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EVALUATION OF MICROSTRAIN AROUND DISTALLY INCLINED IMPLANT-SUPPORTED FIXED PARTIAL DENTURE USING LOW PROFILE ATTACHMENT (AN IN-VITRO COMPARATIVE STUDY)

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ABSTRACT

INRTODUCTION: The microstrain (με) around inclined implants will influence the selection of the type of attachment system. Studies that evaluated the microstrain around zirconium monolithic implant-supported posterior restorations with angled abutments and Low profile abutments with elastic Seeger System are lacking.
OBJECTIVES: The study aimed to assess the microstrain developed around angulated implants under vertical and oblique loading using two connection systems (OT BRIDGE and multiunit abutments (MUA) attachment systems) retained implant-supported zirconium monolithic three-unit fixed partial dentures (FPDs) using strain gauges.
MATERIALS AND METHODS: Two dummy implants were inserted in one epoxy resin class II Kennedy's classification mandibular model. The anterior implant was positioned in a vertical 0º at the right second premolar, while the posterior implant was positioned at 30º distal angulation at the right second molar. Eight zirconium monolithic three-unit FPDs were digitally designed to be assigned to 2 main groups (n=4) according to the type of attachment system (OT BRIDGE attachment group, MUA attachment group). Each group received two loads (vertical 0º and oblique 30º) in a buccolingual direction from 0 to 100 N using a universal testing machine at the center of the FPDs.
RESULTS: The microstrain around the distally angulated implant with OT BRIDGES was significantly lower than MUA vertically but vice versa in 30º obliquely.
CONCLUSION: The microstrain was significantly affected by the type of attachment system. OT BRIDGE attachment can be utilised in place of MUA attachment over angulated implants in FPDs, as a favourable stress distribution was found by vertical loading.
KEY WORDS: Fixed partial denture, OT-BRIDGE attachment, MUA attachment, Strain, Strain gauges.
CLINICAL IMPLICATIONS: The distally angled implant with the low-profile attachment in limited posterior restorative space can be used to increase the supporting occlusal table.

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INTRODUCTION

Since implants are unable to respond to occlusal loading or provide feedback, dental implant rehabilitation procedures may result in biological and mechanical complications.[1] Overload is caused by several causes, including implant-related issues regarding bone quality, prosthetic design, and patient's behavioral habits such as clenching and bruxism. [2-4] Therefore, biomechanically implant/restoration loading is necessary for the clinical success and long-term viability of implant-supported prosthesis. [5]

One of the requirements for any implant prosthesis to survive over the long term is minimum peri-implant strain. A peri-implant strain of over 4000 microstrain causes a pathologic bone fracture. [6] Therefore, upon selecting the type of prosthesis for a specific clinical situation, the esthetics and function of peri-implant strain induced in the surrounding bone should also be evaluated to ensure the prosthesis's long-term success. [7] FPD supported by implants is a popular treatment modality for partially edentulous patients. [5]
Stress distribution values surrounding the supporting implants are improved by the

inclination of implants in FPD. [8,9] Multiple biomechanical advantages are being attained by a large anteroposterior distance as a result of implant implantation with tilt, providing an adequate distribution of load in the occlusal plane, as well as avoiding a long cantilever distance and an increased bone-implant contact with the effective use of longer implants.[10]
The implant survival is directly impacted by the attachment system that is chosen. [8] Angled abutments can compensate for altered implant positions to allow its prosthesis assembly.[4] On the other hand, it might generate off-axis force on the implant[11], leading to unequal load distribution and increased strain. [12]
Multi-unit abutments have a range of angle adjustments and an exterior conical connection, allowing for a passive fit of dental prosthesis. The main drawbacks of the MUAs are their large diameter and the weakness of their secondary screw. On the contrary, its use is strongly advised due to its numerous biological and functional benefits. In recent years, several prosthetic edentulous arches have offered the OT Equator attachment as a substitute for MUA. [13]
Furthermore, low profile abutments utilizing the elastic Seeger System seem like a viable option for prosthetic challenging retreatment to resolve and get beyond the inaccurate implant placement and parallelism. The OT Bridge's Seeger System provides excellent stability, passivation, and, most importantly, management of implant disparallelisms. [14,15]
Various approaches have been used to assess the stresses on implant-supported FPDs [16], including finite element stress analysis [17-19], photoelastic stress analysis[20,21], and strain analysis. Strain gauge analysis is a method of measuring strain around an implant body that makes use of changes in electrical resistance when specific materials are subjected to a force. [20]
Few studies were presented in literature discussing microstrain regarding implant-supported posterior restorations using zirconium monolithic three-unit FPDs with straight, angled, and low profile abutments utilizing the elastic Seeger System. Therefore, the present study aimed to evaluate the microstrain developed around angulated implants using two different attachment systems (OT BRIDGE and MUA) retained implant-supported zirconium three-unit FPDs under both vertical and 30-degree oblique loading. The null hypothesis stated no significant difference between OT BRIDGE and MUA attachment systems retained implant-supported FPDs regarding the microstrain developed around angulated implants.

MATERIAL AND METHODS

Eight zirconium three-unit FPDs were constructed on one epoxy resin mandibular model with class II Kennedy's classification after placement of two implants at the right second premolar and second molar region. Based on the assumptions of a 5% alpha error and 80% study power, the sample size was estimated. The mean ± standard deviation (SD) stress on a 30° tilted titanium implant was calculated to be 25.41 ±3.18 megapascals (MPa) [22] and the mean ± SD stress on 2-implants with OT bridge attachment=114.5 ±42.61 N/m^2 × 10^2, equivalent to 0.012 ±0.004 MPa. [23] Based on a comparison of means, the sample size has been set up using a software program (G*Power 3.1.9.4; Heinrich Heine University Düsseldorf). The sample size was raised to 4 to take into consideration any potential processing mistakes in the laboratory.
A cone beam computed tomography was used to scan the epoxy resin model which was coated in a substance that mimics mucosa. According to Ramses Medical Products Factory, this mucosa had a 1.5 mm thickness that was constructed from flexible polyurethane. The implants' locations were virtually chosen using Blue Sky Plan software (Blue Sky Bio). Three-dimensional (3D) printing technology (Form 2; Formlabs) was used in the design and printing of the surgical guide. [24]
A CAD/CAM surgical guide was utilized to facilitate the insertion of two dummy implants (IS Dummy Implant; Neobiotech Co Ltd) measuring Ø4.1×10-mm in length into the mandible. The straight implant was inserted anteriorly, and the posterior implant was angled at 30 degrees distal angulation [25] with torque 35 Ncm and the final implant insertion was placed manually by the surgical torque wrench according to the manufacturer's recommendations. The straight second premolar implant was screwed with the screw in abutment (IS straight abutment; NeoBiotech) and manually tightened to 30 Ncm via a torque wrench (Torque wrench TW400; NeoBiotech) then the straight abutment (cylinder) was connected to it. According to the type of abutment screwed to the 30º distally angulated implant at the second molar area, eight zirconium monolithic three-unit FPDs were divided into 2 main groups: OT-BRIDGE attachment group (Rhein 83 Srl), and MUA attachment group (IS angled abutment; NeoBiotech).
In the OT-BRIDGE attachment group, the distally angulated dummy implant was fitted with OT EQUATOR (OT EQUATOR abutment; Rhein 83 Srl) and secured to 25 Ncm (Fig.1). The Extragrade titanium abutment with the short screw was connected to the OT EQUATOR abutment (Fig. 2). The open side of the white Seeger (Seeger with handle; Rhein 83 Srl)

must be positioned that was forced by an anti-rotational device located into the abutment (Fig. 5).

In the MUA attachment group, the distally angulated dummy implant was fitted with 30° angulated multiunit abutments (IS angled abutment; NeoBiotech) and adjusted to 30 Ncm using a manual torque wrench (Fig. 1). The straight abutment (cylinder) was connected to 30° angulated MUAs (Fig. 2).

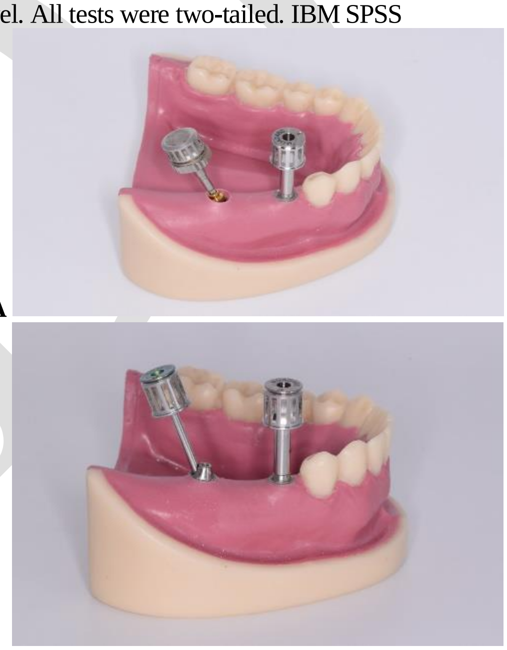
Identica Blue desktop scanner (Medit Co Ltd) was applied to scan the epoxy model after applying CAD/CAM spray (SCAN-LAC) over the abutments. The Exocad software (Dental DB 2.3Matera; Exocad GmbH) was utilized (Fig. 3,4) once the. STL file obtained from the Exocad was imported to design CAD/CAM screw-retained zirconium monolithic three-unit FPDs. Zirconia blank (Zr discs, Luxen MULTI 1100 D98; Dentalmax) was chosen as the material for the FPDs.The FPDs of both groups were milled using a dental milling machine (DWX-52Di; DGSHAPE). A fissure bur was employed to cut the connecting sprue using a straight handpiece. Smoothening and finishing of the bridges were being done. An ultrasonic cleaning machine was used for 30 seconds to remove all FPDs residual zirconia.

The fitting surfaces, seating, adaptation, and margin of the FPDs were checked on the epoxy resin model after finishing the sintering cycle then the FPDs were cemented using cement resin (B&E CHEMI CORE DUAL A3 AUTOMIX) to their corresponding abutments. Finally, by employing a digital torque gauge (HTG2- 200Nc; IMADA CoLtd), prosthetic screws were placed and mounted with 25 Ncm for the OT BRIDGE attachment group and 15 Ncm for the MUA attachment group per the manufacturer's instructions (Fig. 5).

This study employed eight self-protected linear strain gauges (KFGS; Kyowa Electronic Instruments Co Ltd) with gauge factors of 2.13 ±1%, gauge lengths of 1 mm, and gauge resistances of 119.6 ±0.4Ω to quantify microstrain in peri-implant tissues. The rectangular strain gauges rosettes were placed in the designated locations in the epoxy model. In addition to those prepared at the crestal region (mesially and distally), prepared sites with an approximate 2 mm depth were made between the strain gauge rosettes and the tested implant at the buccal and lingual aspects parallel to each implant's long axis. [26] To guarantee the full setting of the Cyanoacrylate adhesive (CC-33A; Kyowa) utilized, the strain gauges were cemented into their respective sites and kept in place for 5 minutes using Teflon sheets. The gauges were then remained for a full day. To record the developed microstrain, a multichannel circuit strain meter (PCD-300A; Kyowa Electronic Instruments Co Ltd) was wired up.

A static load in compression mode was applied from 0 to 100 N in the vertical [27] and 30-degree oblique in a buccolingual direction [28] using the universal testing machine (UTM) (Lloyd instrument LR5K; AMETEK GmbH). The device's rounded loading tip was placed on the central fossa of the lower first molar with a head speed of one mm/min [29] (Fig.6). Microstrain values were recorded for each tested dummy implant, and these values were statistically presented.

Normality was investigated using the Shapiro-Wilk test and data were parametric. The descriptive statistics of strain values around the abutment included mean and standard deviation. Data were compared between MUA and OT BRIDGE attachment groups using an independent t-test while vertical and oblique loading within each group was compared using a paired t-test. To evaluate the impact of the loading and intervention on strain values, a Two-way ANOVA was employed. The p-value of 0.05 was assigned as the significance level. All tests were two-tailed. IBM SPSS



A

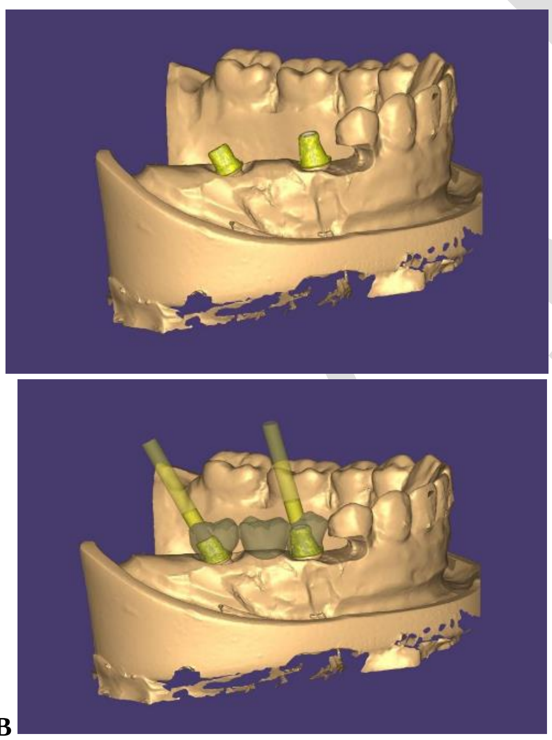
B

Figure 1. Abutments were connected to dummy implants using A, OT BRIDGE abutment. B, Multiunit abutments.

A

B

Figure 2. Titanium cylinders were connected to abutments before scanning using A, OT BRIDGE abutment. B, Multiunit abutments.



A

B

Figure 3. Virtual design of fixed partial denture with OT BRIDGE abutment after A, Scanning. B, Designing.

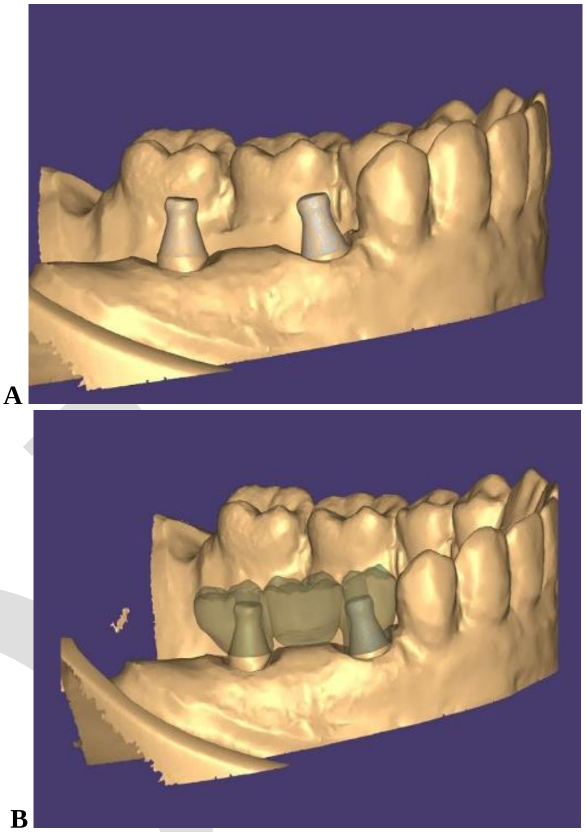


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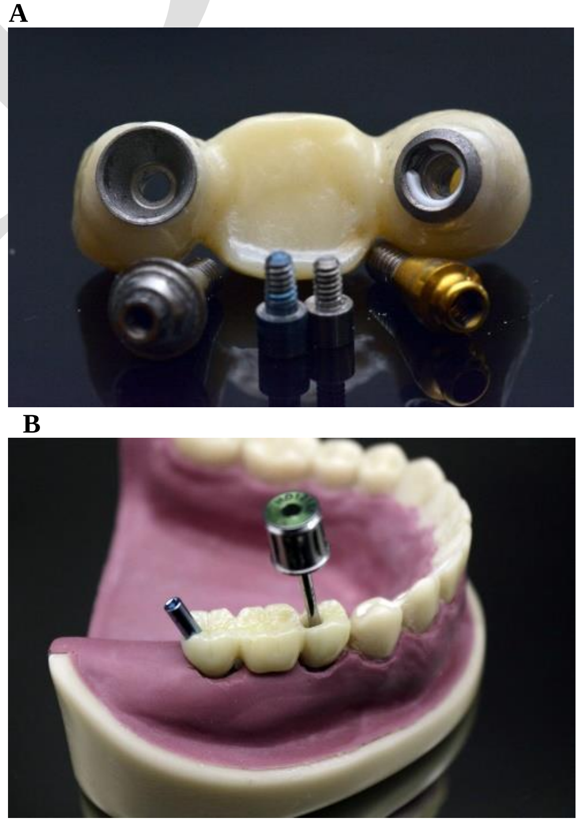
Figure 4. Virtual design of fixed partial denture with Multiunit abutment after A, Scanning. B, Designing.

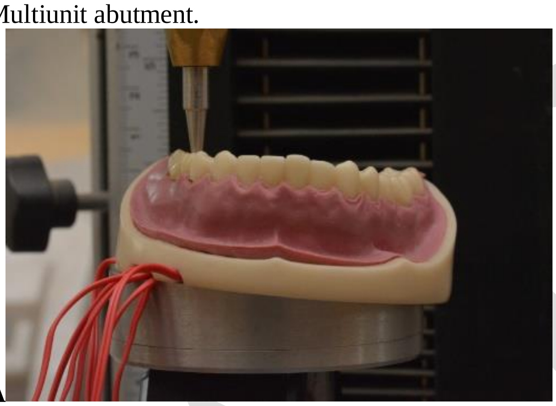
A



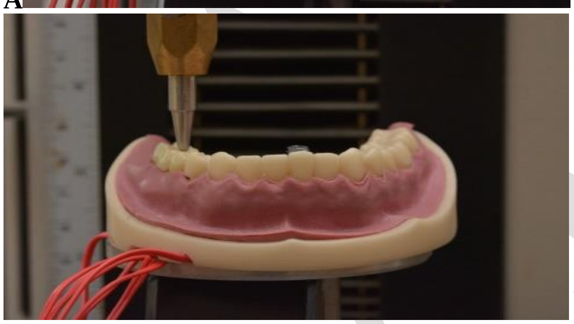
B

C

Figure 5. Fixed partial dentures were constructed A, placement of Seeger ring in OT BRIDGE. B, fixed partial denture was screwed to OT BRIDGE abutment. C, fixed partial denture was screwed to Multiunit abutment.



A



B

Figure 6. Application of load on center of fixed partial denture A, Vertical load. B, 30-degree oblique load.

Table 1: Comparison of microstrain values around implants at premolar and molar region after vertical and oblique loading using two attachment systems

		OT BRIDGE attachment	MUA attachment Mean (SD)	P value
Vertical	Second premolar	22.83 (0.93)	63.94 (3.85)	<0.001*
	Second molar	27.20 (0.87)	35.08 (0.79)	<0.001*
	P value	<0.001*	<0.001*	
Oblique	Second premolar	65.78 (0.56)	80.56 (1.65)	<0.001*
	Second molar	41.52 (0.61)	28.98 (0.56)	<0.001*
	P value	<0.001*	<0.001*	

*Statistically significant difference at p value<0.05

Table 2: Comparison of microstrain values around different implants using MUA and OT BRIDGE attachment systems after vertical and oblique loading

		OT BRIDGE attachment	MUA attachment Mean (SD)	P value
Second premolar	Vertical	22.83 (0.93)	63.94 (3.85)	<0.001*
	Oblique	65.78 (0.56)	80.56 (1.65)	<0.001*
	P value	<0.001*	0.002*	
Second molar	Vertical	27.20 (0.87)	35.08 (0.79)	<0.001*
	Oblique	41.52 (0.61)	28.98 (0.56)	<0.001*
	P value	<0.001*	<0.001*	

*Statistically significant difference at p value<0.05

Table 3: Adjusted means for intervention and loading

Variables		Mean	SE	95% CI	*P* value
Intervention	MUA attachment	52.14	4.25	43.73, 60.55	0.035*
	OT attachment	39.33	4.25	30.92, 47.74	
Loading	Vertical	37.26	4.25	28.85, 45.67	0.006*
	Oblique	54.21	4.25	45.80, 62.62	

*Statistically significant difference at p value<0.05, SE: Standard Error, CI: Confidence Interval

RESULTS

Table 1 summarizes the mε values around the dental implants with two attachment systems. A statistically significant difference became clear between the two attachment systems. The MUA attachment of the zirconium monolithic three-unit FPD showed a significant increase of microstrain around the premolar implant (63.94 ±3.85) than those of at the second molar region (35.08 ±0.79) when loaded vertically (P<.001*). On the other hand, when the FPD was loaded obliquely, both types of attachment showed a significant increase of microstrain at the second premolar region implant than the second molar implant (P<.001*). When comparing the microstrain around both implants when loaded vertically and obliquely, MUA attachment was associated with significantly greater microstrain than OT BRIDGE attachment except at the molar implant (28.98 ±0.56) when loaded obliquely.

Table 2 compares the microstrain loaded vertically and obliquely, there was a significant increase of microstrain around both implants of both attachments when loaded obliquely than vertically except at MUA attachment in the second molar.

Table 3 shows that when using Two Way ANOVA, the zirconium monolithic three-unit FPD using MUA attachment was associated with greater microstrain (52.14) than OT BRIDGE attachment (39.33). On the other hand, the oblique loading was associated with greater microstrain (54.21) than the vertical loading (37.26).

DISCUSSION

Understanding the dental implants' behavior under masticatory load, as well as analyzing their impacts with various angles or components of prosthetics, leads to customized reconstruction for every individual patient and therapeutic need. [17] In all-on-four rehabilitation, MUA and OT-Bridge may be regarded as dependable prosthetic anchoring systems that can withstand cyclic occlusal loads on the distal cantilever without appreciably reducing preload during screw tightening. [30] Before and after the posterior angulated implants are loaded, OT Bridge exhibits less screw loosening than MUA so that the microstrain won't be increased. [31] In this present study, the OT BRIDGE attachment showed significantly lower microstrain values than the MUA attachment around both implants except at the second molar implant when loaded obliquely. Therefore, the null hypothesis was proven to be rejected.

The results of this study emphasized that the microstrain was higher surrounding the straight implant as opposed to the distally angulated implant under vertical and oblique loading in MUA attachment. Combining angled abutments with an altered implant orientation may lead to a decrease in microstrain within the implant system. The angled abutment enhanced strain distribution by reorienting the implant when it wasn't positioned in an optimal axial position as mentioned by Tian et al. [4]

The potential for angled abutments to create stress is both controversial and debatable. [4] This finding was in line with those of Kilic et al. [10] and Boukhlif et al. [9] who mentioned that when comparing the model with 0°tilt to the other two fixations with 15° and 30° of tilting, the framework bridge is being exposed to higher stress values. On the other hand, this current study conflicted with Cavallaro et al. [16] Bahuguna et al. [27] Brosh et al. [20] and Begg et al. [21] in which they concluded that stresses produced and resulted through both axial and oblique loading are being increased as the abutment angulation being increased. These differences may need to be considered for a more complete comparison.

Upon comparing the microstrain around both implants when loaded vertically, OT BRIDGE attachment was associated with a significantly lower microstrain than that being produced by MUA attachment. The minor stresses were being exerted around the peri-implant bone and fixture but there might be an increase in the produced stresses above the head of the attachment due to the OT EQUATOR abutment's design. [18,19] Moreover, one important distinction between the biomechanical properties of these two systems which provide stability and passivity, even in the face of strong diparallelisms was the Seeger acetal ring of the OT BRIDGE attachment system which aids in stabilizing the prosthetic structure. [15] This outcome was matched with the finding of Cervino et al. who observed that the Seeger acetal ring guarantees a prosthesis with better retention, stability, and force distribution in the absence of screwing systems. [14] In Coordination with Cicciù et al. who mentioned that the minor stress around the peri-implant bone tissue and fixture was the Equator retained system's advantage in shape. [18]

On the other hand, the increase of microstrain around the distal implant with OT BRIDGE abutment when loaded obliquely may result due to the off-axis and uneven implant load distribution that is caused by the biomechanical effects of implant and abutment inclination. [11,12] This finding was in line with the finding of Tian et al., who concluded that an unfavorable stress distribution resulted from the implant being positioned in no optimal axial position since a straight abutment was unable to rectify the implant's improper orientation. [4]

The current study showed that when an oblique load was applied to dental implants, the microstrain value was being created around them that was higher significantly compared to the microstrain when a vertical load was applied. The distribution of force on both the implant and the surrounding bone was being improved by vertical load, leading to reduced strain. Moreover, the bending moment was being produced by the oblique load, leading to more microstrain values in comparison with those developed due to vertical loading, in which inclined implants had a larger angle of load than an axial one. [25] This result is in agreement with Guven et al. [28] who stated that the stress values on applying oblique load were found to be of higher values than that produced from axial loading, particularly on using angled implants.

Finally, clinical studies should be carried out to confirm these results and to study the microstrain developed around inclined implants using different attachment systems. Moreover, other methods of stress distribution analysis could be performed around inclined implants to evaluate the microstrains generated around inclined implants with different attachment systems.

The limitations of this study were that there was no sufficient information that fully investigated and evaluated the effect of different attachment systems supported on positional inclined implants that alter the biomechanical properties of the stresses applied on bone around implants attached to an FPD framework.

CONCLUSIONS

The following conclusions were being made in light of the current in vitro study's findings:

1. OT BRIDGE attachment can be utilised in place of MUA attachment over angulated implants in FPDs, as a favourable stress distribution was found by vertical loading.
2. The straight implant was associated with greater microstrain values for FPD with both types of attachments.
3. Higher microstrain values were being developed around implants on applying an oblique load than that produced with the vertical load.

ABBREVIATIONS

με: Microstrain.
MUA: Multiunit Abutment.
FPDs: Fixed Partial Dentures.
SD: Standard Deviation.
MPa: Megapascals.
CAD: Computer-Aided Design
CAM: Computer Aided Manufacturing
UTM: Universal Testing Machine.
N: Newton.
MM: Millimetre.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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