Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/c3t3xb60

IN VITRO STUDY TO EVALUATE FATIGUE RESISTANCE OF VARIOUS IMPLANT OVERDENTURE STUD ATTACHMENTS WITH VARIOUS DENTURE BASE MATERIALS

Dr. Paawan Sharma[1], Dr. Anuj Kishor Shukla[2*], Dr. Varun Sachan[3*], Dr. Apoorva Sharma[4*]

[1]PG student, Department of Prosthodontics and Crown & Bridge, BRS Dental College and hospital , Panchkula. Email paawan1713@gmail.com
[2]Assistant Professor, Department of Prosthodontics Crown and Bridge, Institute of Dental Sciences, Bareilly. anujkishor7@gmail.com
[3*]Senior lecturer, Department of Prosthodontics and Crown & Bridge , Saraswati Dental College and Hospitals, Lucknow. Email- dr.varunsachan@gmail.com
[4]Senior Lecturer, Department of Conservative Dentistry and Endodontics, Triveni Institute of Dental Sciences, Hospital & Research Centre Bodri, Chhattisgarh. Drapoorva03@gmail.com

***Corresponding Author:** Dr. Varun Sachan
*Senior Lecturer, Department Of Prosthodontics And Crown & Bridge , Saraswati Dental College And Hospitals, Lucknow. Email- Dr.Varunsachan@Gmail.Com

Abstract

Background: The long-term success of implant-supported overdentures depends significantly on the mechanical durability of the attachment system and the compatibility of the denture base materials. Stud attachments like Locator, Ball, and ERA are commonly used, each interacting differently with acrylic resins and high-performance polymers.

Objective: This in vitro study aimed to evaluate and compare the fatigue resistance of various stud attachments—Locator, Ball, and ERA—when combined with different denture base materials: heat-cured polymethyl methacrylate (PMMA), injection-molded PMMA, and polyetheretherketone (PEEK).

Methods: A total of 90 test specimens were divided into nine groups (n = 10 each) based on attachment type and denture base material. Each specimen underwent cyclic insertion and removal testing up to 10,000 cycles to simulate 5 years of clinical use. Fatigue resistance was measured by retention force before and after cycling, using a universal testing machine.

Results: Before cycling, Locator attachments demonstrated the highest mean initial retention force (22.5 ± 1.3 N), while Ball attachments showed the lowest (14.7 ± 1.8 N). After 10,000 cycles, PEEK-based dentures retained significantly more force (18.6 ± 1.2 N) than heat-cured PMMA (12.1 ± 1.5 N) ($p < 0.01$). Locator-PEEK combinations showed the highest post-cycle retention (20.4 ± 0.9 N), followed by ERA-injection PMMA (17.2 ± 1.1 N).

Conclusion: Locator attachments combined with PEEK denture bases exhibited superior fatigue resistance. Material selection for denture bases significantly affects long-term retention, emphasizing the importance of attachment-base compatibility for implant overdentures.

Introduction

Implant-supported overdentures have revolutionized prosthodontic rehabilitation, especially for edentulous patients who require improved retention, stability, and function [1]. Among the different attachment systems available, stud attachments such as Ball, Locator, and ERA are widely used due to their simplicity and clinical effectiveness [2]. However, their performance over time is influenced not only by their mechanical design but also by the properties of the denture base material into which they are embedded [3].

Fatigue resistance, defined as the ability of a material or attachment system to withstand repetitive loading and unloading, plays a critical role in the longevity and effectiveness of overdenture prostheses [4]. Frequent insertion and removal of dentures generate cyclic forces that may degrade the attachment's retentive properties and compromise the overall prosthesis performance [5].

Traditional denture bases are typically fabricated from heat-polymerized polymethyl methacrylate (PMMA), known for its ease of processing and biocompatibility. However, its mechanical limitations, such as low fatigue resistance and high water sorption, have led to the exploration of alternative materials, including injection-molded PMMA and high-performance polymers like polyetheretherketone (PEEK) [6], [7]. These new materials offer promising mechanical advantages, but their interaction with stud attachments remains under-researched.

Previous studies have investigated the retention of individual attachments or the wear of materials independently [8], [9], but comparative assessments of various stud attachments across different base materials in terms of fatigue resistance are limited. Thus, there exists a research gap regarding the optimal attachment-base combination for clinical durability.

This in vitro study aimed to evaluate the fatigue resistance of three commonly used implant overdenture stud attachments—Locator, Ball, and ERA—when used with three different denture base materials: heat-cured PMMA, injection-molded PMMA, and PEEK. The null hypothesis was that there would be no difference in fatigue resistance among different attachment-base combinations.

Materials and Methods

Study Design and Groups:

Ninety specimens were fabricated and divided into nine groups (n = 10) based on the combination of three stud attachments (Locator, Ball, ERA) and three denture base materials (heat-cured PMMA, injection-molded PMMA, PEEK).

Attachment Systems:

Commercially available attachment systems were used:

- Locator (Zest Anchors Inc.)
- Ball (Straumann)
- ERA (Sterngold)

Denture Base Materials:

- Heat-cured PMMA (DPI Heat Cure, India)
- Injection-molded PMMA (Ivocap High Impact, Ivoclar)
- PEEK discs (BioHPP, Bredent)

Specimen Preparation:

Each attachment system was embedded into its respective base material using standardized cylindrical molds (20 mm diameter, 10 mm height). Metal housings were embedded following the manufacturer's recommendations. All specimens were stored in distilled water at 37°C for 24 hours before testing.

Fatigue Testing Protocol:
Specimens were subjected to 10,000 insertion-removal cycles using a custom-built fatigue simulator. The cyclic movement mimicked clinical wear equivalent to 5 years of denture usage. Pre- and post-fatigue retention force was measured using a universal testing machine at 50 mm/min.

Data Collection and Analysis:
Initial and final retention forces were recorded. Mean ± standard deviation (SD) was calculated for each group. Statistical analysis was performed using two-way ANOVA to assess interaction effects between attachment types and base materials, with a significance threshold of $p < 0.05$. Post-hoc Tukey's test was applied for intergroup comparisons.

Results

Pre-Cycle Retention Force:
Before cyclic loading, Locator attachments had the highest mean retention force (22.5 ± 1.3 N), followed by ERA (18.1 ± 1.0 N) and Ball (14.7 ± 1.8 N).

Post-Cycle Retention Force:
Retention forces declined in all groups after 10,000 cycles. However, significant differences were observed among the base materials and attachment types.

Table 1. Post-cycle retention force (mean ± SD, in N)

Attachment Type	Heat-Cured PMMA	Injection PMMA	PEEK
Locator	14.8 ± 1.1	18.6 ± 1.2	**20.4 ± 0.9**
Ball	10.2 ± 1.5	13.7 ± 1.3	16.8 ± 1.0
ERA	11.4 ± 1.2	17.2 ± 1.1	18.7 ± 0.8

Statistical Findings:
Two-way ANOVA showed significant effects of both attachment type ($p < 0.001$) and denture base material ($p < 0.001$) on retention force. Interaction between the two variables was also statistically significant ($p = 0.004$).
Post-hoc analysis revealed that Locator-PEEK combinations had significantly higher retention than all other groups ($p < 0.05$). Heat-cured PMMA groups exhibited the lowest overall retention.

Discussion

The present study aimed to investigate the fatigue resistance of various stud attachments in conjunction with different denture base materials. Our findings demonstrate that both the type of attachment and the denture base material significantly affect long-term retention.
Locator attachments consistently outperformed Ball and ERA attachments in both initial and post-fatigue testing, aligning with previous findings that highlight their superior design and dual retention mechanism [10]. ERA attachments also demonstrated strong fatigue resistance, particularly when paired with injection-molded PMMA and PEEK.
PEEK emerged as the most durable denture base material, with significantly less loss in retention after cyclic loading compared to PMMA variants. Its high elastic modulus and wear resistance likely contribute to better preservation of attachment-retaining interfaces [11], [12]. These findings support growing evidence of PEEK's potential in prosthodontics as a high-performance material [13].
Comparing our results with studies by Bayer et al. [14] and Elsyad et al. [15], who noted degradation of Ball and Locator systems in PMMA bases, confirms the importance of base material selection. Our data suggest that injection-molded PMMA also offers better fatigue resistance than heat-cured PMMA, possibly due to enhanced polymer cross-linking and homogeneity [16].

One limitation of this study is the in vitro setting, which does not perfectly replicate oral conditions. Thermal cycling, mastication forces, and patient-specific habits could further affect attachment longevity [17]. Future research should consider aging protocols and clinical validation.

Conclusion

This in vitro study demonstrated that fatigue resistance of implant overdenture stud attachments is significantly influenced by both the type of attachment and the denture base material. Locator attachments showed the highest retention post-fatigue, especially when used with PEEK bases. These findings suggest that clinicians should consider material compatibility to enhance long-term overdenture success.

References

1. Thomason JM, Kelly SA, Bendkowski A, Ellis JS. Two implant retained overdentures—a review of the literature supporting the McGill and York consensus statements. J Dent. 2012;40(1):22–34. doi:10.1016/j.jdent.2011.12.003
2. Al-Ghafli SA, Michalakis KX, Hirayama H, Kang K. Attachment systems for implant retained overdentures: a literature review. Implant Dent. 2009;18(2):95–102. doi:10.1097/ID.0b013e318198cf3b
3. Williams RJ, Ochiai KT, Hojo S, Nishimura R, Caputo AA. Retention of maxillary implant overdenture bars of different designs. J Prosthet Dent. 2001;86(6):603–607. doi:10.1067/mpr.2001.119439
4. Cheng T, Liu Y, Wang R, Gao X, Wright RF, Ma Y. Maxillary implant overdentures with different bar designs: a 3-year randomized clinical trial. Clin Oral Implants Res. 2012;23(9):1055–1061. doi:10.1111/j.1600-0501.2011.02390.x
5. Krennmair G, Seemann R, Weinländer M, Piehslinger E. Influence of attachment type on the clinical outcome of mandibular overdentures supported by two implants. Clin Oral Implants Res. 2011;22(10):1034–1039. doi:10.1111/j.1600-0501.2010.02085.x
6. Mengatto CM, Montagner A, Soares FZ, et al. Bond strength of different adhesive systems to PEEK: a systematic review. J Prosthet Dent. 2021;125(5):839.e1–839.e9. doi:10.1016/j.prosdent.2020.06.018
7. Schwitalla AD, Müller WD. PEEK dental implants: a review of the literature. J Oral Implantol. 2013;39(6):743–749. doi:10.1563/AAID-JOI-D-11-00102
8. Sadig WM. A comparative in vitro study on the retention and stability of implant-supported overdentures. Quintessence Int. 2009;40(4):313–319. PMID: 19417884
9. Naert I, Alsaadi G, Quirynen M. Prosthetic aspects and patient satisfaction with two-implant-retained overdentures: a 10-year randomized clinical study. Int J Prosthodont. 2004;17(4):401–410. PMID: 15382779
10. Varghese PK, Ramesh S, Rajapur A, Issrani R, Shrikar H. Retentive capacity of different attachment systems for mandibular overdenture: an in vitro study. J Contemp Dent Pract. 2019;20(9):1063–1067. doi:10.5005/jp-journals-10024-2642
11. Spazzin AO, Silva LHD, Guimaraes JG, Meira JB. Flexural strength of indirect composite resins and effect of thermomechanical aging. J Appl Oral Sci. 2009;17(6):595–600. doi:10.1590/S1678-77572009000600012
12. Kurtz SM, Devine JN. PEEK biomaterials in trauma, orthopedic, and spinal implants. Biomaterials. 2007;28(32):4845–4869. doi:10.1016/j.biomaterials.2007.07.013
13. Tannous F, Steiner M, Shahin R, Kern M. Retentive forces and fatigue resistance of thermoplastic resin clasps. Dent Mater. 2012;28(3):273–278. doi:10.1016/j.dental.2011.11.018
14. Bayer G, Stark H, Eckert SE, Heinemann F. Retention force of different attachment systems for implant overdentures: an in vitro study. J Prosthet Dent. 2010;103(4):216–222. doi:10.1016/S0022-3913(10)60034-6

15. Elsyad MA, Khirallah AS, Faramawy AG. The influence of different implant overdenture attachments on stress distribution: a finite element study. J Prosthodont. 2017;26(2):95–101. doi:10.1111/jopr.12371
16. Vallittu PK. Flexural properties of acrylic resin polymers reinforced with unidirectional and woven glass fibers. J Prosthet Dent. 1999;81(3):318–326. doi:10.1016/S0022-3913(99)70279-6
17. Cakarer S, Can T, Yaltirik M, Keskin C. Complications associated with the ball, bar and locator attachments for implant-supported overdentures. Med Oral Patol Oral Cir Bucal. 2011;16(7):e953–e959. doi:10.4317/medoral.17312