Influence of Internal Abutment Components on Preload, Screw Surface, and Microgap

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Introduction

Most studies regarding preload, screw physical characteristics, and alterations in implant microgap focused on external implant crest configurations.[1-4] Within the internal hex configuration, little data is available regarding differences between engaging and non-engaging abutments and its influence on the mentioned variables.[5]

The aim of this study is to investigate differences between engaging and non-engaging abutments, in internal hex implants, regarding preload, screw characteristics, and alterations in microgap before and after cyclic loading (CL).

Materials & Methods

A total of 36 internal hex implants were used. Samples were grouped into 4 groups. Group 1: Single units with engaging abutments (n=6), Group 2: Single units with non-engaging abutments (n=6), Group 3: 3-unit fixed dental prosthesis with a hemi-engaging design (n=12),Group 4:3- unit FDP with 2non-engaging abutments (n=12) (Fig.1 and 2). All specimens went through CL using a cyclic loading electrodynamic universal testing machine (Fig. 3). Load was applied to the units (1.0×106 cycles) for each loading axis, reflecting approximately 40 months of function.[6] Sine wave waveform cyclic loading with a force of 100 N was applied at a loading rate of 10 Hz. After each 180,000 cycles, the machine was stopped, and specimens were inspected for any movement or damage. Preload evaluation protocol is described in Fig. 4. Surface roughness was evaluated using a 3D optical metrology system (Fig. 5). To evaluate thread depth, an upright optical microscope Axio-imager was used (Fig. 6). Microgap was evaluated using Discovery V12 sterio-microscope (Fig. 7). Two random screw samples were selected from each group to analyze using scanning electron microscopy (SEM) (Fig. 8-10).

Specimens

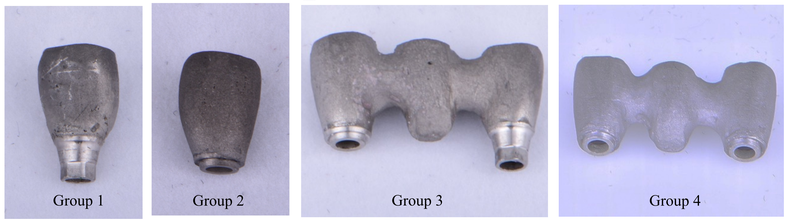

Fig. 1. All prosthetic components used were screw-retained complete cast metal alloy crowns. All specimens were designed in a similar manner with similar abutment and pontic dimensions (buccolingual, 7 mm; mesiodistal, 8 mm; interocclusal, 8 mm). A silicone key was fabricated to ensure replication of the dimensions in all specimens. A high noble alloy (Wilbond 52SF; Wil- kinson Dental Alloys) was used to cast all specimens using custom abutments (Goldadapt; Nobel Biocare AG).

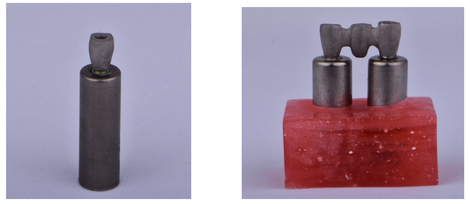

Fig. 2. Implants were mounted on 10×31-mm acrylic resin blocks embedded in the center of cylindrical metal tubes (to improve support) with 1 mm of the implant platform exposed

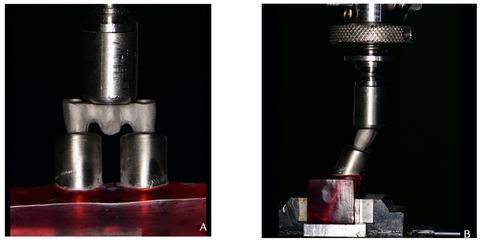

Fig. 3. The specimens went through axial CL first then the RTV was measured. After complete data collection from axial CL, 36 new abutment screws were used, and the specimens were loaded laterally 30° with the same CL settings. All specimens were mounted firmly using a custom-made holding device.

Instruments

Fig. 4. A digital screw torque meter (MGT50; Mark-10) was used to measure screw torque values with decimal precision. The handle for the abutment screwdriver (UniGrip; Nobel Biocare AG) was mounted in the 3-jaw chuck of the digital screw torque meter. The abutment screw was tightened to 35 Ncm per manufacturer's recommendation twice, 10 minutes apart. Five minutes later, RTV was measured before CL and referred to as initial preload (IP). After CL, RTV was measured and referred to as final preload (FP).

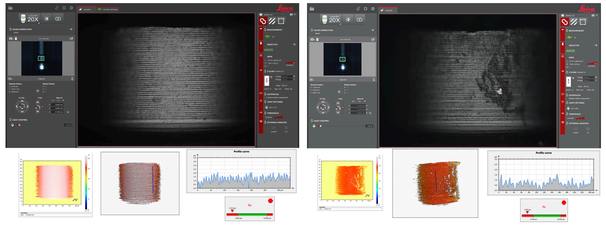

Fig. 5. Screw surface roughness was measured in μm using a mechanical digital surface profilometer and optical profiler (3D Surface Metrology Microscope, Leica DCM8) under 20x magnification. LeicaScan V6.2 scanner and LeicaMap 7.3V software was used (Leica DCM8, Wetzlar). Surface roughness evaluation was performed in three sites of the screw including the head, stem, and thread before and after each axis of CL.

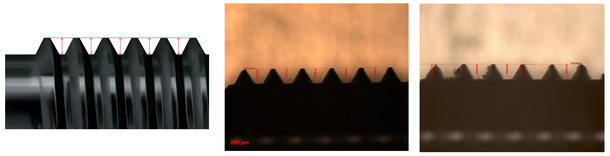

Fig. 6. To evaluate screw thread depth, an upright optical microscope Axio-imager m2m with AxioVesion V4.9.1 software (Carl Zeiss, Oberkochen) under 5x magnification was used. Distance between the thread crest and the screw stem was measured in micrometers. Five readings were reported (reflecting the 5 full threads of the screw) and an average was calculated for each screw before and after each axis of CL

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Instruments

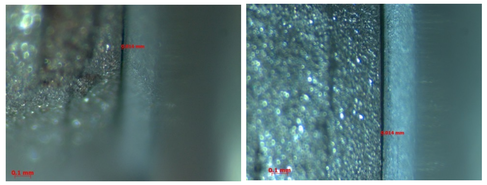

Fig. 7. Microgap was evaluated before and after each CL axis using Discovery V12 sterio-microscope (Zeiss, Oberkochen, Germany) under x60 magnification and software (AxioVision SE 64 bit release 4.8.3 (09-2011). Three random sites were selected to measure the size of the microgap vertically using a scale. An average between the 3 sites is then reported. Two investigators evaluated the microgap and a measurement was reported when both investigators reached an agreement with each readings.

SEM Evaluation Sites

Fig. 8. Scanning Electron Microscopy (SEM) evaluation was performed in 3 sites: Head, stem, and thread under 30x, 200x, and 500x magnifications before and after lateral CL.

Specimens Before Cyclic Loading

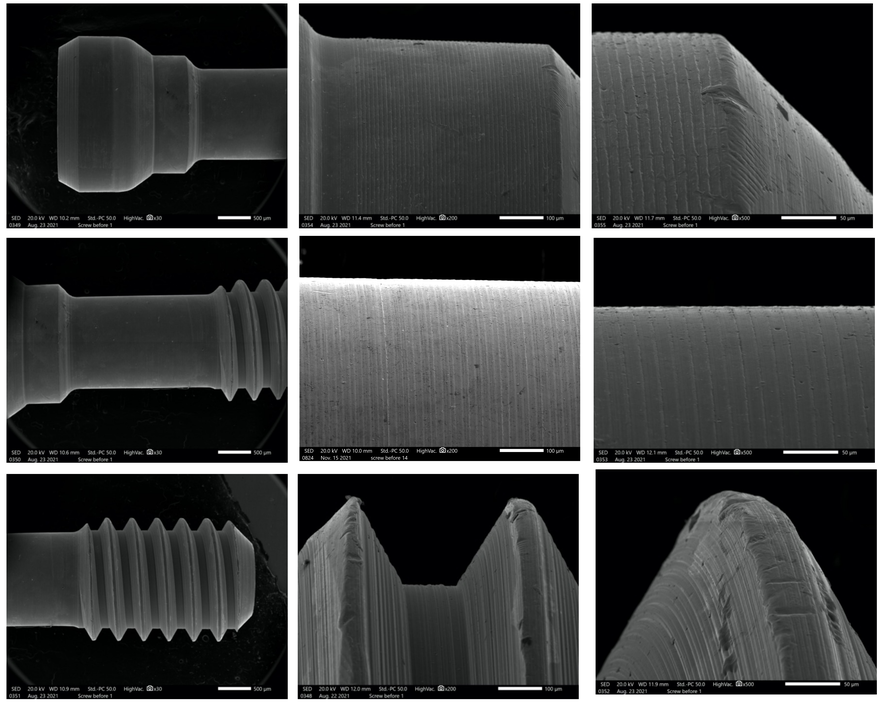

Fig. 9. Scanning Electron Microscopy before CL. .

Specimens After Cyclic Loading

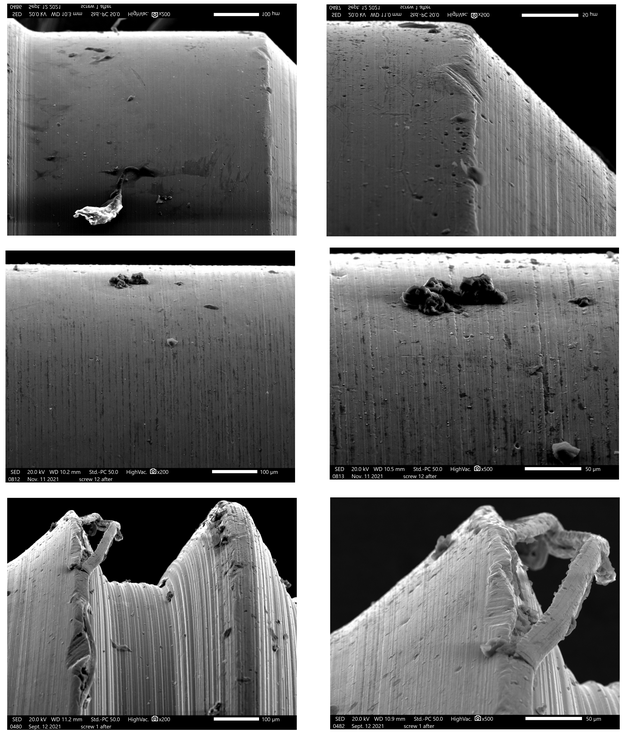

Fig. 10. Scanning Electron Microscopy after CL. .

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Results

The mean initial preload was 26.54Ncm, the mean final preload was 25.09Ncm. The mean preload efficiency before loading was 75.81% and 71.67% after. The average surface roughness was 0.369µm for the head of the screw, 0.328µm for the stem, and 1.819µm for the thread before loading. After loading, the average surface roughness was 0.298µm in the head of the screw, 0.255µm for the stem, and 1.544µm for the thread. The average thread depth before loading was 201.97µm and 199.07µm after. The average microgap size before loading was 11.2µm and 11.0µm after. Results are summarized in tables 1-5.

Loading Type	Anti-rotational component	Before CL			After CL			RTD (FP-IP) (Ncm)	PE difference (%)	p	paired sample t-test (p-value)
		IP (Ncm)	PE (%)	p	FP (Ncm)	PE (%)	p				
Axial	Engaging (N=12)	25.79 ± 0.81	73.69 ± 2.91	0.146	24.58 ± 2.32	70.24 ± 6.64	0.818	-1.21 ± 2.04	-3.45 ± 5.83	0.263	0.218
	Non-engaging (N=24)	26.60 ± 1.86	76.01 ± 5.33		24.23 ± 4.99	69.23 ± 14.25		-2.38 ± 5.85	-6.79 ± 16.72		0.059
Lateral	Engaging (N=12)	27.63 ± 1.88	78.93 ± 5.38	0.129	23.50 ± 3.00	67.14 ±8.6	0.016*	-4.13 ± 2.63	-11.79 ± 7.51	0.001*	<0.001*
	Non-engaging (N=24)	26.48 ± 2.17	75.65 ± 6.20		26.98 ± 4.25	77.10 ± 12.15		0.50 ± 4.20	1.44 ± 11.99		0.562
	Abbreviations: CL: cyclic loading, FP: final preload, IP: initial preload, PE: preload efficiency, RTD: reverse torque difference * p-value < 0.05										

Table 1. Comparison of initial preload, final preload and preload efficiency before and after cyclic loading between engaging and non-engaging abutments (Mean ± SD) using Mann-Whitney test and paired sample t-test exploring change in preload within groups.

Loading type	Group	Before CL			After CL			RTD (FP-IP) (Ncm)	PE difference (%)	p	paired sample t-test (p-value)
		IP (Ncm)	PE (%)	p	FP (Ncm)	PE (%)	p				
Axial	1 (N=6)	25.58 ± 1.07	73.10 ± 3.05	0.089	23.50 ± 2.68	67.14 ± 7.67	0.149	-2.08 ± 2.31	-5.95 ± 6.60	0.060	0.078
	2 (N=6)	25.50 ± 1.67	72.86 ± 4.78		25.08 ± 2.06	71.67 ± 5.88		-0.42 ± 1.53	-1.19 ± 4.37		0.534
	3 (N=12)	25.87 ± 1.38	73.93 ± 3.95		26.29 ± 1.83	75.12 ± 5.22		0.42 ± 1.86	1.19 ± 5.30		0.453
	4 (N=12)	27.21 ± 1.98	77.74 ± 5.66		22.46 ± 6.35	64.17 ± 18.14		-4.75 ± 7.44	-13.57 ± 21.25		0.049*
Lateral	1 (N=6)	27.75 ± 1.99	79.29 ±5.70	.079	23.83 ± 2.38	68.10 ± 6.80	.503	-3.92 ± 2.73	-11.19 ± 7.79	.262	0.017*
	2 (N=6)	26.58 ± 1.66	75.95 ± 4.73		27.27 ± 3.44	77.90 ± 9.83		0.68 ± 3.53	1.95 ± 10.09		0.656
	3 (N=12)	27.71 ±1.48	79.17 ± 4.24		26.46 ± 4.88	75.60 ± 13.95		-1.25 ± 4.31	-3.57 ± 12.33		0.337
	4 (N=12)	25.71 ± 2.53	73.45 ± 7.22		25.46 ± 4.47	72.74 ± 12.77		-0.25 ± 4.98	-0.71 ± 14.23		0.865
	Abbreviations: CL: Cyclic loading, FP: final preload, IP: initial preload, PE: Preload efficiency, RTD: reverse torque difference Group 1: Single units with engaging abutments Group 2: Single units with non-engaging abutments Group 3: 3-unit fixed dental prosthesis (FDP) with a hemi-engaging design (1 engaging and 1 non-engaging abutment) Group 4: 3-unit FDP with 2 non-engaging abutments * p-value < 0.05										

Table 2. Comparison of initial preload, final preload and preload efficiency before and after cyclic loading between groups (Mean ± SD) using the one-way ANOVA test and paired sample t-test exploring change in preload within groups.

Loading	Screw Surface Roughness (Ra)	Site	Engaging (N=12)	Non-engaging (N=24)	p
Axial	Before Cyclic Loading	Head	0.409 ± 0.116	0.349 ± 0.110	
		Stem	0.317 ± 0.126	0.313 ± 0.101	
		Thread	1.756 ± 0.229	1.781 ± 0.264	
	After Cyclic Loading	Head	0.326 ± 0.088	0.263 ± 0.091	0.054
		Stem	0.250 ± 0.097	0.242 ± 0.082	0.799
		Thread	1.446 ± 0.209	1.420 ± 0.171	0.696
	Difference (paired sample t-test)	Head	0.083 ± 0.061 (0.001*)	0.086 ± 0.077 (<0.001*)	0.906
		Stem	0.067 ± 0.040 (<0.001*)	0.071 ± 0.067 (<0.001*)	0.839
		Thread	0.310 ± 0.145 (<0.001*)	0.360 ± 0.205 (<0.001*)	0.452
Lateral	Before Cyclic Loading	Head	0.351 ± 0.065	0.377 ± 0.046	
		Stem	0.337 ± 0.020	0.345 ± 0.031	
		Thread	1.881 ± 0.087	1.857 ± 0.092	
	After Cyclic Loading	Head	0.276 ± 0.010	0.331 ± 0.077	0.077
		Stem	0.256 ± 0.040	0.271 ± 0.042	0.340
		Thread	1.636 ± 0.126	1.671 ± 0.142	0.484
	Difference (paired sample t-test)	Head	0.075 ± 0.054 (0.001*)	0.047 ± 0.051 (<0.001*)	0.129
		Stem	0.081 ± 0.028 (<0.001*)	0.075 ± 0.036 (<0.001*)	0.606
		Thread	0.245 ± 0.160 (<0.001*)	0.186 ± 0.124 (<0.001*)	0.234

Table 3. Comparison of screw surface roughness (Mean ± SD) of the head, stem and thread before and after cyclic loading in engaging and non-engaging abutments using the Mann-Whitney test and comparison after cyclic loading using the paired sample test.

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Loading type	Average Screw Thread Depth (µm)	Engaging (N=12)	Non-engaging (N=24)	p
Axial	Before Cyclic Loading	202.06 ± 2.53	202.89 ± 1.33	
	After Cyclic loading	198.80 ± 2.62	199.90 ± 1.35	0.192
	Difference (paired sample t-test)	3.26 ± 1.54 (<0.001*)	2.99 ± 1.15 (<0.001*)	0.559
Lateral	Before Cyclic Loading	201.07 ± 0.98	201.44 ± 1.18	
	After Cyclic loading	198.78 ± 1.36	198.51 ± 1.52	0.601
	Difference (paired sample t-test)	2.29 ± 1.14 (<0.001*)	2.93 ± 0.86 (<0.001*)	0.066

Table 4. Comparison of screw thread depths (Mean ± SD) before and after cyclic loading in engaging and non-engaging abutments using Mann-Whitney test and comparison of screw thread depth after cyclic loading using the paired sample t-test.

Loading type	Microgap size (µm)	Engaging (N=12)	Non-engaging (N=24)	p
Axial	Before Cyclic Loading	12.9 ± 4.8	12.2 ± 3.8	0.628
	After Cyclic Loading	10.6 ± 2.4	12.7 ± 5.0	0.191
	Difference (µm) (paired sample t-test)	-2.3 ± 3.6 (p = 0.054)	0.5 ± 4.8 (p = 0.624)	0.091
Lateral	Before Cyclic Loading	12.7 ± 3.4	11.8 ± 2.6	0.404
	After Cyclic Loading	10.6 ± 2.3	12.1 ± 2.4	0.084
	Difference (µm) (paired sample t-test)	-2.1 ± 2.7 (p = 0.022*)	0.2 ± 2.5 (p = 0.650)	0.015

Table 5. Comparison of microgap size (Mean ± SD) before and after cyclic loading in engaging and non-engaging abutments using Mann-Whitney test and paired sample t-test.

Conclusion

There was no difference between loading types on prelaod, surface characteristics, or microgap. There was no difference between engaging and non-engaging abutments in terms of preload, screw surface characteristics, or microgap. Nonetheless, final preload after lateral loading was lower in engaging abutments. For single units, there was a drop in preload after lateral loading in engaging abutments only. There is evidence suggesting that for FDPs, the abutment design might impact preload.

Acknowledgment

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