strength at 61.61 MPa.

Post hoc LSD analysis revealed statistically significant differences ($p \leq 0.001$) between all group comparisons. The flexural strength of Group 3 was significantly lower than that of all other groups, indicating a pronounced weakening effect of sodium hypochlorite on PETG material. While both chlorhexidine and glutaraldehyde treatments also reduced flexural strength compared to the control, the reduction was less severe. These results suggest that disinfectants, particularly sodium hypochlorite, negatively impact the mechanical properties of PETG,

GRAPH 2 - Effect Of Various Disinfectants On The Flexural Strength (Mpa) Of The PETG Group

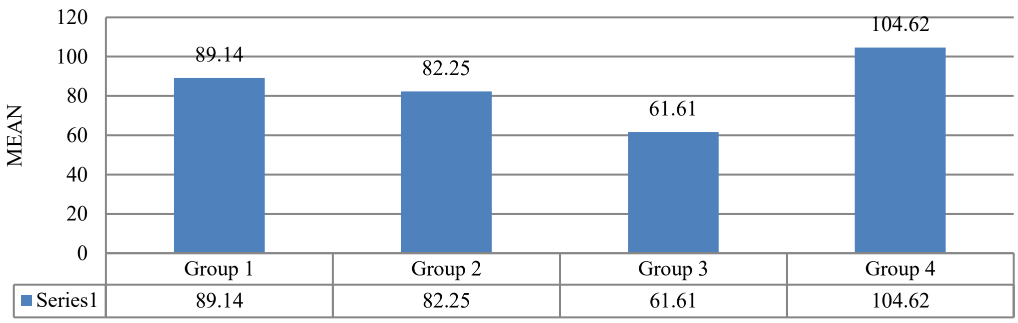


Table 6. Intergroup comparison of Flexural Strength between PMMA and PETG Group in Various Disinfectants

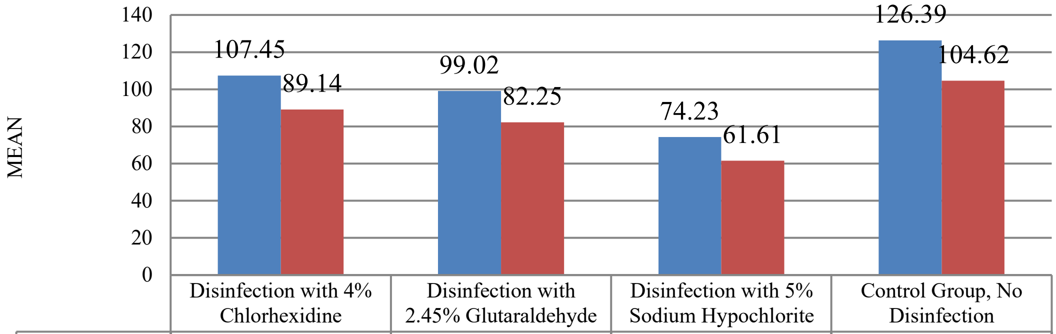
		Mean	Std Dev	Std Error	P value	Significance
Disinfection with 4% Chlorhexidine	PMMA Group	107.45	3.11	0.80	0.001	Significant
	PETG Group	89.14	3.04	0.79		
Disinfection with 2.45% Glutaraldehyde	PMMA Group	99.02	6.23	1.61	0.001	Significant
	PETG Group	82.25	4.93	1.27		
Disinfection with 5% Sodium Hypochlorite	PMMA Group	74.23	3.57	0.92	0.001	Significant
	PETG Group	61.61	2.95	0.76		
Control Group, No Disinfection	PMMA Group	126.39	2.39	0.62	0.001	Significant
	PETG Group	104.62	2.14	0.55		

The intergroup comparison of flexural strength between PMMA and PETG materials under various disinfection protocols revealed statistically significant differences across all tested conditions ($p = 0.001$). For each disinfectant, the PMMA group consistently exhibited higher mean flexural strength compared to the PETG group. Specifically, under disinfection with 4% chlorhexidine, the PMMA group showed a mean flexural strength of 107.45 MPa, significantly greater than the 89.14 MPa observed in the PETG group. Similarly, with 2.45%

glutaraldehyde, PMMA maintained a higher flexural strength (99.02 MPa) than PETG (82.25 MPa). A comparable trend was noted with 5% sodium hypochlorite, where PMMA recorded 74.23 MPa, outperforming PETG at 61.61 MPa.

Even in the control group (no disinfection), the PMMA specimens demonstrated superior mechanical performance (126.39 MPa) compared to PETG (104.62 MPa). These results indicate that PMMA possesses better flexural strength and retains its mechanical integrity more effectively than PETG when exposed to common disinfectants.

GRAPH 3- Intergroup comparison of Flexural Strength between PMMA and PETG Group in Various Disinfectants



	Disinfection with 4% Chlorhexidine	Disinfection with 2.45% Glutaraldehyde	Disinfection with 5% Sodium Hypochlorite	Control Group, No Disinfection
PMMA Group	107.45	99.02	74.23	126.39
PETG Group	89.14	82.25	61.61	104.62

IV. DISCUSSION

This study assessed the effect of chemical disinfection on the flexural strength of two widely used occlusal splint materials: PETG and PMMA. A consistent decline in flexural strength was observed after 60 days of exposure, particularly with sodium hypochlorite (NaOCl), which caused the greatest degradation. PMMA decreased to 74.23 MPa and PETG to 61.61 MPa, due to NaOCl's oxidizing action that leads to polymer chain scission and matrix embrittlement [17,18].

PMMA consistently showed higher flexural strength than PETG under all conditions. This is attributed to PMMA's thermosetting, cross-linked structure, which offers better resistance to chemical degradation than the linear, thermoplastic structure of PETG [9,12,14].

Chlorhexidine gluconate showed the least negative impact. PMMA retained 107.45 MPa and PETG 89.14 MPa. Although a slight reduction was observed, it was significantly lower than that caused by glutaraldehyde and NaOCl. These findings are consistent with previous studies by Pinto et al. , Yaseen et al. and Ouanounou et al who noted minimal mechanical changes after chlorhexidine exposure[10,16,19].

Glutaraldehyde caused a moderate reduction (PMMA: 99.02 MPa, PETG: 82.25 MPa). Its chemical interaction with polymer chains explains the deterioration, as previously reported by Savabi et al, Walczak et al. and Gadhave et al. [11,13,20].

From a clinical perspective, chlorhexidine—especially at lower concentrations such as 2%—is the most suitable for routine disinfection while NaOCl should be avoided due to its aggressive nature, which significantly compromises material integrity[15,16]. Future research should focus on developing chemically resistant polymers or protective coatings and conducting long-term in vivo studies under real clinical conditions.

V. CONCLUSION

Within the limitations of this in vitro study, it can be concluded that both PMMA and PETG materials exhibit sufficient baseline flexural strength for application in occlusal splints. However, prolonged exposure to chemical disinfectants significantly compromises their mechanical integrity. Among the agents tested, 5% sodium hypochlorite resulted in the most substantial reduction in strength, while 4% chlorhexidine gluconate demonstrated the least impact.

PMMA consistently showed greater resistance to chemical degradation compared to PETG, making it a more suitable choice for the fabrication of occlusal splints intended for long-term use. This superior performance is attributed to PMMA's cross-linked thermosetting polymer structure, which provides enhanced stability under chemical stress.

Considering these findings, chlorhexidine gluconate—especially at lower concentrations—is recommended as the disinfectant of choice for routine cleaning of hard occlusal splints due to its minimal adverse effect on flexural strength and proven antimicrobial efficacy. Sodium hypochlorite should be avoided in regular practice due to its aggressive effect on material properties.

Further clinical investigations and long-term evaluations are essential to validate these outcomes in real-world settings and to guide the development of improved materials and disinfection protocols that ensure both functional longevity and biocompatibility of hard occlusal splints.

References

[1]. Okeson JP. Management of Temporomandibular Disorders and Occlusion - E-Book [Internet]. Google Books. 2019 [cited 2025 May 25]. Available from: https://books.google.com/books?hl=en&lr=&id=RxmGDwAAQBAJ&oi=fnd&pg=PP1&ots=5lRQ74ZDtv&sig=vzNNTl2fqvzI2CRmeSLmb0YpZhg

[2]. Gohil DJ, Kumar DS, Kumar DR, Sharma DD, Dr Bathel Yeptho. OCCLUSAL SPLINT THERAPY - AN OVERVIEW. IJRAR - International Journal of Research and Analytical Reviews (IJRAR) [Internet]. 2022 Apr [cited 2025 May 25];9(2):584–8584–8. Available from: http://ijrar.org/viewfull.php?&p_id=IJRAR22B1300

[3]. The Glossary of Prosthodontic Terms 2023. Journal of Prosthetic Dentistry. 2023 Oct 1;130(4):e1–3.

[4]. Choudhary S, Rao HM, Rohilla AK, Jayam C. (PDF) The Occlusal Splint Therapy: A Literature Review [Internet]. ResearchGate. 2015. Available from: https://www.researchgate.net/publication/281242480_The_Occlusal_Splint_Therapy_A_Literature_Review

[5]. CHECHERITA L, BELDIMAN MA, STAMATIN O, FOLA L, FORNA NC. Aspects on structure of material used for different types of occlusal splints [Internet]. www.researchgate.com. 2013. Available from: https://www.researchgate.net/profile/Maria-Antonela-Beldiman/publication/274387620_Aspecte_privind_structura_materialelor_utilizate_pentru_diferite_tipuri_de_gutiere_ocluzale_Aspects_on_Structure_of_Materials_used_for_Different_Types_of_Occlusal_Splints/links/5ea30065a6fdccd7944ebf6f/Aspecte-privind-structura-materialelor-utilizate-pentru-diferite-tipuri-de-gutiere-ocluzale-Aspects-on-Structure-of-Materials-used-for-Different-Types-of-Occlusal-Splints.pdf

[6]. Dathan PC, Nair KC, Kumar AS, AR L. Flexural Strength is a Critical Property of Dental Materials-An Overview [Internet]. 2023. Available from: https://www.researchgate.net/profile/Chandrasekharan-Nair-3/publication/372035454_Flexural_Strength_is_a_Critical_Property_of_Dental_Materials-An_Overview/links/64b15c2eb9ed6874a51a08f3/Flexural-Strength-is-a-Critical-Property-of-Dental-Materials-An-Overview.pdf

[7]. Chau VB, Saunders TR, Meade Pimsler, Elfring DR. In-depth disinfection of acrylic resins. ˜The œjournal of prosthetic dentistry/˜The œJournal of prosthetic dentistry. 1995 Sep 1;74(3):309–13.

[8]. Alqarni H, Jamleh A, Chamber MS. Chlorhexidine as a Disinfectant in the Prosthodontic Practice: A Comprehensive Review. Cureus. 2022 Oct 21;..

[9]. Dupaix RB, Boyce MC. Finite strain behavior of poly(ethylene terephthalate) (PET) and poly(ethylene terephthalate)-glycol (PETG). Polymer. 2005 Jun;46(13):4827–38.

[10]. De Rezende Pinto L, Rodríguez Acosta EJT, Távora FFF, Da Silva PMB, Porto VC. Effect of repeated cycles of chemical disinfection on the roughness and hardness of hard reline acrylic resins. Gerodontology. 2009 Jun 8;27(2):147–53.

[11]. Savabi O, Attar K, Nejatidanesh F, Goroohi H, Badrian H. Effect of different chemical disinfectants on the flexural strength of heat-polymerized acrylic resins. The European journal of prosthodontics and restorative dentistry [Internet]. 2013 Sep;21(3):105–8. Available from: https://pubmed.ncbi.nlm.nih.gov/24261101/

[12]. Rodrigues SA, Nunez Pantoja JMC, Takahashi JMFK, Consani RLX, Mesquita MF. Effect of chemical cleaning agents on the flexural strength of acrylic and hard denture line resins. General dentistry [Internet]. 2013 Jul;61(4):e1-4. Available from: https://pubmed.ncbi.nlm.nih.gov/23823352/

[13]. Walczak K, Thiele J, Geisler D, Boening K, Wieckiewicz M. Effect of Chemical Disinfection on Chitosan Coated PMMA and PETG Surfaces—An In Vitro Study. Polymers. 2018 May 16;10(5):536.

[14]. Grzelak K, Łaszcz J, Polkowski J, Mastalski P, Kluczyński J, Łuszczek J, et al. Additive Manufacturing of Plastics Used for Protection against COVID19—The Influence of Chemical Disinfection by Alcohol on the Properties of ABS and PETG Polymers. Materials. 2021 Aug 25;14(17):4823.

[15]. Grzelak K, Łaszcz J, Polkowski J, Mastalski P, Kluczyński J, Łuszczek J, et al. Additive Manufacturing of Plastics Used for Protection against COVID19—The Influence of Chemical Disinfection by Alcohol on the Properties of ABS and PETG Polymers. Materials. 2021 Aug 25;14(17):4823

[16]. Yaseen YA, hassan I hazem. The effect of some disinfectant solution on the flexural strength of poly methyl methacrylate -Based Polymers [Internet]. www.ijdmsrjournal.com. 2022 [cited 2022]. Available from: www.ijdmsrjournal.com

[17]. Ehteshami A, Rashno M. Effects of Sodium Hypochlorite and Hydrochloric Acid on Hardness and Surface Roughness of Orthodontic Thermoplastic Retainers. Journal of Research in Dental and Maxillofacial Sciences. 2025 Mar 1;10(1):51–8.

[18]. Alkaltham N, Reem Aldhafiri, Al-Thobity AM, Alramadan H, Hussain Aljubran, Ijlal Shahrukh Ateeq, et al. Effect of Denture Disinfectants on the Mechanical Performance of 3D-Printed Denture Base Materials. Polymers. 2023 Feb 26;15(5):1175–5.

[19]. Poppolo Deus F, Ouanounou A. Chlorhexidine in Dentistry: Pharmacology, Uses, and Adverse Effects. International Dental Journal [Internet]. 2022 Mar;72(3). Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9275362/

[20]. Gadhave RV, Mahanwar PA, Gadekar PT. Effect of glutaraldehyde on thermal and mechanical properties of starch and polyvinyl alcohol blends. Designed Monomers and Polymers. 2019 Jan 1;22(1):164–70.