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Peri-implant Strain Evaluation of Ti Si Snap Versus Locator Attachments in Two-Implant Retained Mandibular Overdentures: An In Vitro Study

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Aim: This in vitro study was conducted to evaluate peri-implant strain induced by two different types of attachments; (Ti Si snap and Locator) in implant-retained mandibular overdentures.
Materials and methods: Twelve completely edentulous acrylic resin models were 3D printed. Two implant analogues were inserted in each model in the intra-foraminal region. Acrylic resin mandibular overdentures were fabricated over two types of implants attachments: Group I involved Ti Si snap attachment while Group II involved Locator attachment, where n=6 for each group. Retention sil was applied as the female component in the fitting surface of overdentures of both groups. Strain gauges were bonded to the model at the mesial and distal surfaces of each implant analogue. The peri-implant strain was recorded during unilateral and bilateral loading using a universal testing machine. Data were collected, tabulated, and statistically analyzed using independent sample-t test at a 95% level of confidence.
Results: Group I (Ti Si group) revealed a higher induced strain compared to Group II (Locator group) during bilateral loading as well as on the loaded side during unilateral loading. However, Group I (Ti Si group) showed significantly reduced mean strain values at the unloaded side in comparison to Group II (Locator group) .
Conclusion: Based on the limitations of this study, it could be concluded that Locator attachment exhibited a better stress distribution pattern compared to Ti Si attachment retaining mandibular overdentures during bilateral loading and on the loaded side during unilateral loading.

Keywords: Strain gauge, Ti Si snap, Locator attachment, overdenture

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Introduction

The use of dental implants for the restoration of fully edentulous patients has led to significant enhancements in the overall quality of life, masticatory function, patient satisfaction and the health of remaining supporting structures. Since 2002, implant-retained overdentures supported by two inter-foraminal implants have been recognized as the gold standard for treatment of fully edentulous patients, owing to their simplicity, minimal invasiveness, cost-effectiveness and high success rates.[1,2]

The attachment type used to secure an overdenture to dental implants is considered crucial for implant success, particularly in managing the stresses transferred to the implant during function. Previous studies have shown that the attachment type could influence the stresses on the bone surrounding the implants, where improper loading could result in excessive stresses on the surrounding bone, which could potentially lead to bone resorption and implant failure.[3,4]

The Locator, which was first introduced in 2001, is one of the most commonly used attachments. It is supplied in several vertical heights; thus, it could be considered as an optimum treatment option for prosthetic cases with limited vertical space. The locator attachment is characterized by its double retention, self-aligning capability, ease of insertion and removal and is designed to accommodate up to 40° implant divergency. This type of attachment is available in several colors and retention levels. Additionally, it is quick and simple to maintain and repair.[5]

Recently, the Ti Si Snap attachment (Bredent medical® GmbH & Co. KG, Senden, Germany) was introduced, characterized by its titanium-silicone composition designed to provide a snap effect. A corresponding female matrix attachment named Retention.sil (R.S, Bredent Medical, Germany), comprising polyvinylsiloxane (PVS), has been developed as a silicon matrix attachment for implant overdentures. This attachment replaces the conventional component within the denture base. Moreover, retention sil acts as a shock absorber, it decreases loading magnitude transmitted to the implant-bone interface, so it reduces the stresses applied to the implants. Furthermore, retention. sil. housing entirely blocks the area surrounding the male part of the attachment, thus reducing microbial adherence and plaque accumulation that induce inflammation of the peri-implant tissue, development of pockets and loss of bone.[6,7]

It has been reported that Retention sil attachment offered resilience and high tensile strength, effectively securing the prosthesis through mechanical interlocking and frictional contact. This combination ensures a high level of patient comfort during eating and chewing while maintaining the denture's stability. Additionally, it demonstrates ease of repair and cost-effectiveness. [8,9]

Studies indicated that the retention silicon-based overdenture attachment with Ti Si snap abutments, based on a bollard-like design, represents a suitable matrix product for resilient retention of implant overdentures, owing to its favorable biological, physical, and retention properties. It has been reported that the Ti Si snap abutments' high guiding cone allows safe and reliable denture fixation with simply two implants, resulting in complete control of the denture during removal and insertion. Moreover, in cases of insufficient bone height, implants can be angled to optimize the use of available bone. Therefore, the use of angled Ti Si Snap abutments on obliquely placed implants could help to adjust the path of insertion of the prosthesis. [9,10]

There are various techniques for analyzing the stresses and the resulting strain that are transmitted to the peri-implant areas, such as photo elastic, finite element analysis and strain gauges. Strain gauges work via calculation of the deformation occurring in a body through computing the alteration in its electrical resistance and converting it to an electric voltage that can be precisely measured at the location of the strain gauge. This stress analysis method has enhanced the understanding of stress transmission and distribution across various prosthetic appliances attributed to the small size of the strain gauges and the linearity in the resistance rate change. [5,11,12]

Several studies have assessed the stresses and the resulting strain transmitted to the peri-implant area during using Locator attachments retaining mandibular overdentures, with the conclusion that Locator attachments showed favorable and homogenous stress distribution [(13-16)]. Other studies have investigated the effect of distally and labially inclined implants on the stresses transmitted to the peri-implant area with the use of Ti Si attachments retaining mandibular overdentures and recommended that dental implants should be installed parallel to each other and perpendicular to the edentulous ridge in order to minimize stresses induced in the peri-implant area. [9,17]

To the best of the authors' knowledge, the strain induced from applied stresses of Ti Si attachments retaining mandibular overdentures on the peri-implant area, compared to those of Locator attachments, is still lacking in the literature. In this context, the primary objective of the current study was to compare the peri-implant strain induced on both Ti Si snap and locator attachments used to retain implant mandibular overdentures after both unilateral and bilateral loading. The null hypothesis tested was that there would be no difference in the induced strain mesial and distal to Tisi snap and locator attachments retaining mandibular overdentures during bilateral and unilateral loading.

Materials and methods

Sample size analysis

A power analysis was conducted to ensure sufficient power for a two-sided statistical test of the null hypothesis, which posits that there would be no difference in the measured strain. With an alpha (α) level set at 0.05, a beta (β) level of 0.02 (resulting in a power of 80%), and an effect size (d) of 1.85 derived from previous research [18]; the minimum total sample size required was determined to be 12 samples (6 samples per group). The sample size calculation was performed using R statistical analysis software version 4.3.2 for Windows.

Construction of the 3D model

This study utilized a 3D model that simulated a completely edentulous mandibular arch with two implants placed in the intra-foraminal region to retain mandibular overdenture. An educational completely edentulous mandibular model and a complete denture constructed over it were scanned by a desktop scanner (Medit IdenticaT500, South Korea), followed by the creation of STL file. The created STL file of the model was then imported to an implant planning software (Blue Sky Plan) for determination of the positions of the implants according to the teeth position of the scanned denture. Implant parallelism was checked using parallelism tool. The STL file of the model was modified to include two implant beds in the virtual model using the implant analogue module of the designing software (Exocad Dental CAD, Exocad Inc., Darmstadt, Germany). These two implant beds represented the planned sites for the two implant analogues with dimensions 3.5x12 mm in the intra-foraminal region. Two slots were also designed mesial and distal to the sites of the implants for the attachment of the strain gauges. These slots were positioned 1 mm away from the implants with dimensions of 3mm mesiodistally, 5.5 mm buccolingually and 5 mm occlusogingivally. In order to standardize the position of the strain gauge rosettes within the slots in relation to the implant analogue, a rectangular depression 1 mm in depth was created within the distal wall of the mesial slot and mesial wall of the distal slot with 2 mm buccolingual and 4 mm occlusogingival dimensions (Figure 1).

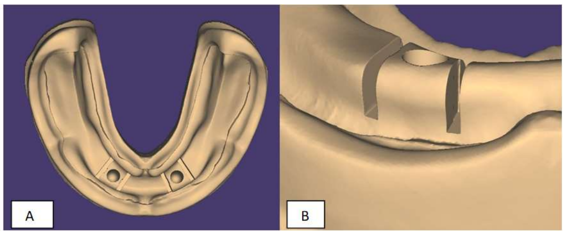

Figure 1: A; Virtual model, B; Grooves for strain gauge attachment

A two-millimeter-thick layer, representing the mucosa, was removed from the crest of the scanned model. The STL file was then sent to the 3D printer (ULTRA 3SP, the Envision TEC (Ferndale, MI) per factory®**).** The cast was printed layer by layer through projecting ultraviolet light onto the layers for polymerization, starting with the base until the entire cast was formed. The raw material utilized in the manufacturing process of the printed model was clear resin (Anycubic, 3D printing UV sensitive Resin, UV wavelength 405 nm, China).

A mucosa key index was designed over the scanned model, which acts like a special tray that fitted over the model, to mimic the viscoelastic behavior of the mucoperiosteum covering the ridge. The key index was subsequently 3D printed using clear resin. The two analogs (Bredent medical® GmbH & Co. KG, Senden, Germany) were attached at their sites in the model using flowable composite (Dentsply SDR flow, USA) (Figure 2).

Figure 2: A; virtual mucosa key index, B; 3D printed model with mucosa key index, C; Analogs were attached in the model.

The mucosa simulation was performed using an addition silicon rubber base material (Multisil-Mask Soft, Bredent, Senden, Germany) that was directly injected into the mucosa key index from the double-mix cartridge. In this manner, the working model's mucosa was replicated with a 2 mm thickness.

Based on the type of attachment used, the models were divided into two equal groups (n=6).

Group I: included six models with Ti Si snap attachments.

Group II: included six models with the Locator attachments.

Tightening of the attachments to the implants was performed using a screwdriver at a torque of 35 N Cm (Figure 3).

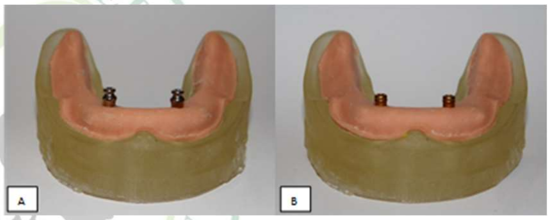

Figure 3: Mucosa stimulation with Ti Si snap attachment (A) and Locator attachment (B)

Construction of the overdenture

Duplication of one of the printed models was performed using Polyvinyl Siloxane impression material (Elite HD + putty soft Zhermack Germany) and poured in dental stone to produce a stone cast for overdenture construction. A trial denture base was constructed using self-cure acrylic resin (Acrostone, Co Ltd Cairo, Egypt) on the stone cast. After selecting acrylic teeth (Acrostone, Co Ltd Cairo, Egypt) of proper size, setting up of the teeth on the trial denture base was performed.

For standardization of both the thickness of the denture base and the position of the artificial teeth in the overdentures, a mold of the waxed-up trial denture base was created using Polyvinyl Siloxane impression material. The superior portion of the mold represented the negative impression of the polished surface of the denture and the artificial teeth. For producing identical overdentures, the artificial teeth of each overdenture were placed in their intended position in the mold, melted base plate wax was then poured into the area between the silicone mold and the stone cast. Following the waxing-up process, twelve replicas of the overdentures were produced using heat-cured acrylic resin (Acrostone, Co Ltd Cairo, Egypt) following the conventional method.

Application of Retention sil

The positions of the attachments in both groups were localized and relieved in the fitting surface of the overdenture. Escape holes were then made in the lingual surface of the overdenture to act as an exit for the extra material and to avoid extra pressure on the attachments. The primer (Multisil-Primer , Bredent) was then applied in the relieved areas, followed by the application of the retention sil 600 (Bredent medical GmbH &Co. KG, Germany) for both Ti Si attachment group and Locator attachment group. The overdenture was then seated over the model, the excess material escaped through the lingual holes and after complete setting of the retention sil , the overdenture was removed from the model and the surplus material was cut off (Figure 4).

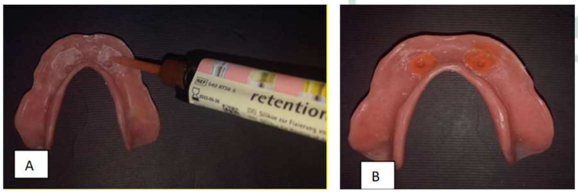

Figure 4: A; Application of Retention sil 600 in the relived fitting surface of the overdenture, B; The fitting surface of the overdenture after application of Retention .sil 600

Installation of the strain gauges and strain measurements

The strain gauges (Kyowa Electronic Instruments Co., LTD, Tokyo, Japan) used in this study had a gauge length of 1 mm, a resistance of 119.6 Ω ±0.4 % and a gauge factor of 2.11 ± 1 %. The strain gauges were installed in the grooves, mesial and distal to the implant analogues and bonded to the model surface by cyanoacrylate based adhesive cement (Pattex super glue, Henkel, Germany). Gentle pressure was applied over the bonded gauges and kept constant for five minutes using a large ball burnisher.

Load application

A multi-channel strain meter (PCD-300 A, Kyowa Electronic Instruments Co.) was attached to the terminals of the lead wire of the strain gauges in order to determine the microvoltage output, which was then translated into microstrain using specialized software (Kyowa PCD 30 A). A static vertical compressive load of 100 N was applied for 15 seconds at a crosshead speed of 0.5 mm/min using a digital universal testing machine (Lloyd LRX; Lloyd Instruments Ltd., Fareham, UK).

Load was applied both bilaterally and unilaterally; for the bilateral loading, the load was applied with a plunger in mid-point of a rectangular-shaped metal bar positioned on the occlusal surface of the artificial teeth in the first molar region bilaterally. For unilateral loading, the central fossa of the right first molar was selected as the location for the load application point, representing the working side.

Measurements of strain were recorded at the loading and non-loading sides of the two peri-implant surfaces (mesial and distal). All measurements were repeated 5 times for each overdenture, with a minimum of 15 minutes lapse between each measurement. Statistical analysis was performed on the mean recorded micro-strain from the five measurements for each of the twelve models. (Figure 5)

Statistical analysis

Data were analyzed using SPSS statistical package for social sciences, version 22 (SPSS Inc., Chicago, IL). Normality testing was performed using Kolmogorov-Smirnov and Shapiro-Wilk tests. Data exhibited normal distribution and were presented as mean and standard deviation (SD) values. Independent sample-t test was employed to evaluate the impact of the two types of overdenture attachments on the induced strain among

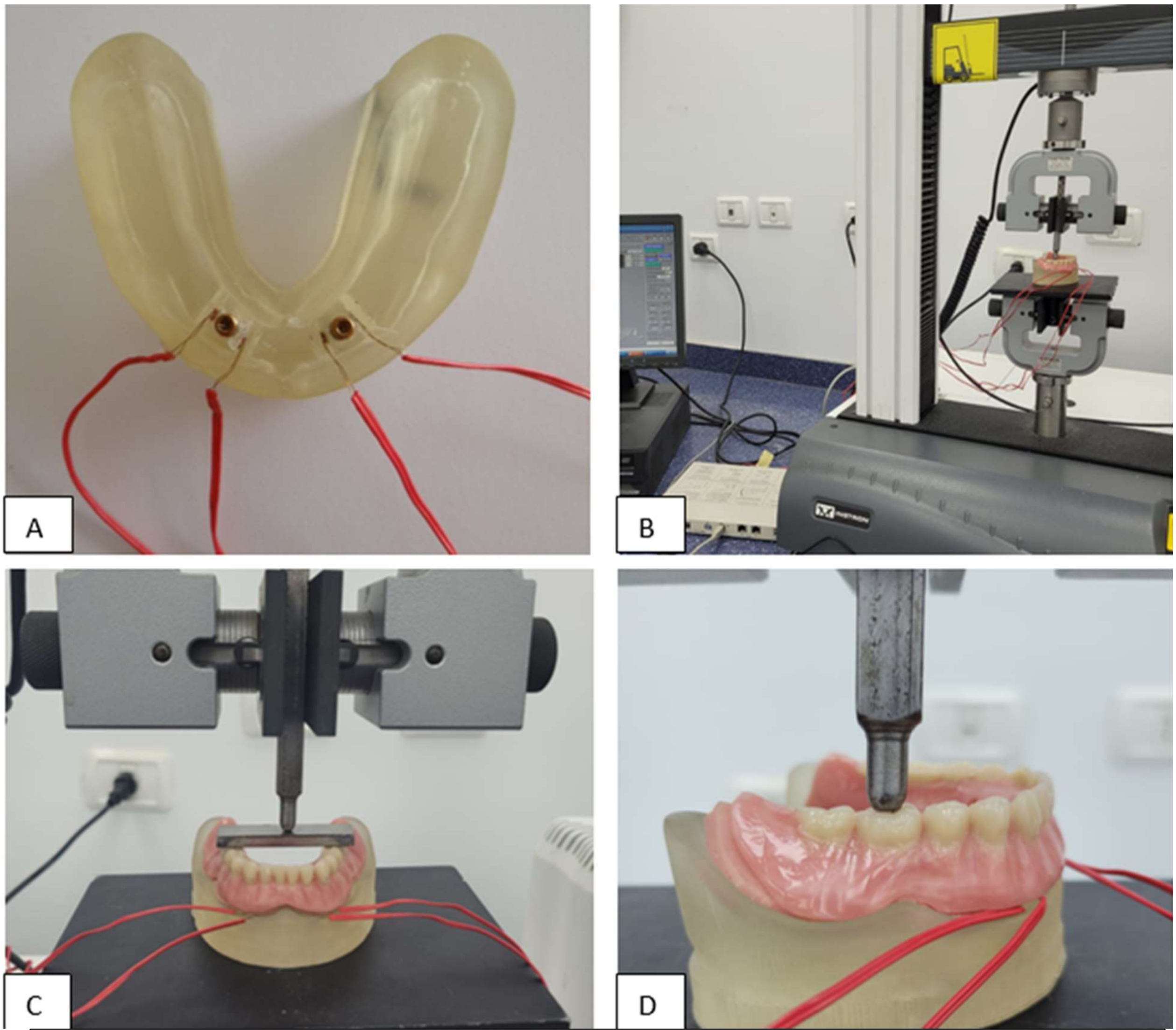

Figure 5: A; Strain gauges installation, B; Load application using the universal testing machine, C; Bilateral load application, D; Unilateral load application

both groups and to compare strain at the mesial and distal surfaces within the same group. The significance level was established at $p < 0.05$.

Results

The independent sample-t test revealed a significant effect for the overdenture attachment material used. Comparing the induced strain during bilateral loading revealed significantly higher mean values ($P < 0.001$) mesial and distal to the implant analogues for Group I (Ti Si group) compared to Group II (Locator group). Statistical analysis revealed insignificant differences ($P > 0.05$) of the mean strain values recorded mesial and distal to the implant analogues on both the right and left sides for both groups (Table 1).

Comparing the induced strain during unilateral loading revealed significantly higher values ($P < 0.001$) at the right side (loaded side) for Group I (Ti Si group) compared to Group II (Locator group) mesial and distal to the implant analogues. However, Group I (Ti Si group) showed significantly reduced mean strain values at the unloaded side (left side) in comparison to Group II (Locator group) mesial and distal to the implant analogues. Statistical analysis revealed significant ($P < 0.001$) higher mean strain values recorded at the mesial side if compared to the distal one of the implant analogues on the right (loaded) side for both groups of the study. For the left (unloaded) side, there was no significant difference (P>0.05) between mesial and distal sides for Group I (Ti Si group). On the other hand, the mean recorded strain at the mesial side was significantly higher (P<0.05) in comparison to that recorded at the distal side for Group II (Locator group) (Table 1).

Table 1: Means, standard deviation values and significance of the induced strain (um/m) at the mesial and distal surfaces of implant analogues for the tested attachment materials during bilateral and unilateral loading.

Attachment type / Strain gauge Channel		Group I Ti Si		Group II Locator		
		Mean	SD	Mean	SD	P value
Bilateral loading	Right mesial	79.34 A a	5.76	46.51 B b	1.92	<0.001*
	Right distal	73.63 A a	4.94	45.11 B b	2.96	<0.001*
	P value	0.13		0.40		
	Left mesial	70.92 A a	6.98	42.12 B b	2.65	<0.001*
	Left distal	74.35 A a	7.91	39.08 B b	3.09	<0.001*
	P value	0.49		0.13		
Unilateral loading	Right mesial (Loaded side)	188.48 A a	9.93	147.89 B a	8.46	<0.001*
	Right distal (Loaded side)	108.73 A b	5.15	86.93 B b	7.25	<0.001*
	P value	<0.001*		<0.001*		
	Left mesial (Unloaded side)	36.50 B b	5.65	86.35 A a	6.51	<0.001*
	Left distal (Unloaded side)	32.88 B b	3.54	75.28 A b	5.47	0.001*
	P value	0.27		<0.05*		

Means with different upper-case superscript letters denote significant differences among rows while those with different lowercase superscript letters indicate significant differences among columns.
* indicates significance at P<0.05.

Discussion

The design of various overdenture attachment systems and their clinical indications remain a controversial issue. When treating fully edentulous patients, it is crucial to consider the stress transfer to the supportive tissues surrounding the implants, as excessive stress can lead to bone resorption. The attachments should be designed to offer optimal distribution of stresses around implants and their supporting structures thereby allowing bone loading within the physiological limits.[13] As there is no single attachment that would fulfill the ideal requirements, due to the unique nature of each clinical situation, careful selection of the appropriate attachment is necessary to satisfy patients' needs and expectations, while ensuring long-term biological and functional outcomes.[19]

Three-dimensional digital printing of models was employed to ensure standardization across the test groups. This approach not only reduces the time required compared to conventional methods, but also enhances accuracy while minimizing production errors. One benefit of computerized design is that strain gauge slots can be standardized with respect to implant analogues, which can be done with greater accuracy than with manual placement. This results in a surface that is consistently smooth, which lowers the likelihood of strain induced by uneven surfaces.[20,21] Implants were placed in the interforaminal area as this showed the best results when compared with using one or four implants.[22]

Mucosal simulation was conducted using a 2 mm thick layer to simulate the viscoelastic properties of the mucoperiosteum covering the edentulous ridge. A silicone rubber base material was chosen for this application due to its excellent dimensional stability, minimal permanent deformation, and superior elastic recovery compared to other materials.[5,23]

The duplication of the printed model to obtain stone casts, as well as the duplication of waxed up overdenture for standardization of both the thickness of the denture base and the position of the artificial teeth were performed using polyvinyl siloxane impression material to ensure standardization of all samples. Addition silicones are reported to be precise and dimensionally stable, thus could be suitable to accomplish the duplicating process later. Moreover, addition silicone can be used several times without losing its accuracy and can record the fine details even in cases where overdenture abutments are present. [24,25]

In order to standardize both study groups, Retention sil silicone base housing was used as the female component in the fitting surface of the overdentures. It has been reported that the use of Retention sil could shorten the duration of visits and the number of follow-up appointments while making denture insertion and removal simple, particularly for elderly patients with limited manual dexterity as it is offered in varying degrees of retention in addition to its resiliency. Its use in immediate loading cases could guarantee minimal stress transfer to the implants. Moreover, for the operator, Retention sil application is considered an easy and time saving procedure (using a chairside technique) and does not require a great space in the denture fitting area. Additionally, the risk of denture breakage is reduced, and aesthetics is enhanced attributed to the pink color of the material. [9,26]

Strain gauges were attached to the crest of the ridge surrounding the implant analogues, as peri-implant stresses and bone loss typically begin at the crest of the alveolar ridge near the implant’s neck. Additionally, potential overloading may result from the compression of cortical bone at the crest of the alveolar ridge. [25] It has been reported that the strain measured on the bone's surface could reflect the stresses applied to it. Therefore, two strain gauges were placed on the mesial and distal sides of each implant analogue.[27-30]

In the current study, both unilateral and bilateral load application was performed to match the varieties in chewing patterns among patients since, some patients prefer chewing on one side while others prefer chewing on both sides. The first molar area was selected for load application during this study because it is widely recognized to be the location where the greatest occlusal stresses are exerted, and the highest contraction of elevator muscles occur.[31]

The results of the present study revealed that the Ti Si attachment showed higher induced strain values during bilateral loading in comparison to Locator attachment with no significant difference recorded on both the mesial and distal sides of the implants of both groups. This could be attributed to the low-profile design of the Locator attachment where the short profile was advantageous in terms of dissipating much of the applied load and thereby reducing the stresses induced on the mesial and distal sides of the implant analogues.[32-35] This could be explained by reducing the lever arm length resulting in a better stress distribution.[35-37] Moreover, the abutment's rotational pivoting feature could help in lowering the rotational center and hence reducing the lateral forces.[38] These results were further justified by Yoon et al, 2021and El Quoriaty et al, 2023 [14,15] who reported that less stresses were generated by the Locator attachment on the cortical and cancellous bone as well as around the implants compared to other attachments.

Furthermore, Yilmaz et al. (2022)[39] reported elevated retentive values for the Ti Si attachment in comparison to other types of attachments. It can be hypothesized that a relationship exists between the moment an attachment loses its retention, and the magnitude of stresses transmitted to both the implant and the surrounding supporting structures; the more rapidly an attachment loses retention, the lower the stress transmitted to the implant.[40] This suggestion further supports the findings of the current study.

Statistical analysis of the strain induced by unilateral loading demonstrated that the TiSi group exhibited a greater mean induced strain on the loaded (right) side in comparison to the Locator attachment group, with higher strain induced on the mesial surface of the implant compared to the distal surface for both groups. This difference may be attributed to the higher profile of the TiSi attachment which could have led to inadequate contact between the denture base and the residual ridge. Consequently, this may result in an excessive transfer of stresses to the implant on the loaded side. [33,34] On the other hand, Ti Si attachment recorded a lower mean strain value at the non-loaded (left) side compared to the locator attachment. This finding could be explained based on the creation of a fulcrum by the Ti Si attachment at the side of load application, with subsequent denture disengagement at the non-loaded side and thus a reduced amount of strain induced. Conversely, the locator attachment provided a level of resiliency that permitted vertical movement of the overdenture at the load application site. Consequently, the overdenture remained engaged on the non-loaded side, leading to an increase in the induced strain[16,27]

Based on the results obtained in the current study, it could be highlighted that the design of the attachment used for retaining implant supported mandibular overdentures could influence the stress and the induced strain on the peri-implant structures, and accordingly, the null hypothesis tested was rejected since there were statistically significant differences in the induced strain mesial and distal to Ti Si snap and Locator attachments retaining mandibular overdentures during both bilateral and unilateral loading.

Conclusion

Considering the limitations of the current study, it could be concluded that Locator attachment exhibited a better stress distribution pattern compared to Ti Si attachment retaining mandibular overdentures during bilateral loading and on the loaded side during unilateral loading.

Declarations

Funding

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethical approval

Ethical committee exemption.

The research was exempted from review by the Ethical Committee (MIU-IRB Chair)as it was determined to be a non – human subject research .

Competing interests

The authors declare that there is no conflict of interest.

References

1. Naert I, Alsaadi G, Quirynen M: Prosthetic aspects and patient satisfaction with two-implant-retained mandibular overdentures: a 10-year randomized clinical study. Int J Prosthodont 2004; 17:401-410.
2. Ekelund J-A, Lindquist LW, Carlsson GE, et al. Implant Treatment in the Edentulous Mandible: A Prospective Study on Branemark System Implants over More than 20Years. Int J Prosthodont 2003; 16: 602–8.
3. Tawil G, Aboujaoude N, Younan R. Influence of prosthetic parameters on the survival and complication rates of short implants. Int J Oral Maxillofac Implants 2006; 21(2): 275-82.
4. Holmgren EP, Seckinger RJ, Kilgren LM, Mante F. Evaluating parameters of osseointegrated dental implants using finite element analysis —a two-dimensional comparative study examining the effects of implant diameter, implant shape, and load direction. J Oral Implantol 1998; 24(2): 80-88.
5. Khorshid HE. A Comparison Between Two Different Types of Attachments in Implant Retained Mandibular Overdentures (A Stress

Analysis Study). Egypt. Dent. J. 2018;64:1894-902.

6. Schweyen R, Beuer F, Arnold C, Hey J. Retentive characteristics of a vinylpolysiloxane overdenture attachment system. Clin Oral Investig 2015;19:947-53.

7. Salama, A. Effect of implant supported overdenture with different bar attachment modalities on the implant and overdenture supporting structures ASDJ. 2019; 22: 181-88.

8. Schweyen R, Arnold C, Setz JM, Hey J. Retentive characteristics of individual and prefabricated polyvinylsiloxane overdenture attachments: Alternative treatment options for geriatric patients. Clin Oral Investig 2019;23:1425-34.

9. Ahlam Es, Mahmoud El Sahy Bd, Ezz Eldin Md. Evaluation of Strains Around Distally Inclined Implants Retaining Mandibular Overdenture with Ti Si Snap Attachment. Med J Cairo Univ. 2022;90(6):895-905.

10. Enan G, Abdelhakim A, Elsharkawy A, Adly M. Evaluation of retention and release period in labially inclined implant retained mandibular overdentures with titanum-silicone snap attachments (comparative in-vitro study). Alexandria Dental Journal. 2023 ;47(4):22–22.

11. Al-Okl A, Al Samahy M, Amin H, Khashaba U. Stresses induced by integrated and' nonintegrated extracoronal semi-precision attachments for maxillary distal extension bases. Al-Azhar Dental Journal for Girls, 2018; 5(3): 297-304.

12. Bahgat S, El Homossany M. Effect of material on stress transmission to the supporting structures in Kennedy Class I restored by Telescopic-retained Removable Partial Denture. (Strain Gauge Study). Egypt. Dent. J. 2018; 64(1): 559-73.

13. Yoon SS, Hong SJ, Paek J, Kwon KR. Stress patterns of two-implant mandibular overdentures depending on the types of attachments. J Dent Implant Res. 2021;40(3):112-19.

14. El Quoriaty H.A, Mohamed.A.Q, Helaly.O.A. Retention and Stress Distribution of Implant Retained mandibular Complete Overdenture with Locator versus Ball and socket Attachments (An in vitro Study). Al-Azhar J Dent Sci. 2023; 26:1-07.

15. El-Abd M F, El-Sheikh M M, El-Gendy M N. Effect of position of single implant with two different attachments on stress distribution of mandibular complete overdenture (in-vitro study). TDJ. 2018; 15: 63-69.

16. Khurana N, Rodrigues S, Shenoy S, Saldanha S, Pai U, Shetty T, N S, Mahesh M, Hegde P. A Comparative Evaluation of Stress Distribution with Two Attachment Systems of Varying Heights in a Mandibular Implant-Supported Overdenture: A Three-Dimensional Finite Element Analysis. J Prosthodont. 2019;28:e795-e805.

17. Mahmoud El Sahy, Ahlam El Sharkawy, and Amal Ezz Eldin . Evaluation of Strains Around Distally Inclined Implants Retaining Mandibular Overdenture with Ti Si Snap Attachment. Med. J. Cairo Univ., 2022; 90 (3): 895-905.

18. Fayyad, Ahmed. "The Effect of Magnetic and Locator Attachments On Strain Around Implants Retaining Mandibular Overdenture: An In Vitro Study." Egypt. Dent. J. 2017;63: 2661-69.

19. Hasanin A, Abo Alfotouh H, Abdel Nabi N.Stress Analysis Of Two Different Attachments For A Single Implant Retained Mandibular Overdentures In The Midline (In Vitro Study) . Egypt. Dent. J.2021;67:689:97.

20. Al Aswad R, Youssef HG. Strains induced by zirconia and metal resin bonded attachments versus extracoronal attachment with full veneer retainer in maxillary distal extension removable partial dentures. Egypt. Dent. J.2022; 68: 3809-22.

21. Alghazzawi TF. Advancements in CAD/CAM technology: Options for practical implementation. J. Prosthodont. Res.2016; 60:72-84.

22. El-Zawahry MM, Ibraheem EM, Nassani MZ, Ghorab SA, El-Anwar MI. Stress analysis of mandibular implant overdentures retained with one, two, or four ball attachments: A finite

a. element study. Dent Res J. 2018;15:437–43.

23. Nabhan M. Effect of different fixed detachable implant supported prosthesis materials on the stresses induced on the supporting structures. Egypt Dent J. 2019;65(1):445–52.

24. Elsyad MA, Elhddad AA, Khirallah AS. The effect of implant diameter on strain around implants retaining a mandibular overdenture with Locator attachments: An in vitro study. Dent mater j. 2016 ;35:938-45.

25. S. Alzahrani A, S. Alshamrani A. Comparison of Different Techniques of Copying Dentures. International Journal of Dental Sciences and Research. 2023;11(2):15–20.

26. Rostom DA, Sheta NM. Evaluation of the Retention of Two Different Retention Mechanisms (Nylon Caps and Retention Sil) in Locators Retained Implant Mandibular Over-Denture. A Randomized Clinical Trial (Rct). Al-Azhar Dent J Girls. 2021;8:65-70.

27. Elsyad MA, Setta FA, Khirallah AS. Strains around distally inclined implants retaining mandibular overdentures with Locator attachments: an in vitro study. J. Adv. Prosth.. 2016; 8:116-24.

28. okuhisa M, Matsushita Y, Koyano K. In vitro study of a mandibular implant overdenture retained with ball, magnet, or bar attachments: comparison of load transfer and denture stability. Int J Prosthodont. 2003;16:128–34.
29. Heckmann SM, Winter W, Meyer M, Weber HP, Wichmann MG. Overdenture attachment selection and the loading of implant and denture-bearing area. Part 1: In vivo verification of stereolithographic model. Clin Oral Implants Res. 2001;12(6) : 617–23
30. Mohammed SL. Effect of Two Different Digitally Constructed Bar Materials on The Supporting Structures of Implant-Retained Mandibular Overdenture (In-Vitro Study). ASDJ. 2023 ;29:15-22.
31. Sadowsky SJ, Caputo AA. Stress transfer of four mandibular implant overdenture cantilever designs. J Prosthet Dent 2004; 92: 328-36.
32. Eltaftazani I, Moubarak A, El-Anwar M. Locator attachment versus ball attachment: 3-dimensional finite element study. Egypt Dent J. 2011;57:73-85.
33. El-Anwar MI, El-Taftazany EA, Hamed HA, Abd ElHay MA. Influence of Number of Implants and Attachment Type on Stress Distribution in Mandibular Implant-Retained Overdentures: Finite Element Analysis. Open Access Maced J Med Sci. 2017; 5(2):244-49.
34. ELsyad MA, Errabti HM, Mustafa AZ. Mandibular Denture Base Deformation with Locator and Ball Attachments of Implant-Retained Overdentures. J Prosthodont. 2016;25(8):656-64.
35. Tokuhisa M, Matsushita Y, Koyano K. In vitro study of a mandibular implant overdenture retained with ball, magnet, or bar attachments: comparison of load transfer and denture stability. Int J Prosthodont. 2003;16(2):128-34.
36. 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;17:401-10.
37. Geckili O, Bilhan H, Bilgin T. Locator attachments as an alternative to ball attachments in 2-implant retained man dibular overdentures. JCDA 2007; 73(8):691-4.
38. Evtimovska E, Masri R, Driscoll CF, Romberg E. The change in retentive values of locator attachments and hader clips over time. J Prosthodont. 2009; 18(6):479-83.
39. Yilmaz E, Gencel B, Geckili O, Sakar O. Comparison of the retention of conventional and polyvinyl siloxane matrix materials with different patrices for implant-retained overdentures: an in vitro study. Int J Prosthodont. 2022;35(3):311–8.
40. Petropoulos VC, Mante FK. Comparison of Retention and Strain Energies of Stud Attachments for Implant Overdentures. J Prosthodont 2011; 20: 286–93.