Brazilian Dental Science

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UNIVERSIDADE ESTADUAL PAULISTA
"JÚLIO DE MESQUITA FILHO"
Instituto de Ciência e Tecnologia
Campus de São José dos Campos

ORIGINAL ARTICLE

DOI: https://doi.org/10.4322/bds.2025.e4609

Wear of two different attachment systems in implant supported mandibular overdentures: a clinical comparative study

Desgaste de dois sistemas de attachments diferentes em overdentures mandibulares suportadas por implantes: um estudo clínico comparativo

Ammar Omar BELAL[1], **Moataz Mostafa Bahgat ELMAHDY**[1], **Sayed Mohammed Mohammed ELMASRY**[1], **Mohamed Ezzat ELSAYED**[1]

1 - Suez Canal University, Faculty of Dentistry, Prosthetic Dentistry, Ismailia, Egypt.

How to cite: Belal AO, Elmahdy MMB, Elmasry SMM, Elsayed ME. Wear of two different attachment systems in implant supported mandibular overdentures: a clinical comparative study. Braz Dent Sci. 2025;28(1):e4609. https://doi.org/10.4322/bds.2025.e4609

ABSTRACT

Introduction: The stud attachment is regarded as one of the most popular systems for the retention of removable overdentures. A new type of PEEK attachment system, such as Novaloc, may have a good prognosis compared to other systems. **Aim of the study:** The purpose of this clinical study is to compare two different attachment systems, Novaloc and Locator, regarding wear resistance under implant-supported overdentures. **Material and Methods:** The research sample consisted of 10 patients with complete lower and upper edentulous. A complete lower denture was made supported by two implants, with a conventional complete denture for each patient. The patients were divided equally into Group 1: Novaloc attachment system. Group 2: Locator attachment system. The wear measurements were done using a digital stereomicroscope and repeated after 4, 8, and 12 months. The data was collected, calculated, and statistically analyzed using the SPSS program. **Results:** According to One-way ANOVAs and independent T-test and throughout the observation period (P-Value > 0.05). The results showed the presence of wear in both attachment systems, but with statistically significant differences, as the amount of wear was greater in the Locator group compared to the Novaloc group. **Conclusion:** Under the circumstances of this study, it can be concluded that the Novaloc attachment system is superior to the Locator in terms of its resistance to wear during the observation period of 1 year when compared to the Locator system.

KEYWORDS

Attachments; Locator; Novaloc; Nylon; Overdenture; PEEK; Wear.

RESUMO

Introdução: A fixação por Attachments é considerada como um dos sistemas mais populares para a retenção de overdentures removíveis. Um novo tipo de sistema de fixação PEEK, como o Novaloc, pode ter um bom prognóstico em comparação com outros sistemas. **Objetivo do estudo:** O objetivo deste estudo clínico é comparar dois sistemas de Attachments diferentes, Novaloc e Locator, com relação à resistência ao desgaste sob overdentures suportadas por implantes. **Material e Métodos:** A amostra da investigação foi constituída por 10 pacientes desdentados totais inferiores e superiores. Foi realizada uma prótese total inferior suportada por dois implantes, e uma prótese total convencional para cada paciente. Os pacientes foram divididos igualmente em Grupo 1: Sistema de fixação Novaloc. Grupo 2: Sistema de fixação Locator. As medições de desgaste foram efetuadas utilizando um estereomicroscópio digital e repetidas após 4, 8 e 12 meses. Os dados foram recolhidos, calculados e analisados estatisticamente utilizando o programa SPSS. **Resultados:** De acordo com as ANOVAs One-way e o teste T independente ao longo do período de observação (p-valor > 0,05). Os resultados mostraram a presença de desgaste em ambos os sistemas de fixação, mas com diferenças estatisticamente significativas, pois a quantidade de desgaste foi maior no grupo Locator em relação ao grupo Novaloc. **Conclusão:** Nas circunstâncias deste estudo, pode-se concluir que o sistema

de fixação Novaloc é superior ao Locator em termos da sua resistência ao desgaste durante o período de observação de 1 ano, quando comparado com o sistema Locator.

PALAVRAS-CHAVE

Encaixes de precisão; Nylon; Sobredentadura; Desgaste de restauração dental; Implantes dentários.

INTRODUCTION

Retention and stability are important factors in the successful fabrication of a complete denture [1,2]. Today implant-supported mandibular overdentures retained by two implants with unpainted systems (ring-ball-cylindrical types) or splinted systems (bar attachment) associated with a maxillary complete denture have been proposed as the first choice of treatment for edentulous patients [3], and this treatment seeks to provide better stability and retention of the mandibular complete denture, thus improving the masticatory function of the patient and providing greater satisfaction, better oral health-related quality of life and comfort, therefore, knowledge of the different attachment systems and an understanding of their mechanical properties, such as retention and load distribution, could help clinicians select the proper attachment for each case [4,5]. The cylindrical attachment systems, which were made from PEEK material, such as the Novaloc or nylon systems like the Locator, were created to address specific indications, such as smaller prosthesis spaces, because of their improved retention and smaller size [6,7]. Due to its improved dual retention over the last two decades, the locator has become the most cylindrical type with the lowest profile height. The matrix is composed of a polyethylene retention device and a 1.2 mm internal retention pin that can withstand an 8-degree maximum angulation in all directions [8-10]. But like any mechanical equipment, the locator will inevitably develop more mechanical issues with time. The male nylon inserts of the locator attachment have been seen to wear out excessively and demand more maintenance over time, which has resulted in a loss of retention [11]. On the other hand, the Novaloc retention device is placed in titanium or Poly-ether-ether-ketone (PEEK) casings and is constructed of PEEK to increase wear resistance, which revealed encouraging findings in a few in vitro studies of the long-term retention of peek retention devices [12-14]. To date of this article, there are not many clinical studies comparing these two types, although there was a study by Abdelaziz et al. 2021 [15] which compares the PEEK and nylon insert in the locator system only. Therefore, to reduce this gap in existing literature, this clinical study was conducted to assess these two different attachment systems, Novaloc and Locator, regarding wear resistance under implant-supported overdentures.

MATERIALS AND METHODS

This clinical research was a case-controlled trial. It was made at the Department of Prosthetics Dentistry at the Faculty of Dentistry at Suez Canal University, after the Scientific Research Ethics Committee with code number: 2021-40.

The research sample consisted of ten complete edentulous patients. The sample size was calculated using Open-Epi version 3.01 (Emory University, USA) at a confidence interval of 95% with one ratio to compare equal groups.

The patients were selected randomly without regard to gender or age. All the patients had good oral and physical health and were accepted based on the following inclusion criteria: all patients had maxillary and mandibular alveolar ridges covered with healthy tissue, Sufficient mandibular alveolar bone confirmed by CBCT, six months at the last extraction, and sufficient inter-jaw space, which was confirmed using the putty index technique. Exclusion criteria were parafunctional habits, alcoholism, a history of radiation therapy in the head and neck region or temporomandibular joint disorders, and systemic diseases that can affect the success of implants.

After explaining the work and study steps to the patients and obtaining their approval through consent. A conventional acrylic complete upper and lower removable denture was produced using the standard procedures that are recognized in the academic community. Primary upper and lower impressions were taken as part of the process, and a final impression was taken using cold acrylic cured trays after border molding to create the wash impression. The jaw relation was

then registered using record bases, artificial teeth were arranged, try-ins were made, dentures were waxed up, flasking procedures were made, and the outcome was made in the patient's mouth with any modifications that were required for the dentures.

After that, the patients were divided equally into: Group 1: Novaloc attachment system. Group 2: Locator attachment system.

A flapless implant placement approach and conventional loading were intended. Therefore, a surgical guide was made using the CAD-CAM to guarantee the implant's accurate placement and orientation in the canine area (Figure 1).

Each patient received two bone Straumann implants (Straumann Dental Implant System, Switzerland), which were 3.3 mm in diameter and 13 mm in length. (Figure 2). After three months, and according to the conventional loading protocol to ensure that the implants can be loaded. Implants were assessed clinically, showing no signs of pain or inflammation, and a radiograph image demonstrated no bone resorption around the implants. After that, implants were exposed, and mounting of the implant system smart peg. The resonance frequency analysis system (Mega ISQ System, South Korea) was used to evaluate the secondary stability and readiness to be loaded based on scientific recommendations.

After that, both Novaloc (Straumann, Möhlin, Switzerland) and Locator (Zest Anchors, Escondido, USA) were placed in the implants and tightened using the driver for each attachment and tightened using the torque ratchet wrench according to the manufacturer's instructions (30 Newton). For all patients, the direct pick-up method was applied to incorporate Novaloc retention inserts and Locator retention replacement males (Figure 3).

Wear measurements were done immediately after the placement of the dentures at the Faculty of Agriculture at Mansoura University, utilizing a professional camera (10MP Tucsen

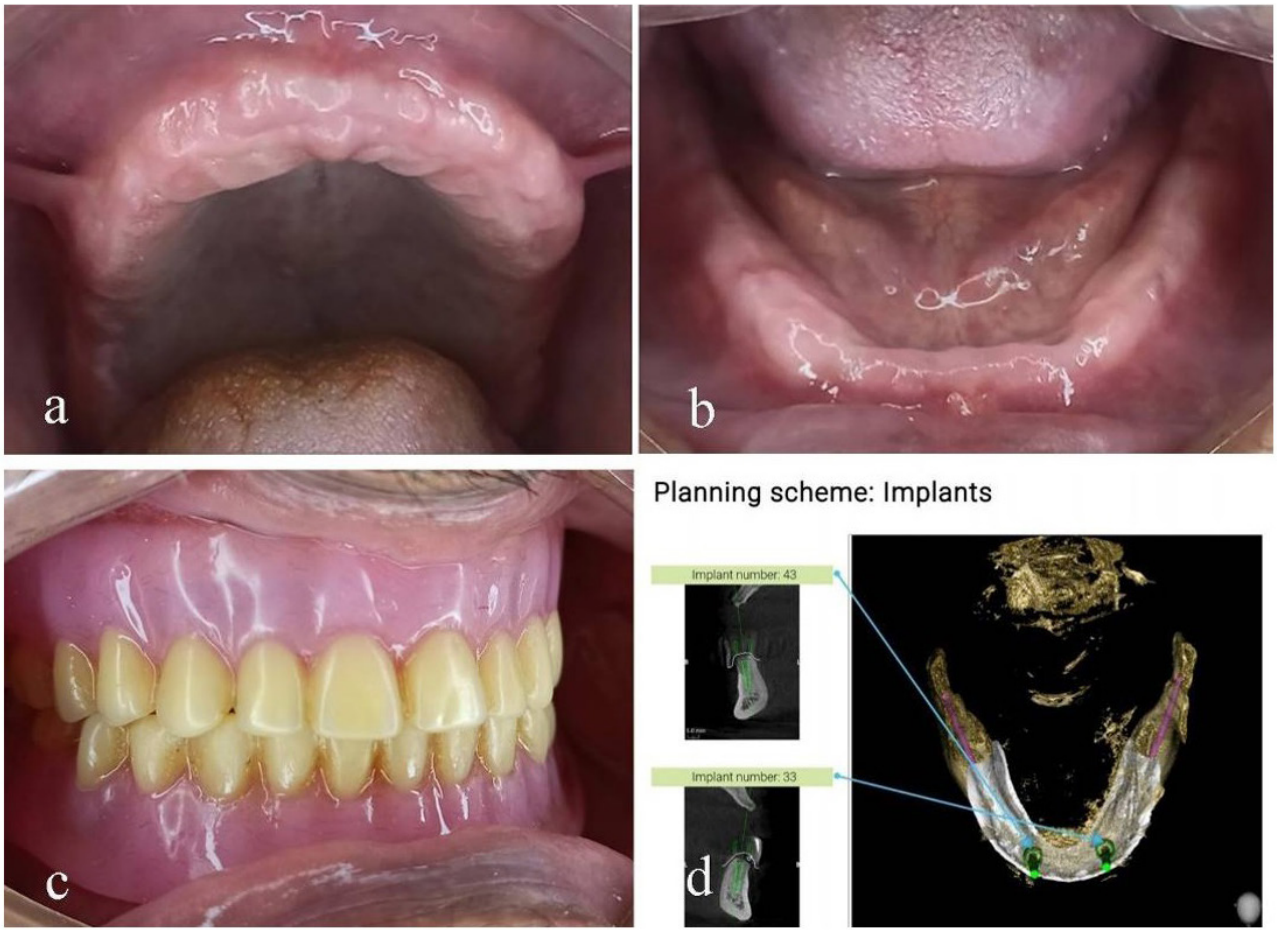

Figure 1. (a) Intraoral view of the upper jaw. (b) Intraoral view of the lower jaw. (c) Conventional Complete denture. (d): surgical guide design with parallel axes.

Figure 2. (a) Check parallelism. (b) Straumann Dental Implant System.

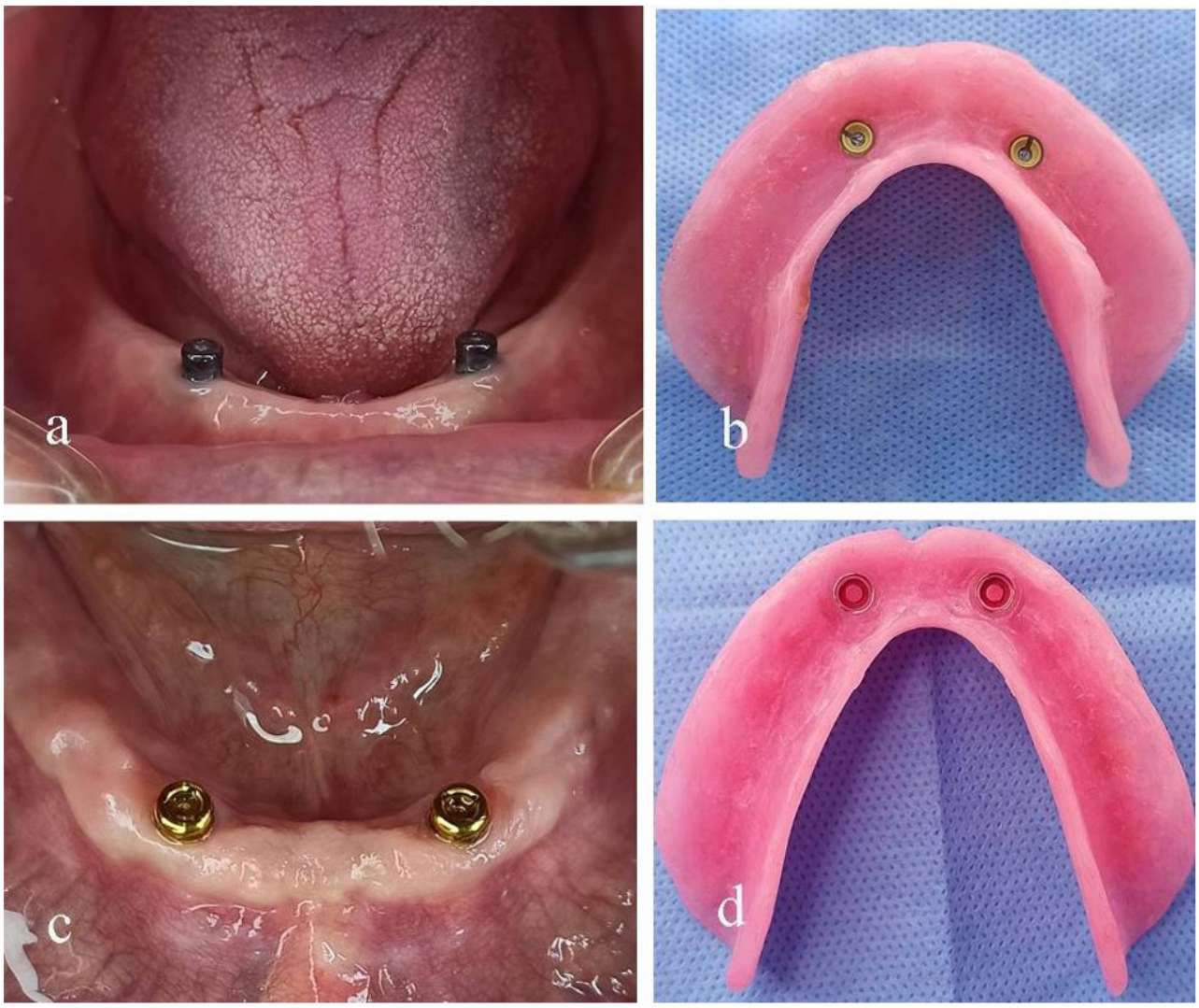

Figure 3. (a) Novaloc attachments were screwed. (b) Novaloc retention inserts. (c) Locator attachments were screwed. (d) Locator retention replacement male.

USB2.0 H series, ISH 1000, China) attached to a stereomicroscope (Olympus SZ61, Japan) at 15× magnification. A stereomicroscope was used to assess wear by measuring internal dimensions and changes in them during observation periods (Figure 4). All attachment inserts for both groups were captured on camera under the same conditions when shooting for documentation to ensure that replicate experiments can be accurately repeated. The digital photos were loaded onto a desktop computer and analyzed using software (Tucsen Mono Microscope ISH1000, China) to measure dimensions. Two perpendicular axes were used in measuring the inside circumference of the insert (A and B) for both groups in millimeters (mm) with a maximum of two decimal places. In addition to two other axes for the diameter of the central plastic core (C and D) for the locator group (Figure 5).

Figure 4. The stereomicroscope (Olympus SZ61, Japan) beside the camera (10MP Tucsen USB2.0 H series, ISH 1000, China).

The observation period was one year, so all measurements were repeated 4, 8, and 12 months after the first session, and changes in attachment sizes were noted by tracking the results (Figure 6).

The data were collected, tabulated, and statistically analyzed using SPSS version 26.0 for Windows, and the normality test (Shapiro-Wilk) was used for normality, and the independent sample t-test was used to compare the two groups, the level of significance (p-value) was set at 0.05.

RESULTS

The stereomicroscope demonstrated the surface characteristics and internal dimensions of Novaloc retention inserts and Locator retention

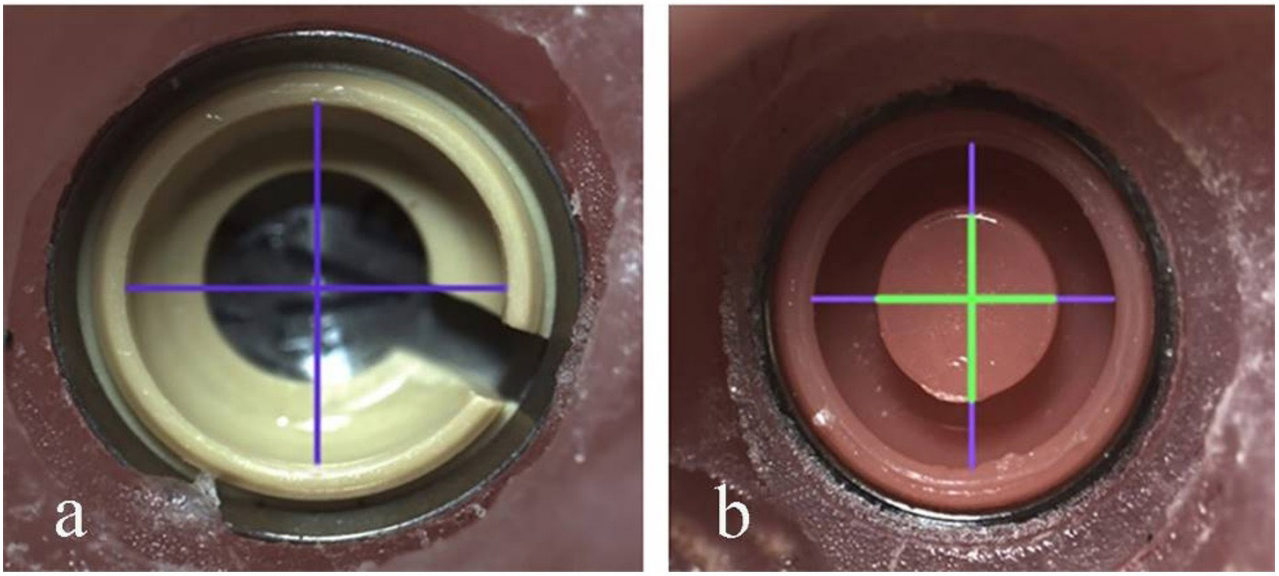

Figure 5. Wear measurements using stereomicroscope, (a) Novaloc retention inserts. (b) Locator retention replacement male. A software program (Tucsen Mono Microscope ISH1000, China) was used to measure the inner circumference of both Novaloc and locator (Axis A, B in blue color, beside the plastic core of Locator Axis C, D in green color).

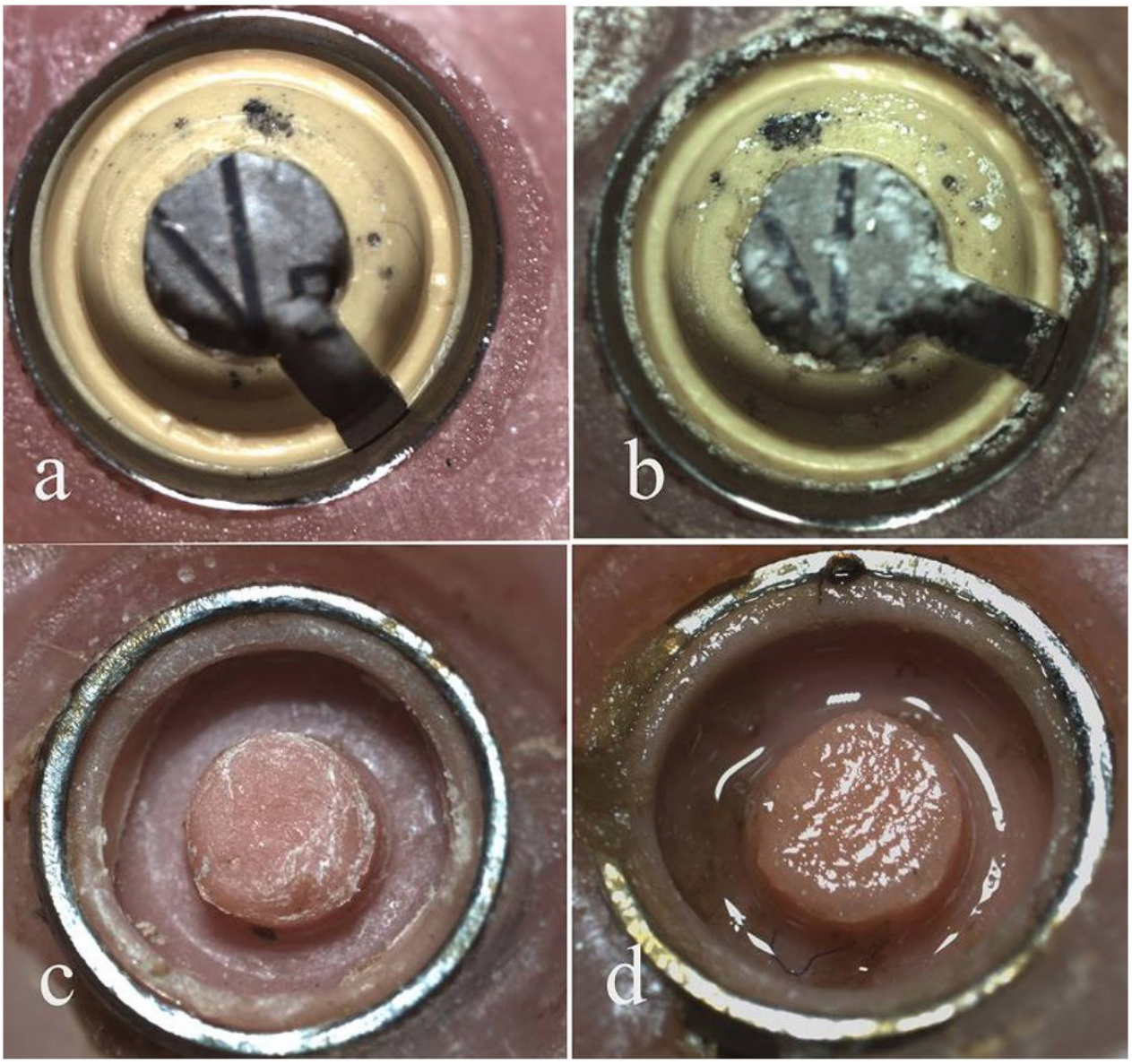

Figure 6. Stereomicroscope image for different periods of observation, with noticeable deformity and deterioration: (a, b) Novaloc retention inserts. (c, d) Locator retention replacement.

replacement males, but due to the difficulty of measuring surface roughness accurately, as the microscope used was not a scanning electron microscope (SEM), because the study was clinical, and the difficulty of coating the insert with the gold layer necessary to show the surface, as is the case in in-vivo studies, only dimensions were measured.

The standard dimensions were measured at time T0 before their functional use in the patient's mouth. The used Novaloc retention inserts and Locator retention replacement males suffered from adhesive, abrasive, and cohesive wear after two observation periods, T1 and T2, with a change in their dimension; however, it was larger in the locator group, but during the final observation, the locator group experienced clear surface fatigue, exhibiting clear deformation and an increase in the outer circumference of the retention replacement males compared to Novaloc retention inserts, while the dimensions of the central plastic core have decreased. The results showed a statistically significant difference between the Novaloc Attachment group and the Locator Attachment for wear along the T0 and T3 periods using an independent sample T-test at $P<0.05$. Generally, the Locator Attachment group had higher values for wear compared with the Novaloc Attachment group at different periods (Table I).

Table I - Comparison between Novaloc Attachment and Locator Attachment in each time.

	Novaloc Attachment Group		Locator Attachment group		Independent T-test	p-value
	mean	SD	mean	SD		
T0	2.780	0.204	4.018	0.123	16.42	<0.005
T1	2.900	0.149	4.210	0.137	20.46	<0.005
T2	2.930	0.170	4.540	0.135	23.43	<0.005
T3	3.040	0.117	4.750	0.158	27.46	<0.005

SD: standard deviation; p: P value for comparing between the studied Groups. Statistically significant at $p \leq 0.05$

DISCUSSION

This study was conducted to assess the clinical performance of two different attachments, Novaloc and Locator, in terms of wear-through dimension changes on retention devices of the attachments using a stereomicroscope [16].

According to scientific reference, the definition of wear is the gradual removal or deformation of material from solid surfaces during their function, which can be attributed to mechanical or chemical causes [17]. wear that occurred has several potential explanations that are associated with the clinical environment of the two attachments, implant angulation, design, and component wear [10]. In other words, the observed wear can be attributed to the continuous mechanical and thermal stimuli that attachment systems experience within the oral cavity, which is caused by patient manipulation of the prosthesis, including insertion and removal, masticatory wear, the acidity of the food eaten by the patient, and deterioration resulting during the cleaning of the prosthesis [18]. Although most of the research comparing the two attachments was conducted in a lab setting in contrast to this clinic study, oral circumstances may vary amongst patients, such as occlusions or mastication cycling on resorbed alveolar ridges. This will lead to denture rotation around the attachment, ultimately causing retention loss because of matrix wear [19,20]. Based on several studies, found the nylon of the Locator retention replacement male was strongly affected by simulated mastication [14], in addition to the effect of the act of insertion and removing the denture or cleaning and brushing it, which could lead to increased wear on the attachments especially for Novaloc [21].

The other reason may be attributed to the slight differences in the surgical guide between the design and its manufacture [22], besides the effect of the length of the implant; as its length increases, the possibility of it deviating laterally increases [23], and since the surgical guide used was supported by mucosa, there was a greater distance between the sleeve and the bone, a greater error in determining the exact depth of the implant in order to achieve symmetry, or an occlusal height equal to the implant. On the opposite side [24], subsequently will affect the angulation and position of the implants and attachments, which the clinic operators cannot see, but their effect on wear will become apparent later, as Misch and Resnik [25] said about attachment complications: If one implant is higher than the other, the prosthesis will disengage from the lower implant during function and rotate primarily on the higher implant. This situation will accelerate the wear. If one implant is farther from the midline, it will serve as the primary rotation point or fulcrum when the patient occludes in the posterior segments. In such a case, the more medial the implant attachment, the faster it will wear, and even a small amount of angulation will cause an undercut and raise the wear rate, this agrees with Choi et al. [12] and Arnold et al. [26] who showed the superiority of Novaloc over Locator during their laboratory studies in the case of parallel and non-parallel implants.

Regarding the design and component factors, as is well known, the two attachments have a cylindrical form and rely on mechanical friction between the abutment and each inner surface retention device to obtain uniform retention in all undercut areas [27]. Added retention of the locator due to the joint's dual retention design, which has a higher contact surface than the Novaloc and thus higher friction; this designation does not exist in the Novaloc, but on the contrary, there is a side groove to expand the Novaloc attachment during the insertion and

removal of the denture, thus relieving pressure and friction on the inner surface [12].

Used materials to make the retention device is the other explanation. Polyethylene or nylon, which has been employed in the locator because of its elasticity and biocompatibility, exhibits significant deformation and needs a lot of maintenance. This may be explained by the low resistance of polyethylene to scratches, despite its flexibility, but the roughness of the surface and the disappearance of the outer layer will lead to increased absorption of oral fluids more than PEEK in Novaloc [28], thus increasing its size and hardness, and thus increasing the effect of friction. Novaloc is made from PEEK, a material with high biocompatibility, good mechanical properties, high-temperature resistance, chemical stability, polishability, and good wear resistance to fatigue and tensile stress [29]. This may explain the findings of some laboratory studies that showed a large drop in locator retention compared to a decline in Novaloc throughout the same period [12]. Although it must be noted that within the observation period of this study.

The performance of both attachments was satisfactory, but results are still consistent with the study of Wakam et al. [30] and Choi [19] about the inevitable occurrence of wear, regardless of the type of attachment used, and also agree with de Souza et al. [31], Passia [13], and Maniewicz [14] on the good prognosis of Novaloc compared with Locator, although the study by Koenig et al. [32] linked the decreasing and aging of Novaloc' s ability to retain overdentures with chemical cleaning agents.

The findings Strengthen that clinicians might prefer the Novaloc attachment for patients who require implants or prosthetics expected to endure significant use or wear. However, given the limited sample size and observation duration, additional studies with larger extended follow-up periods are recommended to confirm these findings and fully assess the long-term performance and patient outcomes associated with both attachment types.

CONCLUSION

Within the limitations of this study in terms of the sample size and duration of observation, the following can be concluded: The Novaloc attachment exhibited better wear resistance, indicating that it may maintain its functional integrity and performance over time more effectively than the Locator attachment. This characteristic is crucial for long-term success in clinical applications, especially in scenarios involving repetitive stress or loading.

LIMITATION

This study has limitations due to a small sample size of 10 patients, affecting generalizability and statistical power. To address this issue, it would be recommended to use non-parametric tests and multiple imputations to account for missing data. While these methods can help improve the study's validity, they are not a substitute for a larger sample size.

Acknowledgements

This article is part of clinical research prepared for a doctoral degree, and it considers all academic and ethical standards of clinical work, with the patient's consent to work according to internationally recognized legal frameworks and according to the instructions of the Faculty of Dentistry at Suez Canal University in Egypt. All appreciation to the supervisors who assisted in the preparation of the research.

Data Availability Statement

All data relevant to this study are included in the manuscript.

Author's Contributions

AOB : Conceptualization, data curation, Writing – Original Draft Preparation, Writing – Review & Editing. MMBE: Supervision. SMME: Supervision. MEE: Supervision.

Conflict of interest

Regarding any product, service, and/or company mentioned in this article, the authors have no financial, proprietary, or other personal interest of any kind.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subject oversight committee's guidelines and policies of the ethical committee, and according to the instructions that are involved in the Faculty of Dentistry, Suez Canal University. The approval code for this study is: 2021-406, Faculty of Dentistry, Suez Canal University.

REFERENCES

1. Paes TJA Jr, Tribst JP, Piva AM, Figueiredo VM, Borges AL, Inagati CM. Influence of fibromucosa height and loading on the stress distribution of a total prosthesis: a finite element analysis. Braz Dent Sci. 2021;24(2):1-7.
2. Mistry R, Pisulkar SK, Borle AB, Godbole S, Mandhane R. Stability in complete dentures: an overview. IOSR J Dent Med Sci. 2018;17:36-41.
3. Warreth A, Ibieyou N, O'Leary RB, Cremonese M, Abdulrahim M. Dental implants: an overview. Dent Update. 2017;44(7):596-620. http://doi.org/10.12968/denu.2017.44.7.596.
4. van de Rijt LJ, Stoop CC, Weijenberg RA, de Vries R, Feast AR, Sampson EL, et al. The influence of oral health factors on the quality of life in older people: a systematic review. Gerontologist. 2020;60(5):e378-94. http://doi.org/10.1093/geront/gnz105. PMid:31729525.
5. Sharma S, Makkar M, Teja SS, Singh P. Implant supported overdenture: a review. J Pharm Biomed Sci. 2017;7(7):x-x.
6. Payne AG, Alsabeeha NH, Atieh MA, Esposito M, Ma S, El-Wegoud MA. Interventions for replacing missing teeth: attachment systems for implant overdentures in edentulous jaws. Cochrane Database Syst Rev. 2018 Oct 11;10(10):CD008001. http://doi.org/10.1002/14651858.CD008001.pub2.
7. Bhattacharjee B, Saneja R, Singh A, Dubey PK, Bhatnagar A. Peri-implant stress distribution assessment of various attachment systems for implant-supported overdenture prosthesis by finite element analysis–A systematic review. J Oral Biol Craniofac Res. 2022;12(6):802-8. http://doi.org/10.1016/j.jobcr.2022.09.002. PMid:36159066.
8. Elsyad MA, Eltowery SM, Gebreel AA. Peri-implant strain around medially inclined two-implant-retained mandibular overdentures with Locator attachments. J Oral Sci. 2017;59(4):483-90. http://doi.org/10.2334/josnusd.16-0626. PMid:29093282.
9. ELsyad MA, Emera RM, Ashmawy TM. Effect of distal implant inclination on dislodging forces of different locator attachments used for mandibular overdentures: an in vitro study. J Prosthodont. 2019;28(2):e666-74. http://doi.org/10.1111/jopr.12710. PMid:29143403.
10. Matthys C, Vervaeke S, Besseler J, Doornewaard R, Dierens M, De Bruyn H. Five years follow-up of mandibular 2-implant overdentures on locator or ball abutments: implant results, patient-related outcome, and prosthetic aftercare. Clin Implant Dent Relat Res. 2019;21(5):835-44. http://doi.org/10.1111/cid.12840. PMid:31454159.
11. Guédat C, Nagy U, Schimmel M, Müller F, Srinivasan M. Clinical performance of LOCATOR® attachments: a retrospective study with 1–8 years of follow-up. Clin Exp Dent Res. 2018;4(4):132-45. http://doi.org/10.1002/cre2.122. PMid:30181910.
12. Choi JW, Yun BH, Jeong CM, Huh JB. Retentive properties of two stud attachments with polyetherketoneketone or nylon insert in mandibular implant over-dentures. Int J Oral Maxillofac Implants. 2018;33(5):1079-88. http://doi.org/10.11607/jomi.6023. PMid:30231095.
13. Passia N, Ghazal M, Kern M. Long-term retention behavior of resin matrix attachment systems for overdentures. J Mech Behav Biomed Mater. 2016;57:88-94. http://doi.org/10.1016/j.jmbbm.2015.11.038. PMid:26705935.
14. Maniewicz S, Badoud I, Herrmann F, Chebib N, Ammann P, Schimmel M, et al. In vitro retention force changes during cyclic dislodging of three novel attachment systems for implant overdentures with different implant angulations. Clin Oral Implants Res. 2020;31(4):315-27. http://doi.org/10.1111/clr.13567. PMid:31876004.
15. Abdelaziz SM, Altonbary GY, El Mekawy N, Hegazy SA. Impact of locator attachments with different retentive insert materials on bite force in mandibular implant overdenture. Egypt J Oral Maxillofac Surg. 2021;12(4):245-54. http://doi.org/10.21608/omx.2022.109075.1145.
16. El Mekawy N, Elhawary MY. Clinical evaluation of inter-implant distance influence on the wear characteristics of low-profile stud attachments used in mandibular implantretained overdentures. J Clin Exp Dent. 2019;11(1):e33-41. http://doi.org/10.4317/jced.55433. PMid:30697392.
17. Abdelbary A. Wear of polymers and composites. Sawston: Woodhead Publishing; 2015.
18. Emami E, Feine J. Mandibular implant prostheses: guidelines for eden-tulous geriatric populations. Cham: Springer; 2018. http://doi.org/10.1007/978-3-319-71181-2.
19. Choi JW, Bae JH, Jeong CM, Huh JB. Retention and wear behaviors of two im-plant overdenture stud-type attachments at different implant angulations. J Prosthet Dent. 2017;117(5):628-35. http://doi.org/10.1016/j.prosdent.2016.09.027. PMid:27863857.
20. Friedrichsen M, Dirksen D, Runte C. In vitro measurement of the retention force of two stud attachment systems during cyclic load. J Prosthodont. 2024;33(2):164-70. http://doi.org/10.1111/jopr.13665. PMid:36779671.
21. Kamonkhantikul K, Homsiang W, Arksornnukit M. Brushing effect on the retentive force of retentive inserts in three denture attachments: an in vitro study. J Prosthet Dent. 2022;128(3):487.e1-12. http://doi.org/10.1016/j.prosdent.2022.06.014. PMid:35934574.
22. Shi Y, Wang J, Ma C, Shen J, Dong X, Lin D. A systematic review of the accuracy of digital surgical guides for dental implantation. Int J Implant Dent. 2023;9(1):38. http://doi.org/10.1186/s40729-023-00507-w. PMid:37875645.
23. El Kholy K, Janner SF, Schimmel M, Buser D. The influence of guided sleeve height, drilling distance, and drilling key length on the accuracy of static Computer-Assisted Implant Surgery. Clin Implant Dent Relat Res. 2019;21(1):107-7. http://doi.org/10.1111/cid.12705. PMid:30589502.
24. Guentsch A, An H, Dentino AR. Precision, and trueness of computer-assisted implant placement using static surgical guides with open and closed sleeves: an in vitro analysis. Clin Oral Implants Res. 2022;33(4):441-50. http://doi.org/10.1111/clr.13904. PMid:35148444.
25. Misch CE, Resnik R. Misch's avoiding complications in oral implantology. USA: Elsevier Health Sciences; 2017.
26. Arnold C, Stampa C, Schweyen R, Hey J, Boeckler A. Retentive characteristics of a new at-tachment system for hybrid dentures. Materials (Basel). 2020;13(15):3434. http://doi.org/10.3390/ma13153434. PMid:32759744.
27. Wakam R, Benoit A, Mawussi KB, Gorin C. Evaluation of retention, wear, and maintenance of attachment systems for single-or two-implant-retained mandibular overdentures: a systematic review. Materials (Basel). 2022;15(5):1933. http://doi.org/10.3390/ma15051933. PMid:35269164.

28. Kamonkhantikul K, Arksornnukit M, Homsiang W. Effect of thermocycling on the retentive force of the retentive inserts in three denture attachments and their water absorption ability. Dent Mater J. 2024;43(1):90-6. http://doi.org/10.4012/dmj.2023-175. PMid:38148022.

29. Zol SM, Alauddin MS, Said Z, Mohd Ghazali MI, Hao-Ern L, Mohd Farid DA, et al. Description of poly (aryl-ether-ketone) materials (PAEKs), polyetheretherketone (PEEK) and polyetherketoneketone (PEKK) for application as a dental material: a materials science review. Polymers (Basel). 2023;15(9):2170. http://doi.org/10.3390/polym15092170. PMid:37177316.

30. Wakam R, Ramalingam S, Mawussi KB, Gorin C, Benoit A. Retention loss and wear assessment of three attachment systems for implant retained-mandibular overdentures: an in vitro study. J Mech Behav Biomed Mater. 2024;150:106269. http://doi.org/10.1016/j.jmbbm.2023.106269. PMid:38043259.

31. de Souza RF, Bedos C, Esfandiari S, Makhoul NM, Dagdeviren D, Abi Nader S, Jabbar AA, Feine JS. Single-implant overdentures retained by the Novaloc attachment system: study protocol for a mixed-methods randomized cross-over trial. Trials. 2018 Apr 23;19(1):243. http://doi.org/10.1186/s13063-018-2606-7. PMid:29685161.

32. Koenig A, Rotenburg L, Fuchs F, Sander S, Lethaus B, Hahnel S. Influence of aging of PEEK attachment inserts on the pull-off force of implant-retained overdentures-A laboratory study. Clin Oral Implants Res. 2023;34(12):1363-72. http://doi.org/10.1111/clr.14180. PMid:37694944.

Ammar Omar Belal
(Corresponding address)
Suez Canal University, Faculty of Dentistry, Prosthetic Dentistry, Ismailia, Egypt.
Email: Ammar_belal@dent.suez.edu.eg

Date submitted: 2024 Dec 01
Accept submission: 2025 Mar 28