

**Original article**

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**Influence of custom tray type on the retentive properties of different impression materials**

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Retention of impression materials in custom trays is crucial for accurate transfer of oral morphology. The aim of this study was to compare the retention of alginate, zinc oxide eugenol paste, and condensation silicone in perforated and non-perforated custom trays, with and without spacing. Retention was measured using a dynamometer and expressed in Newtons (N). Statistical analysis included descriptive statistics, ANOVA, and Student's t-test (SPSS 30.0.0.0,  $p < 0.05$ ). A highly significant difference between materials was found regardless of tray design. Perforations significantly reduced the retention of zinc oxide eugenol paste (9.67 N vs. 6 N) and condensation silicone (13.00 N vs. 10.33 N), while alginate showed no significant difference (2.67 N in both groups). The results indicate that material type has the dominant influence on retention, while tray design has a material-specific effect. Condensation silicone demonstrated the highest retention, whereas alginate showed the lowest. Based on these findings, condensation silicone is recommended for routine clinical practice.

*Key words: retention, custom tray, perforation, adhesive*

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**Uticaj retentivnih sposobnosti različitih otisnih materijala u zavisnosti od vrste individualnih kašika**

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Retencija otisnih materijala u individualnim kašikama od ključnog je značaja za precizan prenos morfologije oralnih struktura. Cilj ovog istraživanja bio je da se uporedi retencija alginata, cink-oksida eugenol paste i kondenzacionog silikona u perforiranim i neperforiranim individualnim kašikama, sa i bez međuprostora. Retencija je merena dinamometrom i izražena u njutnima (N). Statistička analiza obuhvatila je deskriptivnu statistiku, ANOVA test i Studentov t-test (SPSS 30.0.0.0,  $p < 0,05$ ). Utvrđena je visoko statistički značajna razlika između materijala, nezavisno od dizajna kašike. Perforacije su značajno smanjile retenciju cink-oksida eugenol paste (9,67 N naspram 6 N) i kondenzacionog silikona (13,00 N naspram 10,33 N), dok kod alginata nije uočena statistički značajna razlika (2,67 N u obe grupe). Rezultati ukazuju da vrsta materijala ima dominantan uticaj na retenciju, dok dizajn kašike ima materijal-specifičan efekat. Kondenzacioni silikon pokazao je najveće vrednosti retencije, dok je alginat imao najmanje. Na osnovu dobijenih rezultata, kondenzacioni silikon se preporučuje za rutinsku kliničku praksu.

Ključne reči: *retencija, individualna kašika, perforacija, adheziv*

## Introduction

The accuracy of an impression, as a negative representation of the condition and morphology of oral tissues, represents a crucial step in the fabrication of prosthetic restorations. For taking a functional impression, which serves as the basis for the fabrication of a high-quality complete denture, a custom tray is used, fabricated from cold-polymerized acrylic resin on an anatomical model. Its role, in addition to shaping the borders of the future denture, includes controlling the thickness of the impression material, improving stability, and reducing deformation of the impression material (1, 2).

Retention of the impression material to the tray—defined as its ability to remain attached—is of particular importance, as it directly affects the accuracy of transferring oral morphology. Retention is influenced by tray design, the presence of perforations, and the presence or absence of spacing between the tray and tissues (3, 4, 5).

Retention represents the ability of the impression material to remain bonded to the tray during impression making and removal from the oral cavity. Insufficient retention may lead to separation of the material from the tray, impression deformation, and loss of accuracy. Retention mechanisms may be mechanical (perforations, surface roughness) or chemical (adhesives) (6, 7).

In non-perforated trays, retention of elastomeric materials, primarily low-viscosity condensation silicones, is mainly achieved through the use of adhesives. The advantages of this method include better control of material thickness and distribution, as well as a reduced risk of material deformation (8). On the other hand, disadvantages include dependence on proper adhesive application and the risk of impression separation if the adhesive is not evenly applied or adequately dried (8).

Perforations (openings or holes in the tray) enable mechanical retention of the impression material. The material flows through the openings and, upon setting, creates mechanical “locking.” The advantages of perforated trays include improved retention of the impression material, reduced risk of separation from the tray, and less dependence on proper adhesive application (9, 10). Disadvantages include the possibility of uncontrolled material extrusion, potential deformation of thin impression materials, and reduced control of material thickness if spacing is not present (9).

Spacing between the tray and tissues ensures uniform thickness of the impression material, which is crucial for dimensional stability. When present, it reduces internal stresses in the material and increases impression accuracy. In the absence of spacing, uneven material thickness, increased pressure on tissues, and possible deformation of the impression may occur (11).

Literature data indicate that the most favorable clinical results are achieved by combining spacing for thickness control and adhesives (in non-perforated trays) or carefully designed perforations. A perforated tray without spacing may lead to excessive material extrusion, while a non-perforated tray with spacing and adhesive provides optimal retention and accuracy (8, 11, 12).

On the other hand, when zinc oxide eugenol paste is used for impression taking, spacing and adhesives are not required, as the impression is mucostatic and the material achieves optimal impression quality at minimal thickness, adhering adequately to the acrylic surface. Therefore, this material represents the gold standard for functional impressions in complete denture fabrication using the conventional mucostatic technique (13, 14, 15).

The characteristics of custom trays for different types of materials used in functional impressions for complete denture fabrication are presented in Table 1.

Table 1. Optimal properties of custom trays for functional impressions of edentulous jaws

<b>Material</b>	<b>Perforations</b>	<b>Spacing</b>	<b>Key Note</b>
ALGINATE	Yes (mechanical retention).	Yes (2–3 mm). Without it, greater deformation occurs.	Perforations or adhesive required.
ZINC OXIDE-EUGENOL (ZOE)	No. Non-perforated tray.	No. Without spacing – ideal.	Thin layer; rigid material.
CONDENSATION SILICONE (C-silicone)	Optional. No perforations → adhesive required	Yes (1–2 mm). Without it, greater contraction occurs.	Mandatory adhesive.

The aim of the study was to compare the retention values of different impression materials (alginate, condensation silicone, and zinc oxide eugenol paste) in perforated and non-perforated custom trays, with and without spacing.

### **Materials and Methods**

In this study, the retention of three types of impression materials was measured:

- Alginate (Zhermack Alginat Hydrogum 5, Italy)
- Zinc oxide eugenol paste (Pentron Repin, USA)
- Condensation silicone (Xantopren Light Flow, Heraeus Kulzer, Germany)

Custom trays were fabricated on anatomical models of edentulous maxillae (Figure 1). The trays were made from cold-polymerized acrylic resin (Kulzer SR Ivocap Palavit, Heraeus Kulzer, Germany), and their total number and distribution according to the materials used are presented in Table 2.



**Figure 1.** Working model of an edentulous maxilla used in the study

Table 2. Number of custom trays fabricated according to the type of impression material used

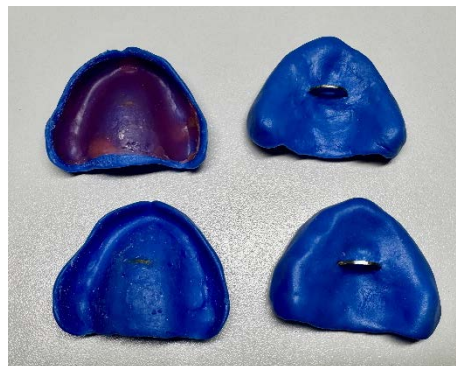
Type of material	Number of custom trays
Alginate	2 trays – with spacing, with and without perforations
Zinc oxide eugenol paste	2 trays – without spacing, with and without perforations
Condensation silicone	2 trays – with spacing, with and without perforations

In the central part of the palatal surface of each tray, a metal ring – an embedded eye hook (Figure 2) – was placed, serving as an anchor point for force measurement. A dynamometer (Figure 3) was used to precisely determine the retention force, with its hook attached to the ring on the tray. The procedure for measuring the retention force and the position of the dynamometer relative to the model during impression removal are shown in Figure 4. Values recorded on the dynamometer were expressed in grams (mass) and subsequently converted to Newtons (N), where approximately 100 g corresponds to 1 N

$$(1) F(N) = m(kg) \times 9,81 \quad (1).$$

$$F(N) = 0,1 \times 9,81 = \mathbf{0.98N}$$

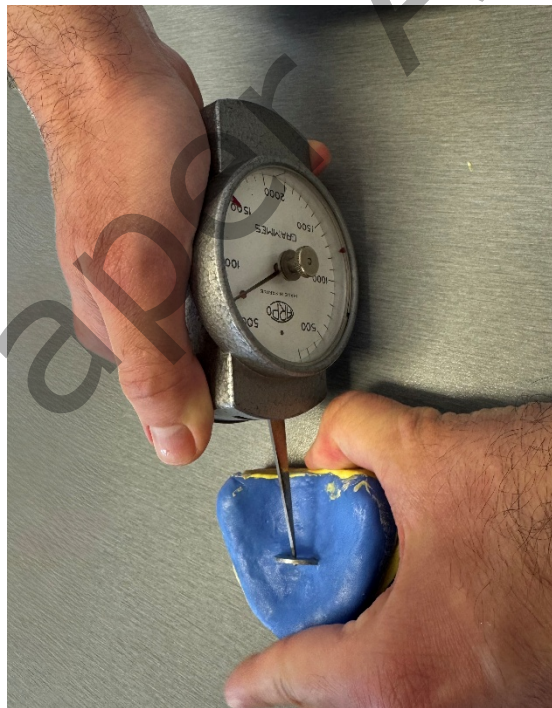
Each measurement was repeated three times to ensure the accuracy of the results obtained.



**Figure 2.** Individual acrylic trays with an embedded metal eye hook on the palatal side.



**Figure 3.** Digital dynamometer used for precise measurement of retention force (grams (g) converted to Newtons (N)).



**Figure 4.** Experimental setup and procedure for measuring force during impression removal from the model.

Perforations in the trays were made using a sharp steel round bur fixed in a micromotor handpiece (Figure 5). In the study, Sili Adhesive (Detax GmbH & Co. KG, Germany) was used in a thin layer. The drying time for the blue-transparent adhesive lasted a few minutes.



**Figure 5.** Preparation of perforations in the custom tray using a sharp steel round bur attached to a micromotor handpiece.

Comparison of the retention forces of different impression materials and differently fabricated custom trays is possible because clinically and literature-recommended methods for taking functional impressions were used (15, 16).

### **Statistical Analysis**

Data were analyzed using descriptive statistics, ANOVA for comparing differences between materials, and the independent samples Student's t-test to determine the effect of perforations on retention within the same material group. All calculations were performed using SPSS Statistics 30.0.0.0, with a significance level of  $p < 0.05$ .

### **Results**

In this study, the retention force of three different impression materials (alginate, zinc oxide eugenol paste, and condensation silicone) was measured in combination with perforated and non-perforated custom trays. The data obtained were analyzed using descriptive statistics (mean values and standard deviations), while the statistical significance of differences between the tested groups was assessed using ANOVA and t-tests.

### Descriptive Statistics of Results

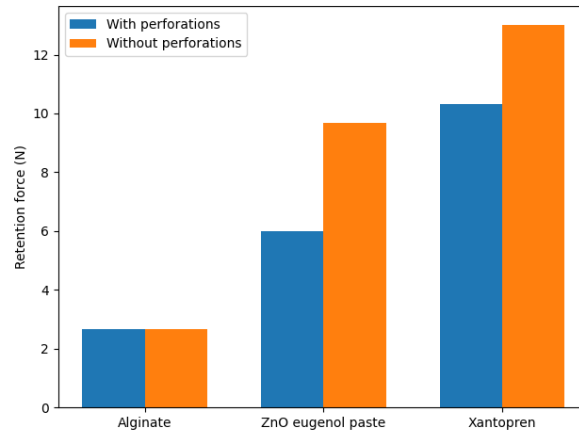
The mean values of impression removal force (N) and standard deviations for each group are presented in Table 3.

Table 3. Mean values ( $\bar{x}$ ) and standard deviations (SD) of retention force (N) for the tested groups

Material	Tray type	Measurement 1 (N)	Measurement 2 (N)	Measurement 3 (N)	Mean ( $\bar{x}$ )	SD
Alginate	With perforations and spacing	2	3	3	2.67	0.58
Alginate	Without perforations and with spacing	3	2	3	2.67	0.58
ZOE paste	With perforations and without spacing	7	6	5	6.00	1.0
ZOE paste	Without perforations and without spacing	10	8	11	9.67	1.53
Xantopren	With perforations and spacing	10	11	10	10.33	0.58
Xantopren	Without perforations and with spacing	12	13	14	13.00	1.0

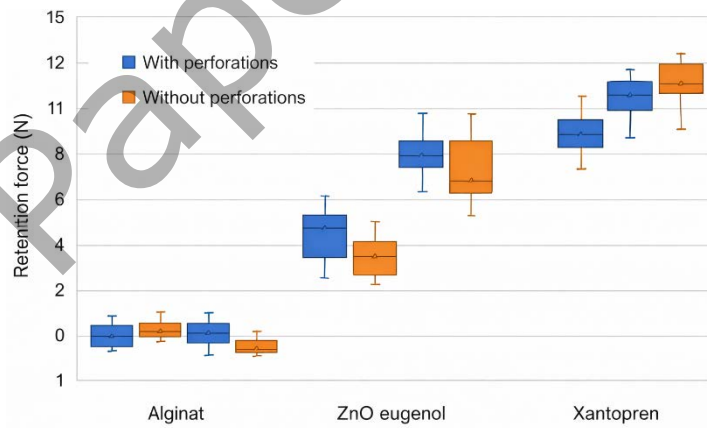
### Presentation of Results in Figures

Figure 6 shows the mean retention force (N) of the three tested impression materials depending on the presence of perforations in the custom trays.



**Figure 6.** Mean retention force of different impression materials.

The analysis showed that alginate exhibited the lowest and identical mean retention force values (2.67 N), regardless of the presence of perforations. For zinc oxide eugenol (ZOE) paste, significantly higher retention was observed in non-perforated trays (9.67 N) compared to perforated ones (6.00 N). Condensation silicone (Xantopren) achieved the highest retention values in both groups, with the maximum force of 13.00 N measured in non-perforated trays with adhesive, while in perforated trays it was 10.33 N.



**Figure 7.** Range and distribution of retention force measurements (N).

Figure 7 shows the range and distribution of individual retention force (N) measurements for each tested material and tray type.

The analysis of individual measurements, presented in Figure 7 (Box-plot), indicates varying degrees of variability depending on the material used and the type of tray. While alginate and Xantopren showed high measurement stability with minimal deviations—values for Xantopren in non-perforated trays ranged narrowly from 12 N to 14 N—the greatest variability was observed for zinc oxide eugenol paste in non-perforated trays, with a recorded range from 8 N to 11 N.

In addition to descriptive indicators, significance tests were applied to precisely determine differences between the tested groups. Using one-way analysis of variance (ANOVA), a highly statistically significant difference in retention force was found between alginate, zinc oxide eugenol paste, and condensation silicone ( $p < 0.05$ ), indicating that the type of material significantly influences the bond strength with the tray, independent of its design.

#### **Statistical Analysis of Significance (ANOVA and t-test)**

The effect of perforations within each material group was evaluated using the independent samples Student's t-test. For zinc oxide eugenol paste, a statistically significant difference ( $p < 0.05$ ) was observed in favor of non-perforated trays, which provided higher removal resistance (9.67 N) compared to perforated trays (6.00 N). A significant difference was also found for condensation silicone (Xantopren) ( $p < 0.05$ ), where non-perforated trays with adhesive achieved the highest retention value of 13.00 N. In contrast, alginate did not show a statistically significant difference between perforated and non-perforated trays ( $p > 0.05$ ), as the mean values in both groups remained identical (2.67 N).

#### **Discussion**

The retention of impression material in a custom tray depends on the presence of perforations, the existence of a spacer, and the type of impression material, i.e., its viscosity, elasticity, and adhesive properties (1, 11).

Alginate is a hydrophilic elastic material that exhibits weak chemical adhesion to acrylic custom trays. In order to achieve optimal reproduction properties, it must be present in a thickness of several millimeters, which necessitates the fabrication of a custom tray with a spacer. For this type of

material, mechanical retention is required, i.e., "locking" of the material after setting (17, 18). The results showed identical mean retention force values (2.67 N) regardless of the presence of perforations, which were lower compared to the other two tested materials.

Zinc oxide eugenol paste is a non-elastic and rigid material, which makes it prone to fracture during removal; therefore, perforations are not recommended. For this type of material, trays without spacers are used, since minimal material thickness reduces distortion (15, 19). In this study, trays with and without perforations in the palatal region were used, and significantly higher retention was recorded in non-perforated trays (9.67 N) compared to perforated ones (6 N).

Regarding condensation silicone of low viscosity, it is elastic, hydrophobic, and requires chemical adhesion (adhesive). The results showed a retention value of 13 N. On the other hand, when retention was mechanical, i.e., when perforated trays were used, the values were 10.33 N. In both cases, custom trays with spacers were used, allowing uniform thickness and reducing polymerization stresses. A tray without a spacer would lead to silicone contraction and distortion (9, 20).

Studies by various authors have shown that adhesives provide better retention than mechanical perforations, both in cold-cured and light-cured acrylic custom trays, which are increasingly used (21, 22). Light-cured acrylic trays with perforations provide superior tensile bond strength. Perforations improve retention more than grooves, indicating that tray material and surface design significantly affect impression accuracy (23).

The bond strength of addition silicones to cold-cured acrylic using adhesive agents is higher compared to condensation silicones (24, 25). *Patil et al.* reported the advantage of combining mechanical and chemical retention when using silicones and light-cured custom trays (26).

The retention of impression material to a custom tray depends on tray design, the presence of perforations, and spacers. Although perforations increase mechanical retention, control of material thickness and the use of adhesives play a key role in maintaining dimensional stability of the impression. In modern prosthodontic practice, preference is given to custom trays with spacers and properly applied adhesives, with selective use of perforations depending on the type of impression material.

## Conclusion

Alginate showed the lowest and consistent retention (2.67 N), regardless of perforations. Zinc oxide eugenol paste demonstrated higher retention values in non-perforated trays (9.67 N) compared to perforated ones (6.00 N). Condensation silicone (Xantopren) achieved the highest retention in both groups, particularly in non-perforated trays with adhesive (13.00 N), while in perforated trays it was 10.33 N. Overall, condensation silicone exhibited the best retention, whereas alginate showed the lowest, which may have important implications for their clinical application.

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## References

1. Regis RR, Alves CC, Rocha SS, Negreiros WA, Freitas-Pontes KM. The importance of a two-step impression procedure for complete denture fabrication: a systematic review of the literature. *J Oral Rehabil*. 2016;43(10):771-7. doi: 10.1111/joor.12418.
2. Duncan JP, Taylor TD. Simplified complete dentures. *Dent Clin North Am*. 2004 Jul;48(3):625-40, vi. doi: 10.1016/j.cden.2004.03.007. PMID: 15261797.
3. Jo A, Kanazawa M, Sato Y, Iwaki M, Akiba N, Minakuchi S. A randomized controlled trial of the different impression methods for the complete denture fabrication: Patient reported outcomes. *J Dent*. 2015;43(8):989-96. doi: 10.1016/j.jdent.2015.05.007.
4. Walters RA, Spurrier S. An effect of tray design and material retention on the linear dimensional changes in polysulfide impressions. *J Prosthet Dent*. 1990 Mar;63(3):277-81. doi: 10.1016/0022-3913(90)90194-h. PMID: 2407824.
5. Ansari AS, Alsaidan MA, Algadhi SK, Alrasheed MA, Al Talib IG, Alsaaid AK, Ansari SH. Impression materials and techniques used in fixed prosthodontics: A questionnaire-based survey to evaluate the knowledge and practice of dental students in Riyadh city. *J Family Med Prim Care*. 2021 Jan;10(1):514-520. doi: 10.4103/jfmpc.jfmpc\_2094\_20. Epub 2021 Jan 19. PMID: 34017780; PMCID: PMC8132772.
6. Felton DA, Cooper LF, Scurria MS. Predictable impression procedures for complete dentures. *Dent Clin North Am*. 1996;40(1):39-51.
7. Figueiral MH, Fonseca PA, Pereira-Leite C, Scully C. The effect of different adhesive materials on retention of maxillary complete dentures. *Int J Prosthodont*. 2011 Mar-Apr;24(2):175-7. PMID: 21479288.
8. Nishigawa G, Maruo Y, Irie M, Oka M, Tamada Y, Minagi S. New theoretical model to measure pressure produced during impression procedure for complete dentures-Visual inspection of impression material flow. *Dent Mater*. 2013;29(5):530-4. doi: 10.1016/j.dental.2013.02.005.
9. Carlsson GE, Ortorp A, Omar R. What is the evidence base for the efficacies of different complete denture impression procedures? A critical review. *J Dent*. 2013;41(1):17-23. doi: 10.1016/j.jdent.2012.11.015.

10. Ender A, Mehl A. Accuracy of complete-arch dental impressions: A new method of measuring trueness and precision. *J Prosthet Dent*. 2013;109(2):121–128. doi:10.1016/S0022-3913(13)60028-1.
11. Mehra M, Vahidi F, Berg RW. A complete denture impression technique survey of postdoctoral prosthodontic programs in the United States. *J Prosthodont*. 2014;23(4):320-7. doi: 10.1111/jopr.12099.
12. Petrie CS, Walker MP, Williams K. A survey of U.S. prosthodontists and dental schools on the current materials and methods for final impressions for complete denture prosthodontics. *J Prosthodont*. 2005 Dec;14(4):253-62. doi: 10.1111/j.1532-849X.2005.00051.x. PMID: 16359482.
13. Jayaraman S, Singh BP, Ramanathan B, Pazhaniappan Pillai M, MacDonald L, Kirubakaran R. Final-impression techniques and materials for making complete and removable partial dentures. *Cochrane Database Syst Rev*. 2018 Apr 4;4(4):CD012256. doi: 10.1002/14651858.CD012256.pub2. PMID: 29617037; PMCID: PMC6494560.
14. Aslan YU, Özkan YK. Impression material selection according to the impression technique. In: Özkan Y, editor. *Complete Denture Prosthodontics*. Cham: Springer; 2018. p. 45–58. doi:10.1007/978-3-319-69032-2\_4.
15. Chandak AH, Deshmukh SP, Radke UM, Banerjee RS, Mowade TK, Rathi A. An *In Vitro* Study to Evaluate and Compare the Flow Property of Different Commercially Available Zinc Oxide Eugenol Impression Materials. *Contemp Clin Dent*. 2018;9(Suppl 1):S137-S141. doi: 10.4103/ccd.ccd\_155\_18.
16. Komiyama O, Saeki H, Kawara M, Kobayashi K, Otake S. Effects of relief space and escape holes on pressure characteristics of maxillary edentulous impressions. *J Prosthet Dent*. 2004 Jun;91(6):570-6. doi: 10.1016/j.prosdent.2004.03.020,
17. Walsh JF. Alginate impression materials. *Orthodontist*. 1971 Autumn;3(2):65-7. PMID: 5291502.- Rehberg HJ. Das Alginat-Abformmaterial. *Verarbeitung und klinische Einsatzmöglichkeiten* .Alginate as an impression material. Preparation and clinical use]. *Zahnärztl Mitt*. 1980 Apr 16; 70(8):470-7.
18. Parameshwari G, Chittaranjan B, Sudhir N, Anulekha-Avinash CK, Taruna M, Ramureddy M. Evaluation of accuracy of various impression techniques and impression materials in recording

- multiple implants placed unilaterally in a partially edentulous mandible- An in vitro study. *J Clin Exp Dent*. 2018 Apr 1;10(4):e388-e395. doi: 10.4317/jced.54726. PMID: 29750102; PMCID: PMC5937963.
19. Al-Harbi FA, Ayad NM, Saber MA, ArRejaie AS, Morgano SM. Mechanical behavior and color change of facial prosthetic elastomers after outdoor weathering in a hot and humid climate. *J Prosthet Dent*. 2015 Feb;113(2):146-51. doi: 10.1016/j.prosdent.2014.09.008. Epub 2014 Nov 18. PMID: 25455267.
20. Albuquerque IS, Regis RR, de Souza RF, Gurgel KF, Silva PG, Pinto-Fiamengui LMS, Freitas-Pontes KM. Is a two-step impression mandatory for complete denture fabrication on the severely resorbed mandible? A randomized trial on patient perception and denture quality. *J Dent*. 2020;98:103356. doi: 10.1016/j.jdent.2020.103356.
21. Kumar S, Gandhi UV, Banerjee S. An in vitro study of the bond strength of five adhesives used for vinyl polysiloxane impression materials and tray materials. *J Indian Prosthodont Soc*. 2014;14(1):61-6. doi: 10.1007/s13191-012-0243-5.
22. Marafie Y, Looney S, Nelson S, Chan D, Browning W, Rueggeberg F. Retention strength of impression materials to a tray material using different adhesive methods: an in vitro study. *J Prosthet Dent*. 2008 Dec;100(6):432-40. doi: 10.1016/S0022-3913(08)60260-7. PMID: 19033027.
23. Naidu S, Dhawan P, Raman S. Improving the Accuracy of Dental Impressions: A Study of Tray Adjustments and Materials. *Eur J Prosthodont Restor Dent*. 2025 Feb 28;33(1):49-56. doi: 10.1922/EJPRD\_2824Naidu08.
24. Özcan B, Özcivelek T. Bond strength of maxillofacial silicone to various three-dimensional printing resins compared to conventional substructures. *BMC Oral Health*. 2025;25:1425. doi:10.1186/s12903-025-06854-x.
25. Kambiranda SC, Pinto B, Elpatal MA, Sam G, Chaitra AS, Rani RP. Evaluation of the Bond Strength of Universal Tray Adhesives on Silicone Impression Materials Using an Acrylic Tray. *J Contemp Dent Pract*. 2019;20(12):1406-1411.
26. Patil RV, Vijayraghavan V, Jadhav M, Jajoo S, Desai S, Jagtap C. Comparison of Tensile Bond Strength of Addition Silicone with Different Custom Tray Materials Using Different Retentive Methods. *J Contemp Dent Pract*. 2021 Mar 1;22(3):278-283.

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