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Impact of PEEK matrix attachment on stress distribution of maxillary implant retained overdenture

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Abstract

Application of new modified polymers in prosthetic dentistry involved using “PEEK” in the female part of novaloc attachment. The current study aims to assess stresses induced on maxillary overdenture retained with SLActive coated implant with novaloc attachment employing PEEK as a female part against conventional SLA coated implant with locator attachment. Ten digital resin models were fabricated using digital software. Five for group "I NC" with peek attachment, five for group "II L" with locator attachment. Four implants were planned in the resin models at bilateral lateral incisors and first premolar positions. The strain gauges were installed mesial and distal to each implant, followed by denture placement and load application. Under bilateral loading, group "I NC" implants 1,4 “D” was lower than group "II L" with (27 ± 343) as P=0.0001, “M” was lower with (253.5 ± 5.96) as P=0.0001, similarly in implants 2,3 “D” was lower with (10.5± 4.25) as P=0.03, also “M” was lower with (41 ± 3.5) as P=0.0001. Also, during unilateral loading, group "II L" exhibited higher strain than group "I NC" as (P = 0.0001). where “4D” was higher with a mean difference of (-153.33). while “4M” was higher with a mean difference of (-1978.17). Moreover, “3D” was higher with a mean difference of (-268.33). also, “3M” was higher with a mean difference of (-88.33). Novaloc attachment with its PEEK Matrix offer better stress distribution than conventional locator.

Keywords: Edentulous Maxilla, Implant retained, Overdenture, Polyetheretherketone, Novaloc.

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1. Introduction

Implant failure in the maxilla is often attributed to increased stresses in supporting tissues, usually transmitted through the implants [1]. The type of attachment used and the transfer of loads to the implants are significant factors [2]. During functional loading of the implant a defect in load transfer mechanism can cause overloading in the peri implant bone, this may be induced by improper occlusion, prosthesis, or implant design [3]. Implant success rate depends on primary and secondary stability, with the former depending on the surgical procedure, bone-related factors, and implant shape and design. In contrast, the latter is influenced by implant surface treatment [4,5]. Various methods are available for implant surface treatments, classified as either subtractive or additive. Subtractive methods include machined surfaces, grit blasting or sandblasting, acid etching, dual acid etching, sandblasting, and acid-etched (SLA). On the other hand, additive methods include sintering, plasma spraying, anodization, sol-gel coating implants, and biomimetic agents. These diverse surface treatments aim to provide increased surface area for osseointegration, enhanced bonding, and increased surface roughness [6]. A new tapered implant system, named BLX SLActive, has been introduced to the market. This system features a self-cutting threaded design and an internal conical connection between the implant and abutment. It is constructed from Roxolid material, and its surface is treated using large-grit sandblasting with corundum particles, generating a macro-rough surface. This is followed by acid etching at elevated temperatures for some minutes, followed by immersion in N2 and storage in isotonic solution “NaCl”. This improved hydrophilicity [4,7,8] of implant allowing improved bonding with the surrounding bone [4,7,8]. This implant system involves Novaloc attachment, consisting of a polyetheretherketone (PEEK) matrix and an abutment of amorphous diamond-like carbon. This attachment can enhance mechanical resilience against wear and retention loss due to the material combinations. Besides, it allows compensation for angled implant placement to avoid off-axis loading [9]. Various methods are available for assessing responses in a system composed of the implant site, its surroundings, and the attachment system used. One of these methods is a strain gauge, an electrical sensor connected to the current source and inserted at the measuring point to detect deformations [10]. So, this study aims to assess strain induced on maxillary overdenture retained with SLActive coated implant with Novaloc attachment employing PEEK as a female part against conventional SLA coated implant with Locator attachment using strain analysis.

2. Materials and methods

2.1. Sample size calculation

The sample size was calculated based on a previous study, [11] assuming the normal distribution of responses within each group with a standard deviation of 4.31. The estimated mean difference was set at 15, with an effect size of 2.12 and a probability of 0.8. The Type I error probability associated with this test is 0.05. The sample size was calculated using an independent t-test using G* power software version 3.1.9.7. Total sample size = 5 per group.

2.2. Study design and ethical considerations:

This study was approved by the research ethical committee at the Faculty of Dentistry at Ain Shams University (FDASU-Rec ID 032117), acceptance date 21/3/2021, and Patient consent was obtained. Two groups were designed group one with BLX SLActive implant (Straumann®, RB, BLX, and SLActive Roxolid, Institut Straumann AG-Basel, Basel, Switzerland) with Novaloc attachment system (Novaloc®, Institut Straumann AG-Basel, Basel, Switzerland) stated as a group "I NC", and group two with conventional SLA coated implant , JdentalCare Evolution Plus, (JDentalcare SRL Via Dino Campana, Modena) with the locator attachment system (Locator, JDentalcare S.R.L. Via Dino Campana, Modena) stated as a group "II L"; figure 1.

2.3. Study Model digital construction & implant position planning

To simulate *Invivo* conditions, the invitro research was based on another clinical trial involving patients who had performed implant installation, so, CBCT of one involved patient was extracted Figure 2A. Using software (co-Diagnostix®, Dental Wings GmbH, Dusseldorf, Germany) after scan alignment, 4 "BLX SLActive with a diameter of 3.75 mm and a length of 10 mm implants were chosen on the software and placed at the bilateral maxillary lateral incisor and first premolar positions where the implants were given numbers from 1 to 4 starting from the maxillary right first premolar and Implants were aligned parallel to each other. Using (Meshmixer, Autodesk, San Rafael, CA, USA) software, the denture scan was imported, and from the edit option "face group" was chosen then angle threshold was adjusted to 7. Through using brush tool, the denture fitting surface was marked, then modify was selected from the options for "expand ring" selection, followed by smooth selection and then "invert" option was chosen and after that from "edit" select flip normals, to convert the fitting surface into soft tissue representation of the experimental model. After that from options select "edit" then "extrude" and the offset value was adjusted to -40 mm to make the model base, then from options select "edit" then "make solid" to make the model solid. On software (Exocad Gmbh, Darmstadt, Germany) using model creator, model, implant plan, and denture scan were extruded. Model alignment was adjusted, model type was set to plateless model, and implant positions were verified Figure 2B. Using Straumann library, scan abutments are inserted over the implants. The outline of soft tissue simulation is adjusted through "mask" option, followed by defining the exact extension of gingival simulation, the thickness was adjusted, and the cutback was performed for gingival simulation of 2 mm thick Figure 2C. The gingival layer will cover the entire cast surface, including the vestibule's reflection area Figure 2D. Using (Meshmixer, Autodesk, San Rafael, CA, USA) software, a tray for soft tissue simulation was designed by using the model base and gingival layer where both were extruded with offset value of 2.5mm and in normal direction. Then the tray was made solid from the options. The tray thickness was 4 mm and had three stoppers: two at the first molar area and one at the midline. Channels for strain gauge were placed in the design with a width of 2 mm and a length of 4 mm, both mesial and distal to each implant. On the model base, opposite each channel, a slot was opened. The plan generated for group "I NC" was adapted for group "II L", and the implant type was changed to JdentalCare Evolution Plus (JDENTALCARE SRL Via Dino Campana, Modena), featuring a diameter of 3.75 mm and a length of 10 mm. Subsequently, the plan was extruded into (co-Diagnostix®, Dental Wings GmbH, Dusseldorf, Germany) with the generated model to create the group "II L" model. The models were printed using clear UV-sensitive resin (Shenzen Anycubic Technology Co., Ltd.) with resin 3D printer technology (Anycubic Photon S Resin Printer). The implants were inserted in models, and the attachments (Novaloc, Locator) were screwed Figure 3A. A gingival mask (Multisil-Mask, Bredent GmbH & Co. KG, Germany) was applied, and the thickness was adjusted using the printed tray Figure 3B. The next step involves placing a gingival layer Figure (3B) over the models and inserting attachment housing. For group "I NC", a white, light, 750 g retentive cap was used, while for group "II L", a yellow, light 600 g retentive cap was employed Figure 3A.

2.4. Denture construction

Cone beam computed tomography (CBCT) of the patient's denture was used for a duplicate denture. The models with attachments were scanned using a desktop scanner, the Medit T710 (Medit, South Korea), to fabricate the denture with a housing recess in the denture fitting surface. This allowed for minor discrepancies in denture adaptation after manufacturing. The denture base was 3D printed using NextDent Denture 3D+ (NextDent B.V., Soesterberg, The Netherlands), and denture teeth were printed using NextDent C&B MFH (Micro Filled Hybrid, NextDent B.V., Soesterberg, The Netherlands). The teeth were bonded to the base using resin. The housing pickup was performed using self-cured acrylic resin (Acrostone, Egypt). Subsequently, the gingival mask was removed, and eight strain gauges (Kyowa strain gauge wires, model "KFG-1-120-C1-11 L1M2R", Japan) were installed Figure 3C, 3D. These gauges have a gauge factor of 2.11 ± 1.0%, a gauge length of 1 mm, a gauge resistance of 120.4 Ω ± 0.4%, a transverse sensitivity ratio of 1.0 ± 0.2 %, and an adaptable thermal expansion of 11.7 × 10-6 /°C with temperature compensation for steel.

2.5. Method of evaluation

Gauges were placed mesial and distal to each implant parallel to the long axis in each model, where implants were named 1,2,3,4 starting from the right 1st premolar till the left 1st premolar respectively. The mesial surface was given letter M, the distal surface was given letter D, so each slot was identified by implant number coupled with letter of the surface e.g.,1D as shown in figure 3C, 3D. using a cyanoacrylate-based adhesive (EpoBond super glue, China). The gingival layer was then placed, adhering to the model with EpoBond. Subsequently, the denture was placed for load application. A static vertical load of 100 N was applied unilaterally and bilaterally at the first molar position using a loading device (LLOYD LR5k, LLOYD instruments, Fareham, Hampshire, UK) [11]. The left side served as the loaded side for unilateral loading, while the right side remained unloaded.

2.6. Statistical analysis

Statistical analysis was performed with SPSS 20®, GraphPad Prism®, and Microsoft Excel 2016. Normality testing was performed with the Shapiro-Wilk and Kolmogorov normality tests. An independent t-test was used to compare groups I and II and between unilaterally and bilaterally loaded conditions. A paired t-test was used to compare loaded and unloaded sides between the first premolar and lateral incisor.

3. Results and Discussion

During unilateral loading of both groups as shown in table “1”, group "II L" exhibited significantly higher strain than group "I NC" (P = 0.0001); where on the loaded side “4D”, “4M” were significantly higher with a mean difference of (-153.33),(-1978.17) respectively. Moreover, “3D”, ”3M” also showed significantly higher strain with a mean difference of (-268.33) and (-88.33), respectively. The data for the unloaded side were insignificantly different for both groups regarding implants “1,2” as (P > 0.05). Comparison between implants on loaded “3,4” and unloaded “1,2” sides was performed by using Paired t test as presented in table (2). In comparison between group "I NC" and "II L" during bilateral loading as shown in table “3”, the total strain of “M, D” of “1,4”, “2,3” implant surfaces on both sides was averaged and results revealed that group "I NC" was significantly lower than group "II L" as (P=0.0001). A comparison of loaded side in unilateral loading and average of each surface on both sides “right & left “during bilateral loading in both groups as shown in table “4”, showed that the overall strain during unilateral loading was significantly higher than bilateral in both groups as P=0.0001. Application of new polymers in prosthetic dentistry has been known widely in many fields, so their application in attachment systems is the purpose of the current study, that was carried out on an already established and well-known attachment system using “PEEK” called Novaloc attachment. PEEK is a semicrystalline, thermoplastic material with a high melting temperature. Modification of peek with carbon fibers improves its modulus of elasticity, increasing its range from 3.6 GPa to 18 GPa, which is close to that of cortical bone. [12]. The results of this study showed diminished strain levels applied to supporting structures by “PEEK” material due to its well-known mechanical properties, especially resiliency. These results were in line with a study by Tekin S. *et al* ,[13] in which a finite element analysis examining the effect of PEEK in implant-supported fixed restorations, revealed that the use of PEEK abutments led to lower stresses on the abutments by transferring the stresses to the implant and screw, consequently reducing the stresses transmitted to bone. Also, Shash, Y.H. *et al* ,[14] in another study indicated that using PEEK slightly reduced the stresses transmitted to bone. During unilateral loading conditions, group “I NC” produced lower strain levels in the “M , D”, as well as average of total strain of both surfaces than group “II L” . The observed results could be related to the PEEK housing with the PEEK retentive cap used in the attachment "Novaloc" within the group "I NC". The elastic modulus of PEEK enables it to absorb the forces transmitted to the housing, thereby reducing the stresses on the supporting structures. This phenomenon is commonly called the reduction of the stress shielding effect and is related to its shock-absorbing property [13,15]. While the nylon cap of the "locator" attachment in group "II L" has a double frictional flange, leading to restricted hinge movement of the attachment during function, which increase stress on the implant during posterior loading [16]. In the comparison between implants “3,4”, the average strain of “M,D” of each implant in group "I NC" showed insignificant difference, this suggests an even stress distribution between both implants on the loaded side, owing to the effect of resiliency coupled with reduction of stress shielding provided by the presence of PEEK in attachment. These results are in line with study stating that the more resilient the attachment the more strain will be shared between the implants and bone, reducing strain on the implants [16]. While for group "II L", the average strain was higher in implant “4” than “3” which suggests more strain concentration on implant “4” which may be due to reduced resiliency of the nylon cap of locator attachment and its double frictional flange with internal and external joints that reduced movement of the attachment and made it function more like a rigid attachment, [16] these results are in line with studies stating that the effect of load application on overdenture near or at the implant position increases the load on that implant, While the lateral incisor showed lower stresses because more posterior load application reduces load on anterior implant and in this study the point of load application was at the first molar which was closer to implant “4” [17,18]. increasing functional load and strain around the implants [7]. In group "I NC", “4D” showed higher strain than “3D”, while “3M” showed higher strain than “4M”, also there was a higher strain in one surface of each implant than the other as “4D” was higher than “4M”, “3M” was higher than “3D”, so the strain was not equally distributed along each individual implant. While in group "II L", “4D”, “3D” were insignificantly different, but “4M” was higher than “3M”.

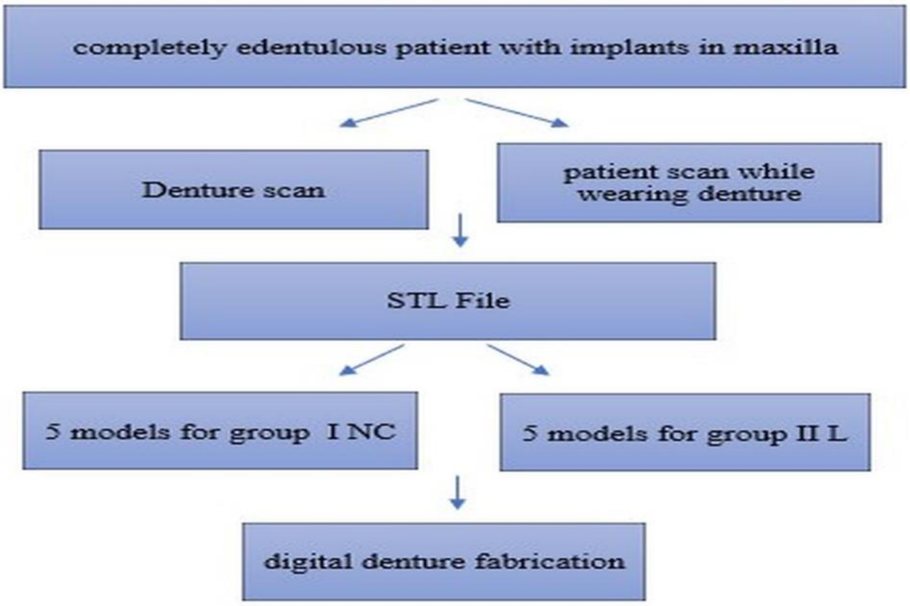

Figure 1: Flow chart showing study design

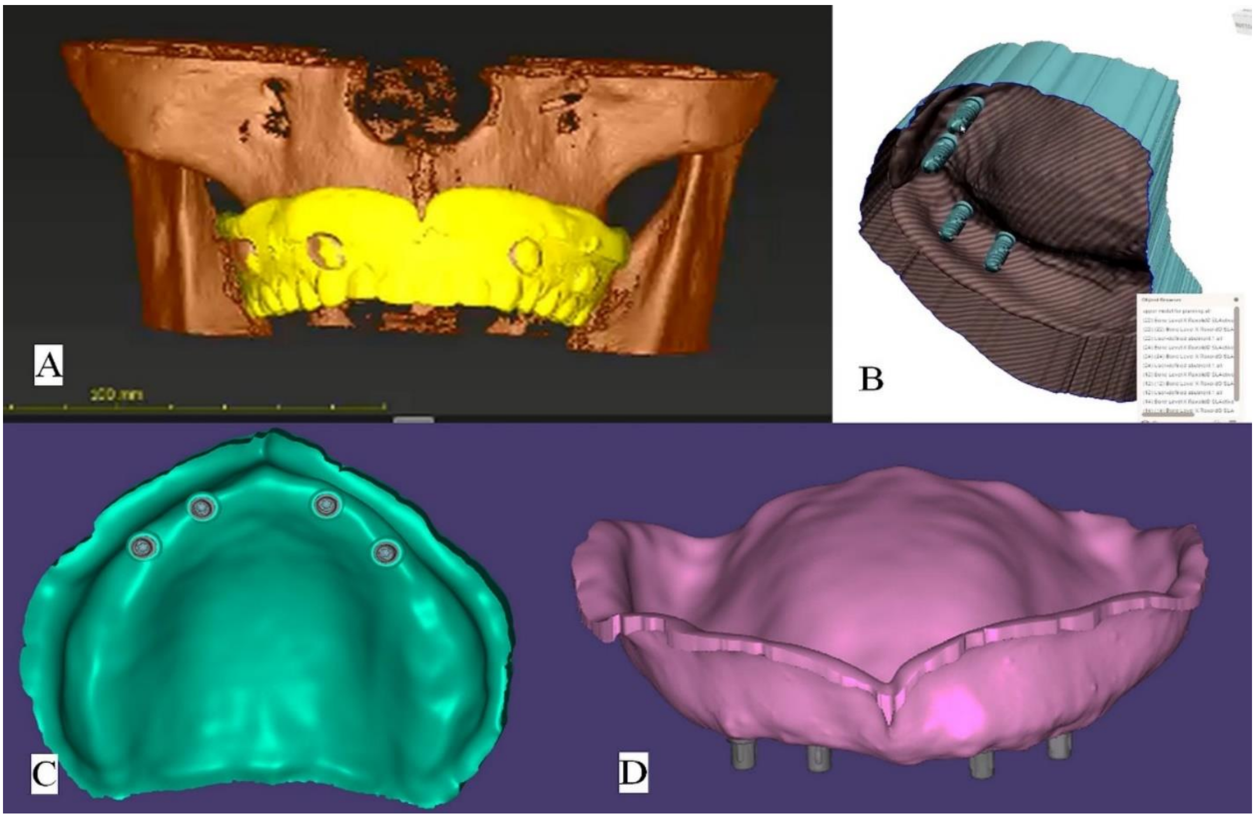

Figure 2A, 2B, 2C, 2D: A: dual scan protocol.

B: Implants positions inside the model.

C: Model after gingival cutback.

D: Gingival layer Design.

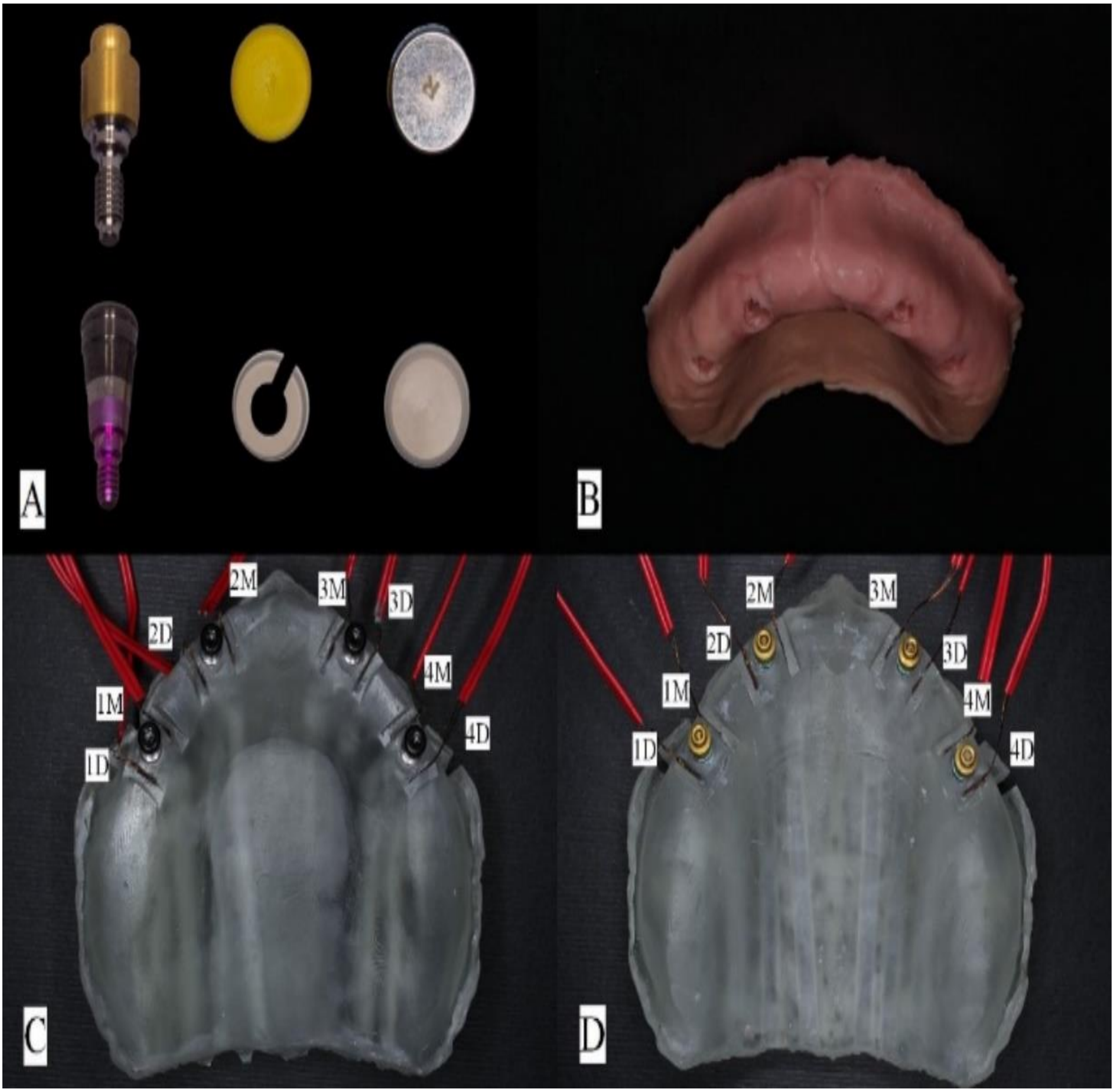

Fig 3A, 3B, 3C, 3D: A: Top left side locator abutment, resin cap, metal housing. Lower left side novaloc abutment, peek insert, peek housing.

B: Gingival layer.
C: Model with implant and novaloc with strain gauge placed.
D: Model with implant and locator with strain gauge placed.
(1D: Distal surface of maxillary right first premolar.
1M: Mesial surface of maxillary right first premolar.
2D: Distal surface of maxillary right lateral incisor.
2M: Mesial surface of maxillary right lateral incisor.
3M: Mesial surface of maxillary left lateral incisor.
3D: Distal surface of maxillary left lateral incisor.
4M: Mesial surface of maxillary left first premolar.
4D: Distal surface of maxillary left first premolar)

Table 1: Comparison between group "I NC, II L" regarding mesial, distal, overall surfaces of 1st premolar and 2nd incisor regarding loaded and unloaded sides of unilateral loaded group

Side	Tooth	surface	I NC		II L		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		P value
			M	SD	M	SD			Lower	Upper	
Loaded	1st premolar	D	96.67	8.16	250.00	7.91	-153.33	4.87	-164.36	-142.31	0.0001*
		M	35.83	7.36	2014.00	9.62	-1978.17	5.11	-1989.73	-1966.61	0.0001*
		overall	66.25	7.54	1132.00	8.73	-1065.75	4.90	-1076.83	-1054.67	0.0001*
	2nd incisor	D	41.67	16.93	310.00	7.91	-268.33	8.28	-287.07	-249.60	0.0001*
		M	81.67	8.16	170.00	7.91	-88.33	4.87	-99.36	-77.31	0.0001*
		overall	61.67	12.01	240.00	7.91	-178.33	6.29	-192.56	-164.11	0.0001*
Unloaded	1st premolar	D	24.17	5.85	70.00	106.24	-45.83	42.97	-143.04	51.37	0.31
		M	37.50	10.37	453.00	878.82	-415.50	354.80	-1218.11	387.11	0.27
		overall	30.83	2.70	261.50	492.50	-230.67	198.82	-680.43	219.10	0.28
	2nd incisor	D	18.33	4.08	82.00	133.07	-63.67	53.75	-185.26	57.92	0.27
		M	45.83	15.94	106.00	41.74	-60.17	18.32	-101.62	-18.72	0.01
		overall	39.17	10.68	94.00	87.24	-54.83	35.55	-135.25	25.58	0.16

*Significant difference as P<0.05

Table 2: Comparison between 1st premolar and 2nd incisor (Paired t test), and comparison between Mesial and distal surfaces (Paired t test) in both groups "I NC, II L" regarding loaded and unloaded sides of unilateral loaded group (Intragroup comparison).

Unilateral loaded							Paired Differences					P value
Side	Group	Surface	1st premolar "1,4"		Lateral incisor "2,3"		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		
			M	SD	M	SD				Lower	Upper	
Loaded side "3,4"	I NC	D	96.67	8.16	41.67	16.93	55.00	11.40	4.65	-66.97	-43.03	0.0001*
		M	35.83	7.36	81.67	8.16	45.83	3.76	1.54	41.88	49.78	0.0001*
		Overall	66.25	7.54	61.67	12.01	4.58	5.57	2.27	-10.43	1.26	0.10
		P value	0.0001*		0.0001*							
	II L	D	225.83	59.62	266.67	106.38	40.83	46.95	19.17	-8.44	90.10	0.09
		M	1685.00	805.93	156.67	33.42	1528.3	773.22	315.67	-2339.7	-716.8	0.0001*
		Overall	955.42	432.61	211.67	69.76	743.75	363.14	148.25	-1124.8	-362.6	0.0001*
		P value	0.005*		0.01*							
Unloaded side "1,2"	I NC	D	39.17	32.47	24.17	13.20	-15.00	19.75	8.06	-35.72	5.72	0.12
		M	35.00	6.32	48.33	21.60	13.33	18.62	7.60	-6.21	32.87	0.14
		Overall	37.08	17.44	43.33	16.63	6.25	12.04	4.92	-6.39	18.89	0.26
		P value	0.750		0.003*							
	II L	D	35.00	34.50	25.83	12.42	-9.17	22.68	9.26	-32.96	14.63	0.37
		M	55.83	11.58	85.83	7.36	30.00	15.49	6.32	13.74	46.26	0.005*
		Overall	45.42	13.71	55.83	8.32	10.42	6.74	2.75	3.34	17.49	0.01*
		P value	0.280		0.0002*							

*Significant difference as P<0.05.

Table 3: Comparison between groups "I NC, II L" (Independent t test), comparison regarding right and left lateral incisor and 1st premolar in "I NC, II L" in bilateral loaded group.

Bilateral loaded			**I NC**		**II L**		**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**		**Sig. (2-tailed)**
			M	SD	M	SD			Lower	Upper	
Right	**1st premolar "1"**	**D**	45	7.91	120	7.91	75	5	-86.53	-63.47	0.0001*
		M	31	6.52	70	7.91	39	4.58	-49.57	-28.43	0.0001*
		overall	38	7.16	95	0	57	3.2	-64.38	-49.62	0.0001*
	Lateral incisor "2"	**D**	9	4.18	27	5.7	18	3.16	-25.29	-10.71	0.0001*
		M	28	5.7	50	7.91	22	4.36	-32.05	-11.95	0.001*
		overall	18.5	2.24	48	11.51	29.5	5.24	-41.59	-17.41	0.0001*
Left	**1st premolar "4"**	**D**	86	7.42	65	7.91	21	4.85	9.82	32.18	0.003*
		M	33	10.37	501	12.94	468	7.42	-485.1	-450.9	0.0001*
		overall	59.5	8.73	283	10.37	223.5	6.06	-237.4	-209.5	0.0001*
	Lateral incisor "3"	**D**	67	10.37	70	7.91	3	5.83	-16.45	10.45	0.621
		M	35	7.91	95	7.91	60	5	-71.53	-48.47	0.0001*
		overall	51	9.12	82.5	7.91	31.5	5.4	-43.94	-19.06	0.0001*
Overall (average of right and left)	**1st premolar "1,4"**	**D**	65.5	7.58	92.5	1.2	27	3.43	19.09	34.91	0.0001*
		M	32	8.37	285.5	10.37	253.5	5.96	239.8	267.2	0.0001*
		overall	48.75	7.91	189	5.18	140.3	4.22	130.5	150	0.0001*
	Lateral incisor "2,3"	**D**	38	6.94	48.5	6.52	10.5	4.25	0.67	20.32	0.03*
		M	31.5	2.24	72.5	7.5	41	3.5	32.93	49.07	0.0001*
		overall	34.75	4.28	65.25	2.24	30.5	2.16	25.52	35.48	0.0001*

*Significant difference as P<0.05

Table 4: Comparison between loaded side in unilateral loading and average of each surface on both sides "right & left " during bilateral loading.

			Unilateral Loaded		Bilateral		MD	SED	95% CI		P value
			M	SD	M	SD			L	U	
I NC	1st premolar	D	96.67	8.16	65.5	7.58	31.17	4.9	-40.8	-18.2	0.0001*
		M	35.83	7.36	32	8.37	3.83	5.15	-14.87	8.87	0.58
		overall	66.25	7.54	48.75	7.91	17.5	4.94	-27.63	-4.87	0.01*
	Lateral incisor	D	41.67	16.93	38	6.94	3.67	8.78	-22.25	18.25	0.83
		M	81.67	8.16	31.5	2.24	50.17	3.67	-56.97	-40.03	0.0001*
		overall	61.67	12.01	34.75	4.28	26.92	5.96	-39	-11.5	0.0001*
II L	1st premolar	D	225.83	59.62	92.5	0.001	133.33	3.54	-165.65	-149.35	0.0001*
		M	1685	805.93	285.5	10.37	1399.5	6.32	-1743	-1713.9	0.0001*
		overall	955.42	432.61	189	5.18	766.42	4.54	-953.47	-932.53	0.0001*
	Lateral incisor	D	266.67	106.38	48.5	6.52	218.17	4.58	-272.07	-250.93	0.0001*
		M	156.67	33.42	72.5	7.5	84.17	4.87	-108.74	-86.26	0.0001*
		overall	211.67	69.76	65.25	2.24	146.42	3.67	-183.22	-166.28	0.0001*

*Significant difference as P<0.05

Also, regarding the implant surfaces, "4M" was higher than "4D", "3D" was higher than "3M". this difference in pattern of strain distribution between both groups and between the implant surfaces within each group could be attributed to the difference in pattern of rotational movements that occurred during loading of different types of attachment systems around fulcrum formed by the implants on the loaded side as stated in a study by Yoda, N *et al* ;[7,17] and by the fact that housing of both attachments formed of different resilient materials where each one of them when subjected to force, it absorbs amount of this force and changes its shape by the absorbed energy [19]. Under unilateral loading conditions, both groups observed higher strain levels on the loaded side. This is related to the finding that the implant on the loaded side acts as a fulcrum around which the overdenture rotates during function, increasing load [17]. While on the unloaded side group "I NC", there was insignificant difference between the overall "M,D" strain in implants "1,2" suggesting better strain distribution as stated previously, but "1M" showed higher strain than "1D" indicating area of higher strain. Regarding group "II L", the average strain of "M,D" of implant "2" showed higher strain than "1" with higher strain at "2M", this might be attributed to fulcrum formed by the implants on loaded side around which the overdenture rotates, also coupled by the effect of double friction cap of locator which tends to disengage causing increased stresses on the unloaded side that eventually expresses itself on implant "2" [17]. Furthermore, the results revealed that implants "1,4" showed higher strain during bilateral loading of both groups than "2,3". This outcome is in line with a study mentioned that the distribution of implants in a curved design, creates a condition similar to class I lever mechanics as the denture saddles cause a cantilever action due to resiliency of mucosa where the implant in the most posterior position, the first premolar, acts as a fulcrum to counteract the rotational forces on the overdenture, increasing stresses over it [20]. Furthermore, the results revealed that, when comparing bilateral and unilateral loading, there were lower strain levels in both groups during bilateral loading. This finding aligns with a study stating that, regardless of the implant site and site of load application, bilateral posterior load showed lower stress levels than unilateral loading at any site. This correlation may be attributed to the even load distribution over supporting structures during bilateral loading. This can be a valuable finding requiring attention during occlusal adjustment. Implementing bilateral balanced occlusion and allowing the patient to chew on both sides simultaneously could be beneficial in reducing the load [21]. Limitations to this study include the difference between the response of the model resin and the natural bone present in maxilla, loading conditions which are more complex in oral environment than in *invitro* and mucosal simulation layer that may differ from the natural mucosa present clinically affecting the response in *in-vivo* conditions [22] *Invivo* research may be conducted to assess these results.

4. Conclusion

Based on the results of this research, the use of BLXSLActive implant with novaloc attachment featuring peek housing and peek retentive cap in the treatment of completely edentulous maxilla, may reduce the stresses transmitted to supporting structures improving success of the prosthesis.

Conflict of interest

The authors declare no conflict of interest.

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