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Measurement of the interface of external connection implants with metal or zirconia abutments under scanning electron microscopy

Medição da interface de implantes de conexão externa com pilares de metal ou zircônia sob microscopia eletrônica de varredura

Blanca **Nieves-Rodriguez**[1] 0009-0007-7588-2473
Jair **Rodríguez-Ivich**[2] 0000-0002-7966-9262
Nana Kwame **Ampomah**[3,4,5] 0000-0001-9362-5365
Fabio Luiz **Andretti**[6] 0000-0002-3075-6250

ABSTRACT

Objective: Microgap at the implant–abutment interface is a critical factor that may influence both survival- and success rates of dental implants. Several studies have found that the shape of the abutment and implant, the kind of connection between the implant and abutment (external, internal, conical, and their variants), the material

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[1] University of Guadalajara, Tonalá University Center, Health Sciences Division. Guadalajara, Mexico.
[2] Autonomous Researcher. Guadalajara, México.
[3] Tufts University, School of Dental Medicine. Boston, Massachusetts, USA.
[4] Boston University Henry M. Goldman, School of Dental Medicine. Boston, Massachusetts, USA.
[5] Tufts University, School of Medicine, Department of Public Health and Community Medicine. Boston, Massachusetts, USA.
[6] University of Tennessee, Health Sciences Center, College of Dentistry, Department of General Dentistry. 875 Union Avenue Memphis, Tennessee 38103, USA. Correspondence to: FL Andretti. E-mail: <fandrett@uthsc.edu>.

of the implant and abutment, tightening torque value of the screw, surface topography and preparation, and the marginal fit between components can all have an impact on the size of the microgap. **Methods**: Eighty external hex implants (4.1 mm) from the same company were divided into four equal groups. Group 1: 4 mm diameter Anti-Rotational (AR) stock titanium abutments; Group 2: scanned (3Series, Dental Wings) and milled (RCS-1, Röders GmbH) 4 mm diameter zirconia abutments; Group 3: scanned (3Series, Dental Wings) and milled (CNC 240, Lava) 4mm diameter Zirconia abutments; and Group 4: two-piece 4.1 mm diameter stock abutments (Ti-base, CEREC, Sirona). Each implant-abutment pair was torqued according with the manufacturer's instructions (30 Ncm, 20 Ncm, 20N cm & 35 Ncm, respectively). The samples were placed in a sample holder and segmented longitudinally. The implant-abutment microgaps was measured at 6 different pre-determined locations using optic microscopy. For each implant-abutment interface, corresponding microgaps at the right- and left sides for M1 (exterior), M2 (middle), and M3 (interior) as shown in Figure 1, were averaged and used for statistical analyses. **Results**: A Kruskal-Wallis population equality rank test was performed on the measurements of microgaps across the four groups (1, 2, 3 and 4). The differences between the rank totals of both M1 and M3 measurements were significant; for M1: 634.00 (1), 852.00 (2), 1143.00 (3), and 611.00 (4) [H (3, n=80) = 16.97, and *p*-value <0.01] and for M3: 674.00 (1), 636.00 (2), 1294.00 (3), and 636.00 (4) [H (3, n=80) = 29.01, and *p*-value <0.01]. Specifically, it was detected that the sum of ranks were relatively larger for the external hex implants that were screwed with zirconia abutments in Group 3. Subsequently, a post-hoc pairwise comparisons using Dunn's test shows that Group 1 microgaps were significantly different from those of Group 3 for both M1 (mean difference =-3.47 and *p*-value <0.01) and M3 (mean difference =-4.22 and *p*-value <0.01). The post-hoc sensitivity analysis using the Dunnett's test confirms that the measurements in Group 1 (controls) were significantly different from those in Group 3 for both M1 (contrast = 38.15, Std. Error = 8.84, 95% CI 18.40–57.91, and *p*-value <0.01) and M3 (contrast = 63.51, Std. Error = 8.36, 95% CI 43.48–83.53, and *p*-value <0.01). **Conclusion**: In this in vitro study, it was found that the Zirconia abutments showed relatively greater microgaps and hence mismatches at the implant-abutment interfaces compared to the prefabricated metal abutments.

Indexing terms: Dental Implant-Abutment Design. Dental abutment. Monolithic zirconia.

RESUMO

Objetivo: O microgap na interface implante-abutment é um fator crítico que pode influenciar as taxas de sobrevivência e sucesso dos implantes dentários. Vários estudos descobriram que o formato do abutment e do implante, o tipo de conexão entre o implante e o abutment (externa, interna, cônica e suas variantes), o material do implante e do abutment, o valor do torque de aperto do parafuso, a topografia e o preparo da superfície e o ajuste marginal entre os componentes podem ter um impacto no tamanho do microgap. **Métodos**: Oitenta implantes hexagonais externos (4,1 mm) da mesma empresa foram divididos em quatro grupos iguais. Grupo 1: pilares de titânio antirrotacionais (AR) de 4 mm de diâmetro; Grupo 2: pilares de zircônia de 4 mm de diâmetro escaneados (3Series, Dental Wings) e fresados (RCS-1, Röders GmbH); Grupo 3: pilares de zircônia de 4 mm de diâmetro escaneados (3Series, Dental Wings) e fresados (CNC 240, Lava); e Grupo 4: pilares de estoque de duas peças de 4,1 mm de diâmetro (Ti-base, CEREC, Sirona). Cada par implante-pilar foi torqueado de acordo com as instruções do fabricante (30 Ncm, 20 Ncm, 20 Ncm e 35 Ncm, respectivamente). As amostras foram colocadas em um porta-amostras e segmentadas longitudinalmente. As microlacunas implante-pilar foram medidas em 6 locais diferentes pré-determinados usando microscopia óptica. Para cada interface implante-pilar, as microlacunas correspondentes nos lados direito e esquerdo para M1 (exterior), M2 (meio) e M3 (interior), conforme mostrado na Figura 1, foram calculadas e usadas para análises estatísticas. **Resultados**: Um teste de classificação de igualdade populacional de Kruskal-Wallis foi realizado nas medidas de microgaps entre os quatro grupos (1, 2, 3 e 4).

As diferenças entre os totais de classificação das medidas M1 e M3 foram significativas; para M1: 634,00 (1), 852,00 (2), 1143,00 (3) e 611,00 (4) [H (3, n=80) =16,97 e valor de *p*<0,01] e para M3: 674,00 (1), 636,00 (2), 1294,00 (3) e 636,00 (4) [H (3, n=80) =29,01 e valor de *p*<0,01]. Especificamente, foi detectado que a soma das classificações foi relativamente maior para os implantes hexagonais externos que foram parafusados com pilares de zircônia no Grupo 3. Posteriormente, uma comparação post-hoc em pares usando o teste de Dunn mostra que as microlacunas do Grupo 1 foram significativamente diferentes daquelas do Grupo 3 para M1 (diferença média =-3,47 e valor de *p*<0,01) e M3 (diferença média =-4,22 e valor de *p*<0,01). A análise de sensibilidade post-hoc usando o teste de Dunnett confirma que as medidas no Grupo 1 (controles) foram significativamente diferentes daquelas no Grupo 3 para M1 (contraste = 38,15, erro padrão = 8,84, IC de 95% 18,40–57,91 e valor de *p*<0,01) e M3 (contraste = 63,51, erro padrão = 8,36, IC de 95% 43,48–83,53 e valor de *p*<0,01). **Conclusão**: Neste estudo *in vitro*, foi descoberto que os pilares de zircônia apresentaram microlacunas relativamente maiores e, portanto, incompatibilidades nas interfaces implante-pilar em comparação aos pilares de metal pré-fabricados.

Termos de indexação: Projeto do Implante Dentário-Pivô. Dente suporte. Porcelana dentária.

INTRODUCTION

Across inter-disciplinary care in prosthodontics, periodontology, and oral and maxillofacial surgery, dental implant therapy has emerged as one of the most common and reliable methods of replacing partial – or fully edentulous spaces.

Implant systems are made up of two main components – the endosteal implant fixture and a prosthesis-supporting abutment joined to fixture with a screw. The weakest part of dental implant is the implant-abutment interface, and this interface may have an impact on marginal bone loss [1]. In general, the implant-abutment connection design can be grouped into two categories – external and internal – although internal connections are currently more common than the external type [2]. Internal connections are further divided into internal hex (hexagons, octagons), internal conical and Morse taper connections [3]. The clinical success rate of external- and internal hexagon connections over a 3-year period have been estimated to be about 97.7% and 97.5%, respectively [4]. Compared to external connections, it has been established that internal connections are relatively more stable, have better resistance to torque loss, and lower incidence of screw loosening [5,6].

A number of research publications have found that implant-abutment systems with internal connections have better outcomes with respect to fitness of abutment, stability, distribution of occlusal loads, marginal seal, and marginal bone loss [1,7-9]. Specifically, it is generally acknowledged that the Morse taper connection has better performance when it comes to survival rate, success rate, and marginal bone loss [3,6,8]. The use of at least four Morse taper connection implants of sufficient diameter and length, combined with good pre-operative planning, has resulted in high survival and success rates for maxillary implant-supported overdentures [3,10].

Microgaps at the implant – abutment interface is a critical factor that may influence clinical success. It has been found that the shape of the abutment and implant, the kind of connection between the implant and abutment (external, internal, conical, and their variants), the material of the implant and abutment, tightening torque value of the screw, surface topography and preparation, and the marginal fit between components can all have an impact on the size of the microgap [11-13]. When it comes to preparation, laboratory procedures such as scanning, milling, and casting can also cause a mismatch between the implant-abutment interface, and hence some authors have proposed the usage of pre-fabricated prosthetic components of titanium, gold alloys, and cobalt chromium to improve adaptation [14]. However, it has been reported that metal-based or fully plastic cast abutments are susceptible to distortion and may compromise abutment-implant adaptation, creating biomechanical complications [15]. Precious alloys have been cast for the manufacture of prosthetic abutments due to their physical properties. The use of alternative alloys has presented disadvantages such as difficulty in finishing and polishing [16]. The greatest disadvantage reported of these abutments by some authors is aesthetics, since it compromises the translucency of the restoration [17,18].

Microgaps at the implant-abutment interface may promote bacteria and their metabolites to accumulate; moreover, fluid passage into the implant-abutment interface increases the number of inflammatory cells in the soft tissue surrounding the prosthesis, which may lead to tissue peri-implantitis, chronic inflammation, and marginal bone loss [9, 19-22]. Additionally, the presence of larger microgaps at the interfaces increase the likelihood of generating micromotion between the abutment and the implant; and this dynamic can eventually lead to the loosening of the screw or even fracture, leading to failure of the implant therapy [9,19-22]. In an in-vitro study that examined microleakage of the prosthetic abutment-implant interface with internal and external connections, it was found that regardless of the torque used to tighten the screw, implants with an internal Morse taper connection exhibit lower levels of microleakage than those with an external connection due to their self-locking characteristics [9] and as a result, these implants are probably more likely to experience a higher rate of treatment success because they are less likely to develop periodontal tissue inflammation caused by bacterial accumulation at the implant-abutment interface [3,10].

The demand for aesthetics has revolutionarized the need of zirconia as a dental material. The exceptional mechanical properties of zirconia and the ease with which they may be machined utilizing Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) methods, are mainly responsible for the widespread use of these materials in clinical settings. Zirconia abutments are available as one-piece tetragonal yttria-stabilized zirconia abutments or with a metal base.

The purpose of this in vitro study is to examine the distribution of spaces (microgaps) between the base of the implant and various prosthetic abutments which have been manufactured using different materials and methods. The null hypothesis is that the various prosthetic abutments would show no statistically significant difference in microgaps between the implant-abutment interfaces.

METHODS

Forty external hex implants (Easy Grip Conexão Sistema de Prótese Ltd., São Paulo, Brazil) with a platform of 4.0 mm and a height of 10 mm were divided into 4 groups. Ten specific abutments were screwed onto the implants of each group. Group 1: The control group was screwed with prefabricated metal abutments (Conexão Sistema de Prótese Ltd., São Paulo, Brazil); Group 2: they were screwed with zirconia abutments scanned (3Series, Dental Wings) and milled (RCS-1, Röders GmbH); Group 3: they were screwed with zirconia abutments scanned (3Series, Dental Wings) and milled with Lava (3M ESPE Dental Products, Ontario, Canada) and Group 4: they were screwed with 2-piece Ti-base abutments (Sirona) scanned and milled with CEREC (Dentsply Sirona, Bensheim, Germany).

Zirconia abutment platforms (part of the external hexagon) were scanned three-dimensionally on the implant analog. The zirconia abutments were prepared according with the shrinkage indicated by the manufacturers. The forty abutments – ten for each group – were tightened to the randomly selected external hex implants.

Equal lengths of the catalyst and the base of the a low-viscosity silicone Imprint II Garant (3M ESPE Dental Products, St. Paul, MN) were injected on a glass plate and mixed according to the recommendations of the manufacturer. The abutment was then positioned and screwed to the implant after the mixed silicone had been deposited on the implant platform. Using a torque wrench, the prosthetic screw connecting the abutments to the implants was tightened. 20 Ncm was the abutment placement torque for zirconia abutments, 30 Ncm for standard titanium abutments, and 30 Ncm for Ti-base abutments. Every abutment was fixed in accordance with the recommendations of the manufacturer. After the setting time elapsed, the excess silicone was cut with # 15 scalpel blade (Solidor. Kyuan Suzhou Medical App. Co. Ltd China). The scalpel blade was replaced by a new one every 3 abutments to avoid tearing of the addition silicone.

The implant-abutment assembly was included in acrylic resin. After inclusion, each set was identified with numbers and letters of the alphabet (A to D). Samples were placed in a sample port and segmented through the long axis in a precision cutting machine (Isomet 4000 Linear Precision Saw, Buhler). The cutting speed used was 3000 rpm with a 1.2 mm/s feed rate under profuse cooling water.

The samples were sanded to reduce the processing marks left on the cutting interface. Sandpaper was used from the coarser to the finer grain grades (grain size 320, 400, 600 and 1200) are using an automatic sander (Arotec Aropol 2V, Arotec). Each sandpaper particle size was used for 30 seconds for sanding the specimens under profuse water irrigation. Every 3 sets the abrasive silicon carbide was replaced by a new one to avoid failure during grinding. Polishing was not carried out to preserve most of the silicone between the implant and the abutment.

Special precautions were taken to minimize the angle of the sample, not to produce distortion in the gap region. These precautions included: applying a uniform pressure over the entire surface of the sample and properly positioning the sample (long axis perpendicular to the assembly direction of the disk) during the cutting procedures. A thorough washing was performed between each step, the specimens were cleaned in water and immersed in an ultrasonic tank using liquid soap.

The final specimens were mounted in parallel with the tabletop measuring microscope (Leica DM 4000, Wetzlar, Germany) to measure in two adjustment areas for internal adaptation (100x magnification). A series of optical micrographs were captured at the implant-abutment interfaces of all pairs. The micrographs were analyzed using software (LAS Image Analysis, Leica Microsystems, Buffalo Grove, IL, USA). The interface microgap was evaluated by calculating the gaps between the abutment and the dental implant. Microgap measurements at the implant-abutment interfaces were performed at three separate points for: M1 (outer), M2 (middle), and M3 (inner), as shown in Figure 1. In effect, for the dextro- and levo halves of each implant-abutment, two points measurements of M1, M2, and M3 were taken and the averages of the corresponding right- and left point measurements were estimated and used for the statistical analyses.

The Scanning Electron Microscopy (SEM) analyses of the implant-abutment interfaces were conducted at the University Center for Exact Sciences and Engineering, University of Guadalajara, Mexico.

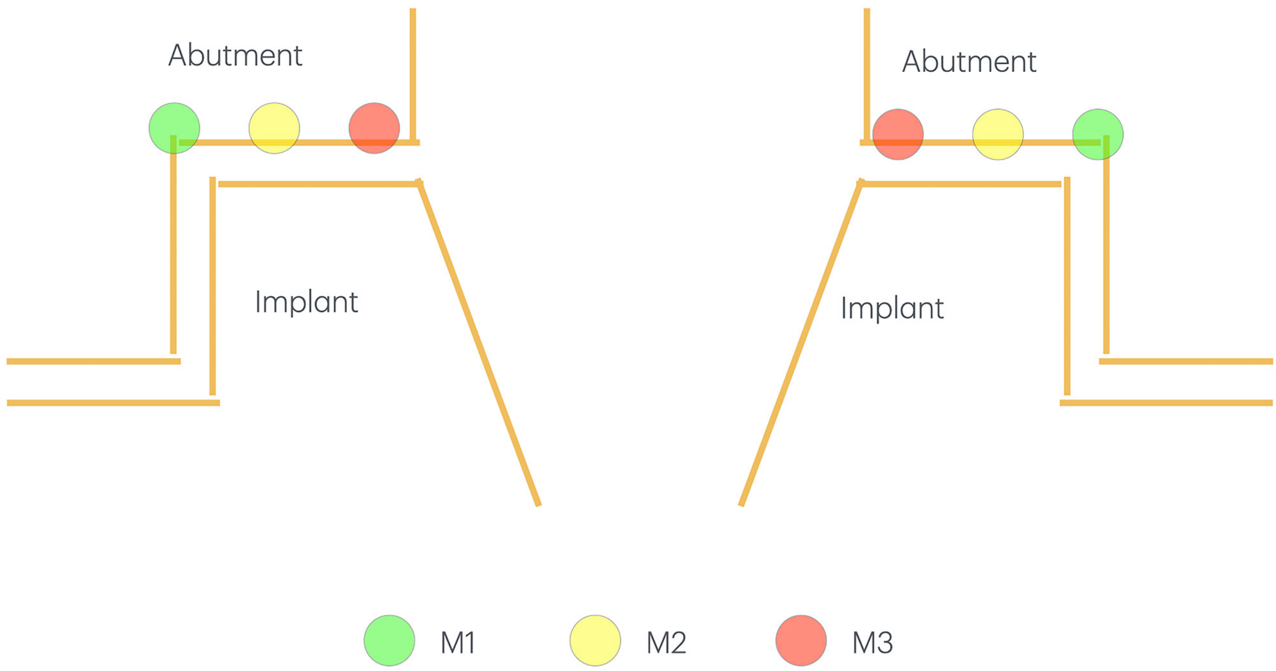

Figure 1. Schematic diagram showing points on the implant-abutment interfaces where microgaps (M1, M2, and M3) were measured.

RESULTS

Statistical analyses were performed with StataSE 18. All hypotheses were tested using a 2-sided test, and a *p* value less than or equal to 0.05 was considered statistically significant. For each implant-abutment interface, the corresponding microgaps at the right- and left sides for M1 (exterior), M2 (middle), and M3 (interior) as shown in Figure 1, were averaged and used for statistical analyses. The Shapiro-Wilk normality test performed for M1, M2, and M3 data showed that these measurements were not normally distributed.

Table 1 shows the descriptive statistics of microgaps in Group 1, Group 2, Group 3, and Group 4. A Kruskal-Wallis population equality rank test was performed on the measurements of microgaps across the four groups (1, 2, 3 and 4). The differences between the rank totals of both M1 and M3 measurements were significant; for M1: 634.00 (1), 852.00 (2), 1143.00 (3), and 611.00 (4) [H (3, n=80) = 16.97, and *p*-value <0.01] and for M3: 674.00 (1), 636.00 (2), 1294.00 (3), and 636.00 (4) [H (3, n=80) = 29.01, and *p*-value <0.01]. Specifically, it was detected that the sum of ranks were relatively larger for the external hex implants that were screwed with zirconia abutments in Group 3.

Subsequently, a post-hoc pairwise comparisons using Dunn's test reveals that the microgaps in Group 1 (figure 2) were significantly different from those of Group 3 for both M1 (mean difference =-3.47 and *p*-value <0.01) and M3 (mean difference =-4.22 and p-value <0.01). The results are displayed in Table 2. Likewise, measurements of microgaps in Group 3 (figure 3) were found to be significantly different from those of Group 4 for both M1 (mean difference =-3.47 and *p*-value <0.01) and M3 (mean difference =-4.22 and *p*-value <0.01). These finding highlights the fact that Zirconia abutments relatively have the largest implant-abutment microgaps and hence adaptations.

Table 1. Distribution of implant-abutment microgaps across the four groups.

Microgaps between Implant and abutment	Group 1 (n=20)	Group 2 (n=20)	Group 3 (n=20)	Group 4* (n=20)	*p*-value**
M1					
Median (min, max) µm	22.60 (3.12, 40.31)	39.66 (3.23, 108.37)	60.60 (13.75, 99.98)	26.17 (2.50, 33.36)	<0.01
Rank sum	634.00	852.00	1143.00	611.00	
Mean (SD)***	21.77 (10.06)	38.21 (36.47)	59.93 (33.00)	20.09 (14.05)	
M2					
Median (min, max) µm	1.57 (0.61, 2.53)	1.30 (0.60, 79.68)	1.02 (0.59, 74.26)	1.60 (0.59, 74.26)	0.23
Rank sum	800.00	982.00	770.00	688.00	
Mean (SD)***	1.54 (0.75)	13.80 (28.45)	8.57 (22.48)	1.85 (1.35)	
M3					
Median (min, max) µm	24.37 (9.34, 51.56)	19.01 (2.60, 73.91)	98.42 (11.71, 132.79)	98.42 (11.71, 132.79)	<0.01
Rank sum	674.00	636.00	1294.00	636.00	
Mean (SD)***	26.87 (16.37)	32.76 (30.59)	90.38 (38.73)	20.89 (9.39)	

Note: *It was observed that for each point measurement of the gap between the implants and the abutments (M1, M2 and M3), the sum of ranks was consistently smaller in Group 4, although the *p*-value across the groups for M2 was not statistically significant. ***p*-values from the Kruskal-Wallis population equality rank test. ***Although distributions across groups were nonparametric, means and standard deviations were calculated for descriptive purposes. SD: Standard Deviation. Min, max: minimum, maximum.

Table 2. Post-hoc analysis using Dunn's Test.

Microgaps	Group1-Group2	Group1-Group3	Group1-Group4	Group2-Group3	Group2-Group4	Group3-Group4
M1: Mean Difference µm	-1.48[a]	-3.47[b]	0.16[a]	-1.98[a]	1.64[a]	3.62[c]
p-value	0.07	<0.01	0.44	0.02	0.06	<0.01
M3: Mean Difference µm	0.26[a]	-4.22[b]	-0.26[a]	-4.48[a]	0.00[a]	4.48[c]
p-value	0.40	<0.01	0.40	<0.01	0.50	<0.01

Note: Group 1: The control group was screwed with prefabricated metal abutments (Conexão Sistema de Prótese Ltd., São Paulo, Brazil). Group 2: Twenty external hex implants were screwed with zirconia abutments scanned (3Series, Dental Wings) and milled (RCS-1, Röders GmbH). Group 3: Twenty external hex implants were screwed with zirconia abutments scanned (3Series, Dental Wings) and milled with Lava (3M ESPE Dental Products, Ontario, Canada). Group 4: Twenty external hex implants were screwed with 2-piece Ti-base abutments scanned (Sirona) and milled with CEREC (Dentsply Sirona, Bensheim, Germany). Mean differences of M1- and M3 microgaps (in bold) shows that the greatest microgaps were detected between Group1-Group2 and Group3-Group4. Different superscript letters within the same row mean statistically significant differences.

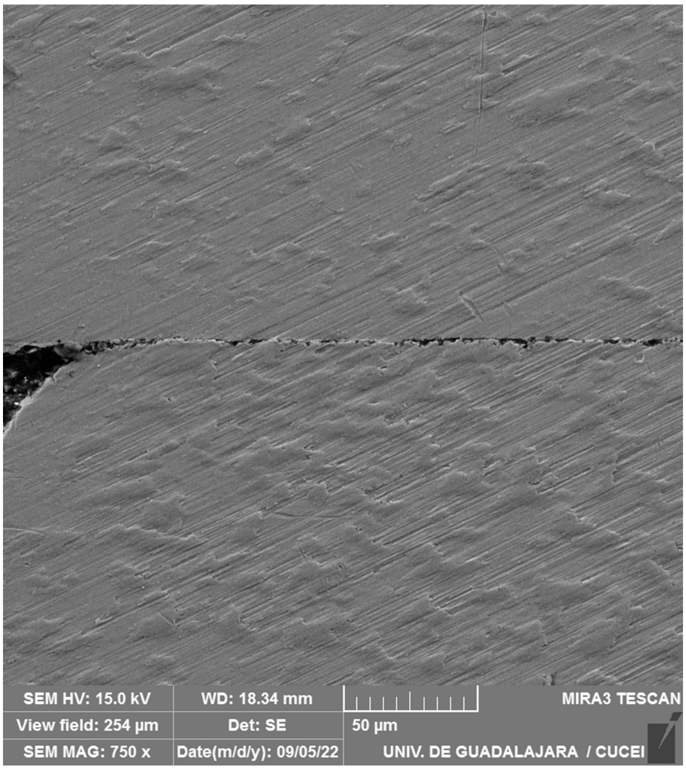

Figure 2. Metal abutment showing better adaptation. (Group 1- Control Group).

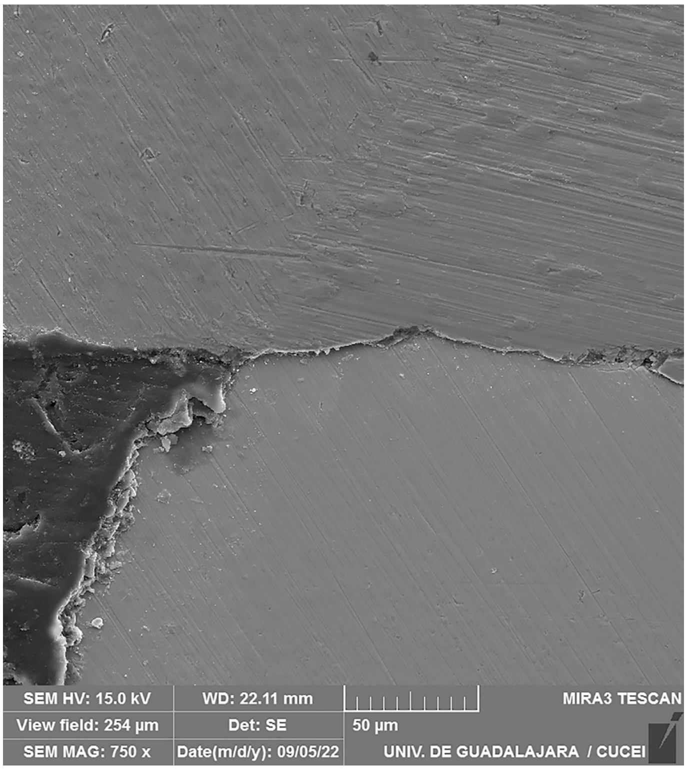

Figure 3. Zirconia abutment showing more irregularities on the surface and deformation of the Titanium implant. (Group 3).

In table 3, a post-hoc sensitivity analysis conducted using the Dunnett's test confirmed that the measurements in Group 1 (controls) were significantly different from those in Group 3 for both M1 (contrast = 38.15, Std. Error = 8.84, 95% CI 18.40–57.91, and *p*-value <0.01) and M3 (contrast = 63.51, Std. Error = 8.36, 95% CI 43.48–83.53, and *p*-value <0.01).

Table 3. Post-hoc sensitivity analysis using Dunnett's Test.

Group Comparisons	Contrast	Standard Error	Dunnett		Dunnett	
			t	*p* > |t|	[95% CI]	
M1 Microgaps (µm)						
Groups						
2 against 1	16.44	8.24	1.99	0.12	-3.32	36.20
3 against 1	38.15	8.24	4.63	0.00	18.40	57.91
4 against 1	-1.68	8.24	-0.20	0.99	-21.44	18.08
M3 Microgaps (µm)						
Groups						
2 against 1	5.88	8.36	0.70	0.82	-14.14	25.91
3 against 1	63.51	8.36	7.60	0.00	43.48	83.53
4 against 1	-5.98	8.36	-0.72	0.82	-26.01	14.05

Note: Post-hoc sensitivity analysis (pairwise comparison) using Dunnett's Test shows that: for M1, the microgaps in Group 1 were significantly different from those in Group 3 (*p*-value <0.01); and for M3, the microgaps in Group 1 were also significantly different from those from Group 3 (*p*-value <0.01). CI: Confidence Interval.

DISCUSSION

In this in vitro study, the null hypothesis that prosthetic abutments made with different materials and manufacturing techniques would not present differences in their adaptation was rejected – Zirconium abutments relatively showed greater microgaps and hence mismatch between the implant-abutment interfaces. Prefabricated metal abutments showed less mismatch between the implant-abutment interface, and regardless of the material of the abutment, various degrees of mismatches were observed between the implant-abutment interface.

Over the past few decades, advancement in dental technologies such as Scanning Electron Microscopy (SEM) and CAD-CAM have made it easier for various researches to investigate the implant-abutment interfaces of various materials and to understand how across the broader spectrum of clinical care and dental material science, microgaps at these interfaces could potentially affect clinical outcomes [9,11-15,17,22] Zirconia abutments are machined before sintering, and this sequential processing have been found to result in approximately 20% to 25% shrinkage of the ceramic material [23,24]. Hence, although Zirconia material has been proven to have a relatively lower risk of being colonized by the oral microbiome compared to Titanium, the relatively larger microgaps seen in zirconia-abutment interfaces compared to metal abutments, may increase microleakage of oral fluids and eventually, bacteria colonization at the interfaces [25,26].

Influence of implant connection types on bone loss and stability

Several factors, including implant neck surface characteristics and connection types, influence marginal bone loss around dental implants [3]. Studies have shown that external connections tend to have greater changes in bone level peri-implant crest bone than the internal connections [3]. The microthreads in the neck of the internal hexagonal implant, as well as the platform shifting concept, are believed to help preserve the bone. Internal connections were introduced to overcome the drawbacks of external connections. They reduce screw loosening and fracture, improve dissipation of loading forces along the implant walls, and minimize implant abutment clearance, reducing bacterial penetration [27]. Studies have shown that internal connections, particularly tapered connections, result in less Marginal Bone Loss (MBL) compared to external connections [27]. Conical connections showed fewer prosthetic complications compared to external connections, indicating better performance in terms of mechanical stability [27]. The choice of implant abutment connection should consider the specific clinical scenario, with internal connections being preferable to minimize complications and improve long-term stability [27].

Mechanical behavior and stress distribution

Dentists should consider the mechanical behavior of different types of implant connections, as the transmission of stress to the bone can affect the long-term success of the implant. Tapered designs, such as the Morse taper, provide high stability and tend to dissipate less stress on the abutment screw compared to internal and external hexagonal connections [3]. The stability of tapered designs increases the stress on the abutment, as a result of the greater resistance provided by the thickness of the implant wall in the cervical region. This stability reduces the likelihood of micromotion during loading, which is beneficial for maintaining osseointegration [3]. External connections interface on top of the implant platform and have been widely used since the development of the first osseointegrated implant, the Brånemark system [27] These connections are prone to micromovements at the level of the implant abutment, which can lead to biological and mechanical complications, such as screw loosening and fractures [27].

Deformation and failure patterns

In groups with internal connections, one study observed plastic deformation in metal components (metal insert, abutment screw, implant shoulder). This deformation was a major factor in failure patterns, which included ceramic abutment fractures and loss of retention [3]. Dentists should consider connection type and material when selecting abutments for dental implants. Internal connections, while providing greater stability, can also cause more wear and deformation of metal components, which could affect long-term performance [3].

The present study presents the space between implant and abutment of the four groups. The largest discrepancy between the groups may have occurred due to processing errors during milling and sintering of the zirconia. Although the zirconia abutments were supposed to have excellent fit, the milling and sintering process may have caused distortions and irregularities in the base of the implant, resulting in poorer fit. As a result of the mismatch between the implant and the abutment, the size of the interface may vary depending on the manufacture of the abutment.

Influence of abutment types on misalignment and stability

The researchers looked at how well screw-retained zirconia frameworks passively and actively fit on two implants. They did this by simulating distortions of the prosthetic workflow using visual, tactile, radiographic, and specific tests such as the 1-screw test (Sheffield). The combination of abutments (EE, E-NE, and NE-NE) affected the passive and active fits differently when the distortions occurred in horizontal and vertical directions. NE-NE specimens showed the greatest tolerance to simulated misfits, while EE specimens were the most affected, particularly in the H100 and V50-150 misfit groups [14]. As the level of simulated misfit increased, the vertical spacing between the implant and the abutment also increase. Horizontal misfits were less tolerated than vertical misfits and could be more damaging [14]. The study highlighted that zirconia frameworks supported by two non-engaging implants tolerated different levels of misfit better than docking, non-engaging frameworks, or both [14]. The use of Implant-engageable abutments in a prosthesis supported by two implants makes it more sensitive to minor changes that occur during the prosthetic workflow, which could cause a poor fit. The study suggests that doctors should aim for as much precision as possible, as even small misalignments can lead to major clinical complications, such as screw loosening, peri-implantitis, and bone loss [14].

Assessment of abutment adaptation

Marginal fit and adaptation of prefabricated machined abutments with laboratory-cast and finished abutments was evaluated for six abutment-implant combinations. Adaptation was evaluated at two sites: the abutment-implant interface and the screw-screw seat [28]. Pre-machined abutments, including those modified in the laboratory, showed superior adaptation compared to those cast from calcined templates [28]. Those with abutments Premachined and lab-modified premachined were better able to adapt to the implants and there was more contact between them than those with cast abutments [28]. The premachined groups showed the greatest contact between the screw and the screw seat, while the groups using cast abutments casts showed significantly less contact [28]. If the plaster abutments do not fit perfectly, bacteria can accumulate, there may be inflammation around the implant, and the screw may loosen because it does not fit properly and does not have enough frictional resistance for rotation [28]. Further development and refinement of custom-made abutments is required, including improvements in pattern design, casting and finishing procedures [28].

Impact of CAD/CAM structures on implant fit

Researchers investigated the fit of screw-retained implant-supported titanium and Zirconium Dioxide (ZrO) Computer-Aided Design and Manufacturing (CAD/CAM) frameworks compared to laser-scanned CAD/CAM titanium frameworks and conventionally cast CoCrW alloy [29]. Accuracy of fit was evaluated by testing a screw and Scanning Electron Microscope (SEM) measurements to evaluate the vertical clearance between the framework platform and the implant shoulder [29].

The hypothesis that there are no differences in the vertical gap between the CAD/CAM groups (ZrO-L, ZrO-M and TIT-L) was accepted, but was rejected when comparing any CAD/CAM group with the and so [5]. Laser-scanned CAD/CAM titanium frameworks showed the most consistent accuracy, while full-arch cast alloy frameworks exhibited clinically unacceptable misfit [29]. The study suggests that to improve the fitting accuracy of CAD/CAM structures, it is necessary to further refine the sintering shrinkage compensation mechanism [29].

Surface wear and misalignment in titanium and zirconium abutments

Factors such as hardness, roughness, surface configuration, and the medium between the two surfaces can have an impact on surface wear. The hexagonal connecting surfaces of the implant on the outside wear at different rates depending on the hardness level of the titanium alloy abutments, full zirconia abutments, and commercially pure grade 4 titanium dental implants. This is because they tighten or move slightly due to repeated loading [30]. The abutments were secured to the implants with a torque of 20 Ncm and cyclically loaded at 300 N with 9 Hz for 1 million cycles.3 Clinicians should be wary of increased misfit and wear caused by machined zirconia abutments at the external hexagon connection [30]. Despite the precise fit of machined zirconia abutments, further misfit and wear could lead to clinical complications over time [30].

Comparison of Ti-Zr NDI and cpTi implants

Single-crown restorations increasingly use Titanium-Zirconia (Ti-Zr) alloy Narrow Diameter Implants (NDI), particularly when the alveolar crest is insufficient for Regular Diameter Implants (RDI) [10]. Ti-Zr NDIs offer increased mechanical strength and excellent biocompatibility, making them a reliable choice for single crown restorations [31]. These implants help preserve a denser area of bone tissue surrounding the implant and prevent excessive proximity to adjacent teeth, thereby reducing unnecessary bone loss [31]. Systematic review and meta-analysis demonstrate that Ti-Zr NDIs have shown significant survival and success rates in single-crown restorations. However, it is important to note that the follow-up period of the studies was very short [31]. The review performed a comparison between Ti-Zr NDIs and Commercially Pure Titanium (cpTi) implants, with a specific focus on the survival, success, and Marginal Bone Level (MBL) changes rates of the implants. Ti-Zr NDIs showed favorable clinical results, similar to cpTi implants [31]. Narrow Diameter Titanium-Zirconia (Ti-Zr NDI) implants offer significant advantages in situations where there is little room for missing teeth or an inadequate amount of remaining jaw bone. This reduces the need for subsequent treatments to improve the bone [31]. To better understand the durability and effectiveness of Ti-Zr NDIs, particularly in weight-bearing locations, additional clinical studies with longer follow-up periods are advisable, as current long-term data are limited [31].

CONCLUSION

Based on the findings of this study, the following conclusions were made: 1) zirconia abutments showed a greater mismatch between the implant-abutment interface; second, prefabricated metal abutments showed less mismatch between the implant-abutment interface, and 2) regardless of the material, different types of mismatches were observed between the implant-abutment interface.

Conflict of interest: The authors declare that there are no conflicts of interest.

Collaborators

B Nieves-Rodriguez, Conceptualization, Data curation, Funding acquisition, Investigation, Methodology. J Rodríguez-Ivich, Methodology, Project administration, Resources. NK Ampomah, Formal analysis, Investigation, Methodology, Software, Validation, Writing – original draft, Writing – review & editing. FL Andretti, Writing – original draft, Writing – review & editing.

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