Cumhuriyet Dental Journal

Volume 18 Issue 2

doi: 10.7126/cdj.58140.5000086296

available at http://dergipark.ulakbim.gov.tr/cumudj/

RESEARCH ARTICLE

Comparison of saliva leakage amounts into internal implant cavities in three different internal implant-abutment interface configurations

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ARTICLE INFO

Article history:
Received 12 January 2015
Accepted 02 February 2015

Keywords:
Microleakage,
Implant configuration,
Abutment,
Implant-Abutment Interface

ABSTRACT

Objectives: The aim of the present in vitro study was to compare the saliva leakage degrees of 3 different implant-abutment interface configurations.

Materials and Methods: Implant systems with 3 different implant-abutment interfaces; internal perpendicular hexagon (IPH) (n=10), 11-degree angle morse-taper (IMT) (n=10), and 1.5-degree-angle cold welding type joints (ICW) (n=10) were selected. Totally 30 implant-abutment specimens were obtained by connecting the abutments to relevant implants. Initial (dry) weights (g) of the specimens were measured, recorded and all specimens were stored into artificial saliva. Subsequent weight measurements were performed at the end of 1st day, 7th day and 30th day storage.

Results: Significant weight differences were found both between experimental groups and between 4 weighting times within groups. Group ICW displayed significantly lowest weight difference values (lowest leakage) at all weighting times compared to groups IMT and IPH. Group IMT displayed higher but not significant weight difference values compared to group IPH at all weighting times.

Conclusions: All tested systems displayed significant weight increases in each of the subsequent measurement times. Cold welding type implant-abutment configuration showed the lowest leakage values and was found the most suitable interface geometry for the minimization of leakage compared to other systems. Perpendicular hexagonal and morse taper type joint configurations displayed similar leakage values.

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INTRODUCTION

The introduction of osseointegrated dental implants in the field of prosthetic dentistry has revolutionized the fixed prosthodontics treatment options that can be offered to patients. Today, osseointegrated dental implants are considered as one of the most successful treatment modalities in dentistry with their long-term predictability and high survival rates. [1]

An implant-supported rehabilitation is usually comprised by an endosseous implant that connects to a transmucosal abutment which supports a prosthetic restoration by means of cementation or screwing. The location of this connection can be either submerged at bone crest level or non-submerged.[1-3] However, when a prosthetic abutment is connected to an implant fixture, a microgap is created between the two components. The presence of a microgap between the implant-abutment (IA) interface enables the penetration and colonization of microorganisms into the internal implant cavity via saliva leakage.[4] The increasing propagation of microorganisms around peri-implant tissues causes chronic inflammatory responses which may lead to the loss of bone and implants.[4-7]

It was reported that high inflammatory cell content was a common finding in regions near to IA connection area. That phenomenon was attributed to the adhesion and proliferation of bacteria on the biofilm formed at the IA interface during prosthetic component installation and may contribute to the development of mucositis or peri-implantitis.[7-9] Several configurative alterations have been made in an attempt to reduce the IA microgap for decreasing both its mechanical and biological drawbacks. However, limited success has been achieved.[8]

Several in-vivo and in-vitro studies emphasized that bacterial invasion of the peri-implant sulcus originated from the internal implant cavity. It was also reported that the access of bacteria into internal implant cavity was due to microleakage between IA interfaces or to the contamination of the internal implant cavity by saliva or blood during implant placement surgery.[8-13] Furthermore, a clinical prospective study noticed that minimal early bone resorption was seen in one-piece implants which do not have an IA interface microgap.[14]

It was determined in other clinical studies that a close correlation exists between the intensity of bacterial accumulation and the amount of peri-implant bone loss. On the other hand, biological complications like increased microleakage, gingivitis, bone destruction and mechanical complications such as increased incidence of abutment rotation, abutment fracture, screw loosening and preload reduction are frequently seen in poorly adapted implant-abutment interfaces.[5,11,14-18]

The amount of bacterial leakage at an IA interface mainly depends on the precise fitting between these two pieces, on the magnitude of tightening torque forces and on the micro-movements between the connected components during chewing functions.[17,19-22] In all implant systems the implant-abutment joint configuration determines the mechanical integrity, strength and stability of the assembly. Internal structures, internal configuration, IA joint configuration, existence of screw grooves, groove geometry, groove frequency, surface topography and chemical composition are critical factors of an implant's physical characteristics.[17,23-27] Internal taper systems were conceived to minimize the screw loosening and screw fracture complications typically seen in external hexagonal butt joint connections. Internal taper is a bioconic connection mechanism (cone-to-cone) whose stability and accuracy is significantly increased by the preloads generated by the contact surfaces and by abutment screw resulting from controlled torque.[26, 27]

Several previous studies compared the microleakage seen in different implants systems having different IA interfaces. Canullo et al.[15] compared the bacterial leakage amount in implants with external hexagon, internal hexagon and conical IA joint configurations and did not find any difference.

Berberi et al.[21] compared the inner volumes and leakage amounts of three different implant systems (Astra Tech, Euroteknika and Dentium) having the same IA joint (conical hex connection with 11-degree angulation) and reported that Astra Tech implants displayed the lowest leakage values.

Baggi et al.[28] compared the bacterial leakage values of two different implants systems with tube-in-tube (internal taper) IA joint and flat-to-flat (external hexagon) IA joint type. The authors reported that tube-in-tube IA joint type showed lower bacterial colonization then flat-to-flat joint type and added that IA interface geometry influenced both bacterial and yeast colonization.

Nascimento et al.[29] compared the saliva leakage degrees of three implants systems with external hexagon, internal hexagon and morse-cone connection IA joint types using microbial counting measurement and stated that the morse-cone IA interface configuration showed the lowest count of microorganisms under both loaded and unloaded conditions. It was emphasized that external and internal hexagon IA joint configurations displayed higher incidence of bacteria.

Despite numerous studies giving detailed knowledge about the microbial leakage detected in different implant systems and its side-effects on peripheral tissues, not any study is available in the literature that compared the degree of fluid microleakage degrees in different internal implant-abutment joint configurations. The purpose of the present in vitro study was to compare the fluid microleakage degrees of 3 different implant systems with internal perpendicular hexagonal, internal 11-degree angle morse taper and internal 1.5-degree angle cold welding type IA joint configurations.

MATERIALS AND METHODS

Three implant systems with different internal IA joint configurations; internal perpendicular hexagonal type joint implant system (IPH) (Swiss-Plus, Zimmer) (n=10), internal 11-degree angle morse-tapered type joint implant system (IMT) (MegaGen) (n=10), and internal 1.5-degree-angle cold welding type joint implant system (ICW) (Bicon) (n=10) were selected, and 3 experimental groups were established. All selected implants were 10 mm long and 3.5 mm in diameter.

Preparation of artificial saliva

The chemical components used for obtaining 1 litre of artificial saliva were prepared as follows: NaCl (1280 mg), $CaCl_2$ (166.5 mg), $MgCl_2(6H_2O)$ (125 mg), KCl (95 mg), CH_3COOK (1505 mg), 85% $K_3PO_4(3H_2O)$ (386 mg) and 85% H_3PO_4 (0.05 ml). These materials were stirred in a metal container full of 1 liter of distilled water until obtaining complete limpidity. The pH value of the obtained solution was between 6.5 and 7.

Weight measurements

Before measurements, all abutments of implant specimens were connected onto their relevant implant fixture using the torque wrench of the relevant system. The magnitude of applied torque forces was determined according to the recommendations of the manufacturers. The implant-abutment connection of ICW implant system was performed via tapping the abutment into the internal implant hole with the specially designed hammer of the system.

After completion of the IA connection procedure, initial (dry) weights of connected implant-abutment specimens (CIASs) were measured at room temperature and obtained values were recorded (g). All CIASs were then transferred into the metal container full of artificial saliva. A thermal cycling equipment with a dwell time of 10 minutes (6 cycles/hour or 144 cycles/day) and a temperature interval between 5°C and 55°C was set into the container.

At the end of 1 day (24 hours) storage, CIASs were taken out of saliva, the surfaces were dried with air-spraying for 2 minutes until obtaining absolute surface dryness and each CIAS was subjected to the second weighting procedure at room temperature. After the completion of each weight measurement the CIASs were returned to the container. Following initial and 1st day saliva storage weighting procedures, 3rd and 4th weight measurements were performed at the end of 7th day and 30th day saliva storage using the previously described method. Obtained values (g) were recorded.

Following the completion of weight measurement procedures the CIASs were embedded with clear acrylic resin into cylindrical plastic boxes (3 cm long and 2 cm in diameter) such as their long axes be perpendicular to the horizontal plane using a parallelometer device (Amann Girrbach, af35, Koblach, Austria). The CIASs were then longitudinally sectioned along their centers with a water-jet cutting apparatus (Peyar Su Jeti, Ostim, Ankara, Turkey) and obtained cross-sections were photographed using a stereomicroscope (Leica EZ4 HD, Wetzlar, Germny) under 8x magnification (Figs 1, 2, and 3). Internal gaps of 3 implant systems were visually compared on photographs in regard of I/A connection fit, gap between internal implant hole and the abutment screw and width of the internal hole basement.

Statistical Analyses

Data were analyzed with a statistical software program (SPSS 9.0 for Windows, SPSS Inc, Chicago, Ill). Descriptive analyses of all measurements were performed. The degree of microleakage was calculated according to weight differences between initial (control) and successive CIAS weights. Differences between weight values obtained at initial, 1st, 7th and 30th days were compared with 1-way ANOVA test for each experimental group. The Bonferroni correction was applied as Post Hoc test for paired comparisons between groups. The comparisons of differences within groups were performed with Paired Samples -T Test.

RESULTS

Means weight values (g) and standard deviations of 3 experimental groups obtained in 4 different weighting times are presented at Table I. Mean weight difference values (g) of experimental groups and standard deviations obtained in 4 different measurement days are shown at Table II. One-way ANOVA test results of weight difference comparisons between initial, 1st, 7th and 30th day weight measurements are displayed at Table III. Paired comparisons between weight differences (g) of experimental groups measured at different times are given at Table IV and statistical significance of weight differences between initial weight values (g) and 1st day, 7th day and 30th day values within groups are presented at Table V. Weight increase

Table 1. Means weight values (g) and standard deviations of 3 experimental groups obtained in 4 different weighting times

Groups	Weighting times	Mean	Std. Dev.	Mean Std. Error
IMT				
Pair 1	Initial	,6527	,00318	,00101
	Day1	,6552	,00654	,00207
Pair 2	Initial	,6527	,00318	,00101
	Day7	,6722	,00593	,00188
Pair 3	Initial	,6527	,00318	,00101
	Day30	,6823	,00753	,00238
Pair 4	Day1	,6552	,00654	,00207
	Day7	,6722	,00593	,00188
Pair 5	Day1	,6552	,00654	,00207
	Day30	,6823	,00753	,00238
Pair 6	Day7	,6722	,00593	,00188
	Day30	,6823	,00753	,00238
IPH				
Pair 1	Initial	,6270	,05644	,01785
	Day1	,6310	,05727	,01811
Pair 2	Initial	,6270	,05644	,01785
	Day7	,6487	,05774	,01826
Pair 3	Initial	,6270	,05644	,01785
	Day30	,6533	,05730	,01812
Pair 4	Day1	,6310	,05727	,01811
	Day7	,6487	,05774	,01826
Pair 5	Day1	,6310	,05727	,01811
	Day30	,6533	,05730	,01812
Pair 6	Day7	,6487	,05774	,01826

Contd...

Table 1. Contd...

Groups	Weighting times	Mean	Std. Dev.	Mean Std. Error
	Day30	,6533	,05730	,01812
ICW				
Pair 1	Initial	,9894	,30216	,09555
	Day1	,9903	,30302	,09582
Pair 2	Initial	,9894	,30216	,09555
	Day7	,9923	,30438	,09625
Pair 3	Initial	,9894	,30216	,09555
	Day30	,9966	,30636	,09688
Pair 4	Day1	,9903	,30302	,09582
	Day7	,9923	,30438	,09625
Pair 5	Day1	,9903	,30302	,09582
	Day30	,9966	,30636	,09688
Pair 6	Day7	,9923	,30438	,09625
	Day30	,9966	,30636	,09688

percentage values of experimental groups according time intervals were depicted at Table VI.

Means and standard deviations of weight difference values of 3 experimental groups measured at 1st, 7th and 30th days are depicted in Fig 4. Graphical comparison of determined weight difference amounts of experimental groups in different measurement times are shown in Fig 5. Graphical comparison of weight increase percentages of experimental groups according time intervals was shown in Figure 6.

Significant weight differences were found both between experimental groups and between 4 weighting times within groups. Group ICW displayed significantly lowest weight difference values (lowest leakage) at all weighting times compared to groups IMT and IPH. Group IMT displayed higher but not significant weight difference values compared to group IPH at all weighting times. It was also determined that the most intensive weight increase in all experimental groups occurred at 0-7 day time interval.

Visual observations of cross-sectional photographs of 3 different implant systems revealed coherent results with those obtained in weight measurements. It was determined that a considerable amount of longitudinal gap existed between abutment screws and internal implant holes in groups

Table 2: Mean weight difference values (g) of experimental groups and standard deviations (min, max) obtained in 4 different measurement days

Weighting Times	Group	Mean (g)	Standard Deviation	Standard Error	Minimum	Maximum
Initial - Day1	IPH	0,0038	0,00605	0,00191	0,00	0,02
	IMT	0,0064	0,00170	0,00054	0,00	0,01
	ICW	0,0008	0,00078	0,00025	0,00	0,00
Initial - Day7	IPH	0,0299	0,00664	0,00210	0,02	0,04
	IMT	0,0348	0,00517	0,00164	0,02	0,04
	ICW	0,0025	0,00345	0,00109	-0,01	0,01
Initial - Day30	IPH	0,0454	0,00954	0,00302	0,03	0,05
	IMT	0,0421	0,00477	0,00151	0,04	0,05
	ICW	0,0068	0,00430	0,00136	0,00	0,02

Table 3. One-way ANOVA test results of weight difference comparisons between initial, 1st, 7th and 30th day weight measurements (confidence level; $p<.05$)

1-Way ANOVA						
Weighting Times	Comparisons	Sum of Squares	df	Mean Square	F	Significance
Initial - Day1	Between Groups	,000	2	,000	5,971	,007
	Within Groups	,000	27	,000		
	Total	,001	29			
Initial - Day7	Between Groups	,006	2	,003	109,871	,000
	Within Groups	,001	27	,000		
	Total	,007	29			
Initial - Day30	Between Groups	,009	2	,005	103,804	,000
	Within Groups	,001	27	,000		
	Total	,010	29			

IMT and IPH, while not any visible gap was detected between the abutment projections and the internal holes in group ICW. However, larger cavities were determined

Table 4. Paired comparisons between weight differences (g) of experimental groups measured at different times

Bonferroni Post Hoc Test's Multiple Comparisons							
Dependent Variable	Main group (a)	Compared group (b)	Mean Difference (a-b)	Std. Error	Signif.	95% Confidence Interval	
						Lower Bound	Upper Bound
Initial - Day1	IMT	IPH	-,00257	,00164	,383	-,0067	,0016
		ICW	,00308	,00164	,213	-,0011	,0073
	IPH	IMT	,00257	,00164	,383	-,0016	,0067
		ICW	,00565*	,00164	,006	,0015	,0098
	ICW	IMT	-,00308	,00164	,213	-,0073	,0011
		IPH	-,00565*	,00164	,006	-,0098	-,0015
Initial - Day7	IMT	IPH	-,00493	,00235	,136	-,0109	,0011
		ICW	,02740*	,00235	,000	,0214	,0334
	IPH	IMT	,00493	,00235	,136	-,0011	,0109
		ICW	,03233*	,00235	,000	,0263	,0383
	ICW	IMT	-,02740*	,00235	,000	-,0334	-,0214
		IPH	-,03233*	,00235	,000	-,0383	-,0263
Initial - Day30	IMT	IPH	,00324	,00297	,855	-,0043	,0108
		ICW	,03858*	,00297	,000	,0310	,0462
	IPH	IMT	-,00324	,00297	,855	-,0108	,0043
		ICW	,03534*	,00297	,000	,0278	,0429
	ICW	IMT	-,03858*	,00297	,000	-,0462	-,0310
		IPH	-,03534*	,00297	,000	-,0429	-,0278

The confidence level was set at $p<.05$

between the apices of abutment screws and the bases of internal implant holes in groups ICW and IMT compared to those of group IPH (Figures 1, 2 and 3).

DISCUSSION

Despite numerous papers giving detailed knowledge about the microbial leakage determined in different implant systems

Table 5. Statistical significance of weight differences between initial weight values (g) and 1st day, 7th day and 30th day values within groups

Groups	Time intervals	Paired differences					t	df	Sig. (2-tailed)
		Mean	Std. Dev.	Std. Error Mean	95% Confidence interval of the difference				
					Lower	Upper			
IMT									
Pair 1	Initial -Day1	-,00252	,00399	,00126	-,00537	,00033	-2,000	9	,077
Pair 2	Initial -Day7	-,01950	,00435	,00138	-,02261	-,01639	-14,165	9	,000
Pair 3	Initial- Day30	-,02962	,00625	,00198	-,03409	-,02515	-14,976	9	,000
Pair 4	Day1 - Day7	-,01698	,00540	,00171	-,02085	-,01311	-9,935	9	,000
Pair 5	Day1 - Day30	-,02710	,00596	,00188	-,03136	-,02284	-14,384	9	,000
Pair 6	Day7 - Day30	-,01012	,00337	,00106	-,01253	-,00771	-9,505	9	,000
IPH									
Pair 1	Initial - Day1	-,00406	,00123	,00039	-,00494	-,00318	-10,458	9	,000
Pair 2	Initial - Day7	-,02176	,00335	,00106	-,02416	-,01936	-20,516	9	,000
Pair 3	Initial - Day30	-,02629	,00268	,00085	-,02821	-,02437	-31,000	9	,000
Pair 4	Day1 - Day7	-,01770	,00327	,00103	-,02004	-,01536	-17,131	9	,000
Pair 5	Day1 - Day30	-,02223	,00237	,00075	-,02393	-,02053	-29,659	9	,000
Pair 6	Day7 - Day30	-,00453	,00195	,00062	-,00592	-,00314	-7,346	9	,000
ICW									
Pair 1	Initial - Day1	-,00092	,00109	,00034	-,00170	-,00014	-2,674	9	,025
Pair 2	Initial - Day7	-,00284	,00311	,00098	-,00506	-,00062	-2,890	9	,018
Pair 3	Initial - Day30	-,00722	,00570	,00180	-,01130	-,00314	-4,004	9	,003
Pair 4	Day1 - Day7	-,00192	,00269	,00085	-,00384	,00000	-2,261	9	,050
Pair 5	Day1 - Day30	-,00630	,00503	,00159	-,00990	-,00270	-3,963	9	,003
Pair 6	Day7 - Day30	-,00438	,00423	,00134	-,00741	-,00135	-3,272	9	,010

Table 6. Weight increase percentage values of experimental groups according time intervals

Groups	Weight increase percentage (%)					
	0-1	0-7	0-30	1-7	1-30	7-30
ICW	0.09	0.20	0.72	0.20	0.63	0.43
IPH	0.63	3.46	4.19	2.80	3.53	0.73
IMT	0.30	2.98	4.53	2.59	4.13	1.50

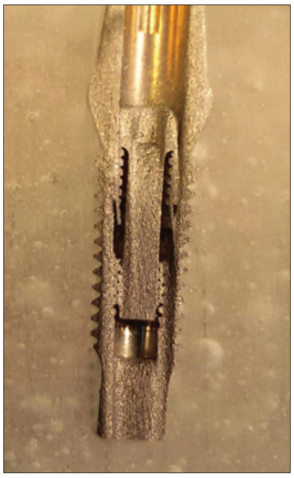

Figure 1. Cross-sectional view of IMT specimen.

Figure 2. Cross-sectional view of IPH specimen.

with different IA connection types, not any study was available in the literature comparing the degree of saliva leakage amount in different internal implant-abutment joint configurations. The present

Figure 3. Cross-sectional view of ICW specimen.

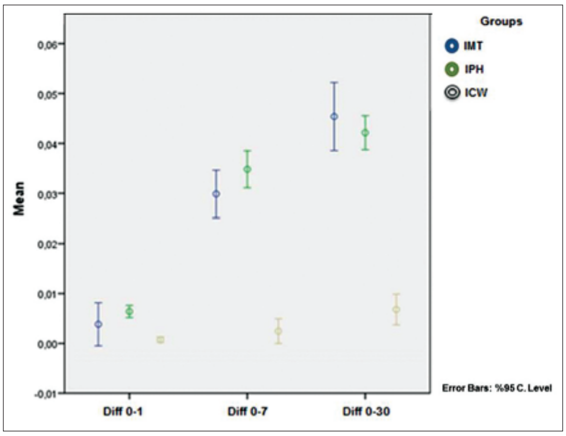

Figure 4. Means and standard deviations of weight difference values of 3 experimental groups measured at 1st, 7th and 30th days.

in vitro study aimed to determine and compare the sealing capability of three popular implant systems with different internal IA joint types.

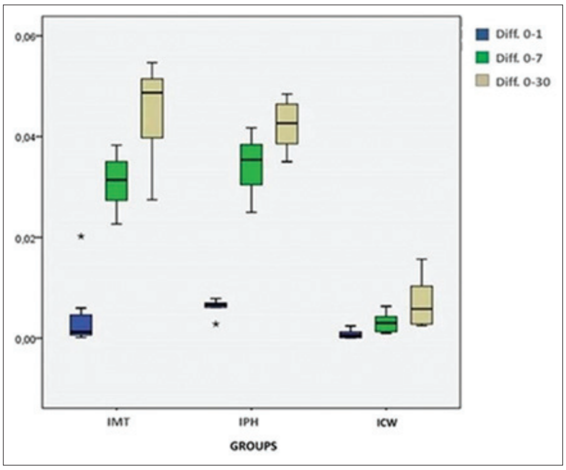

Figure 5. Graphical comparison of determined weight difference amounts of experimental groups in different measurement times.

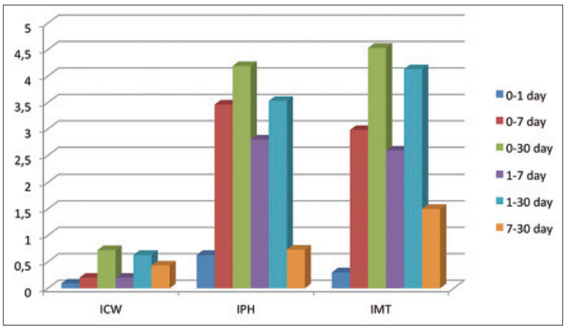

Figure 6. Graphical comparison of weight increase percentage values (%) of experimental groups according time intervals.

Three widely used IA joint configurations; internal cold welding type joint (ICW), internal perpendicular hexagon type joint (IPH) and internal 11-degree angle morse taper type joint (IMT) were selected. Significant weight differences were found both between experimental groups and between 4 weighting times within groups. The 1.5-degree angle cold welding type internal IA joint configuration displayed lowest weight increase values indicating lowest saliva leakage compared to other two systems. Significantly higher weight increase values were found in groups IMT and IPH showing lower sealing capability against leakage. However, no significant differences were found between groups IMT and IPH, despite relatively higher values determined in group IMT. It was also shown that the most intensive weight increase in all experimental groups occurred at 0-7 day time interval (Fig 3).

It was well documented with several studies that the sealing capability, fit accuracy and load distribution of internal IA connections (tube in tube or cone to cone connections) were superior to external hexagonal butt joint type IA connections (1-3, 9, 15, 27, 28). Therefore, internal type IA joint configurations were selected for the present study to obtain more consistent results. The morse taper, perpendicular hexagon and tube-in-tube cold welding type internal connections are actually the main three internal joint configurations used worldwide.

Thermal cycling procedures and use of artificial saliva as storage media were selected in the present study as physical parameters to simulate as close as possible the intraoral conditions. However, probable differences of internal hole volumes between 3 implant systems and weight measurement procedures performed under unloading conditions were the limitations of the present study. It is thought that both limitations were overcome by presenting the weight increase amounts via percentage expressions.

As it was previously emphasized, limited data is available in the literature for comparing the results of previous studies with those of the present study. Therefore, some comparisons can be made with the results of the study of Nascimento et al.[29] who compared the saliva leakage degrees of three implants systems with external hexagon, internal hexagon and morse-cone connection IA joint types using microbial counting measurement. The authors stated that the morse-cone IA interface configuration showed the lowest count of microorganisms under both loaded and unloaded conditions. However, in the present study, no difference of leakage was found between morse taper and perpendicular hexagon IA joint types.

CONCLUSION

Within the limitations of the present study it was determined that all tested implant systems displayed significant weight increases in each of the subsequent measurement times. Cold welding type IA joint configuration showed the lowest saliva leakage values and was found the most suitable interface geometry for the minimization of leakage compared to other systems. Internal perpendicular hexagonal type and internal 11-degree angle morse taper type IA joint configurations displayed similar saliva leakage values. The most intensive weight increase in all experimental groups occurred at 0-7 day time interval.

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How to cite this article: Cumhur Sipahi, Bulent Pişkin, Simel Ayyildiz, Alper Uyar. Comparison of saliva leakage amounts into internal implant cavities in three different internal implant-abutment interface configurations. Cumhuriyet Dent J 2015;18(2):156-169.