Evaluation of the cervical adaptation of the castable UCLA component used in fixed prostheses: A comparative study using scanning electron microscopy

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Abstract: The aim of this study was to evaluate *in vitro* the implant-abutment interface misfitting of external hex UCLA abutments used for full-arch implant-supported prostheses, using scanning electron microscopy (SEM). Six aluminium models were used, which were divided into two groups: a) MINI (1-mm mini-abutments); and b) UCLA (UCLA abutments that were fused with a prosthetic bar). The MINI group was used as control. After applying the torque recommended by the manufacturer, the measurements of the vertical misfitting were obtained via SEM at three points with the same distances, on the buccal and lingual surfaces. The UCLA group presented higher maladjustment (10.8 ± 2.2 µm) than the MINI group (3.1 ± 1.3 µm) ($p < 0.05$). Among the limitations of this study, the UCLA group presented higher marginal vertical discrepancies than control group.
Keywords: Dental implants. Dental prosthesis, implant-supported. Scanning electron microscopy.

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INTRODUCTION

Osseointegrated dental implants represent a great advance in Dentistry and provide for patients the replacement of lost dental elements, recovering function, aesthetics, comfort and phonation. Longitudinal studies have demonstrated the long-term success of osseointegrated implants; however, biological or mechanical complications have been reported, especially due to misfitting at the implant-abutment interface (I-A), resulting in clinical failure of implant-supported rehabilitations.[1-3]

The majority of dental implant systems present a intraosseous portion made of titanium, and a transmucosal prosthetic abutment that supports the prosthesis. The abutments are attached to the implant using a screw-based locking mechanism.[4,5] This connection produces a gap that is susceptible to mechanical and biological risks.[6,7]

Poor adaptation at the I-A interface can cause undesirable loads, which can result in the loosening or fracture of the prosthetic screw or fracture of the implant body, thereby jeopardizing the success of rehabilitation.[6,8,9] Another biomechanical factor to be considered is the static tension that is generated by the lack of adaptation between these components, especially when they are submitted to masticatory forces. A direct relationship has been demonstrated between the magnitude of this gap and the loosening of the prosthetic screw, as well as between the magnitude of the gap and tensions in the structure.[4,10,11]

As well as mechanical risks, the presence of spaces at the I-A interface favors bacterial accumulation, which can increase the risk of tissue inflammation and consequent damage to the bone-implant interface. Given that bacterial biofilm is an important etiologic factor in peri-implantitis, bacterial infiltration into the I-A interface can affect the evolution of treatment and can also interfere with long-term success of dental implants osseointegration.[3,7,12-14]

In this context, the adaptation of the prosthesis on the implants is a fundamental factor for the longitudinal success of the rehabilitation treatment. Accordingly, one of the greatest challenges in planning implant-supported prostheses is choosing components that present precise and passive adaptation over the implants, with the aim of avoiding tensions that may lead to mechanical and biological complications. Karl et al[15] demonstrated that the passive adaptation of prosthetic components on the implants is affected by the materials and by their manufacturing processes.

In 1988 at the University of California, Lewis et al[16] developed a castable abutment —the 'Universal Castable Long Abutment' (UCLA)— which, after melting, could be directly connected onto the implant platform, allowing for to prosthetically restore malpositioned fixations or fixations with inadequate interocclusal space, where aesthetic requirements would not allow for a metallic band. During the melting of this castable abutment, distortions in the manufacturing process can cause poor settlement of the piece on the implant, favoring the occurrence of peri-implantitis. With the objective of enhancing the characteristics of UCLA abutments with better I-A placement, UCLA abutments with pre-machined bases in high noble or noble alloys have been developed.[17]

I-A interface misfitting can be aggravated in prostheses with two or more implants because as well as individual adaptation, there is a need for simultaneous adaptation among the other components of the prosthesis.[6] Given these circumstances, fixed implant-supported rehabilitations that aim at replacing dental elements missing in the dental arch —rehabilitations also known as Branemark protocol— are at the greatest risk of maladjustment, given the extensions and curved shapes of the pieces. The "all-on-four" concept for fixed implant-supported rehabilitations has been adopted with good predictability, in which only four implants are used in the anterior area of the mandible to support a fixed prosthesis.[18,19]

Considering the involved variables and the importance of being able to adapt the protocol-type prosthesis over the implants, the objective of this study was to use scanning electronic microscopy (SEM) for *in vitro* evaluation of the cervical adaptation of UCLA-type prosthetic abutments for a lower prosthesis using four implants with external hex connection.

MATERIAL AND METHODS

To perform this study, the following materials were used (S.I.N., Sistema de Implante, São Paulo, Brazil): 24 TryOn implants (SA 307); 12 mini-abutments (MA 4101); 12 castable UCLA abutments (UCLA 400-Q); and a TMECC (S.I.N., *Sistema de Implante*) mechanical torque wrench.

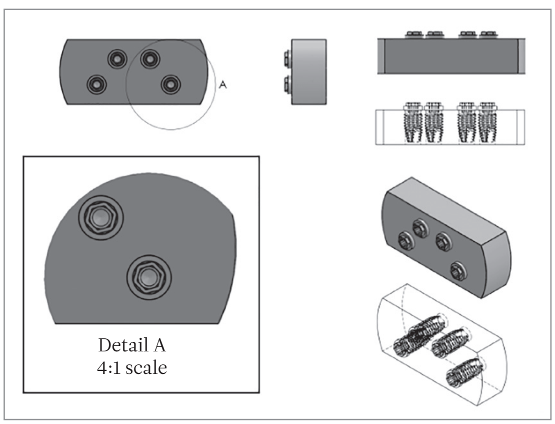

Figure 1: Schematic drawing of the aluminum model (32 x 14 x 7 mm). Detail A, in 4:1 scale.

Preparation of the models

Six standardized models (32 x 14 x 7 mm) were manufactured in aluminum, each with four implants (SA 307) of the external hex type with regular platform, 3.75 mm in diameter and 7 mm in length, placed with a 3-mm spacing. After the milling sequence (CNC milling machine, model VF1, Haas Automation, Inc./CNC Machine Tools, USA) recommended by the manufacturer, the implants were installed in the aluminum models with the mechanical torque wrench, being positioned in a "U" shape (Fig 1).

Creation of the test objects

Six aluminum models were used, with four implants each, which were divided into two groups: a) MINI (MA 4101 1-mm mini-abutments); and b) UCLA (UCLA 400-Q abutments, melted with the prosthetic bar). The UCLA group was created by the placement of four castable UCLA abutments and the manufacturing of the prosthetic bar. After its manufacture, a 32-Ncm torque was applied, according to the manufacturer's recommendations (Figs 2A and 2B), and the interfaces of adaptation between the components and the implants were evaluated using SEM (Model JSM-6390LV/GS, Jeol, Tokyo, Japan). The MINI group (control group) was created by the placement of four mini-abutments with a 20-Ncm torque, according to the manufacturer's recommendations (Figs 2C and 2D). After the application of torque, the adaptation interfaces between the components and the implants were evaluated using SEM. The tightening of the screws of the prosthetic abutments in all groups was performed with the aid of a mechanical torque wrench (TMECC), with the specimen fixed on a bench vise.

Figure 2: Lateral and superior views of the MINI group (**A** and **B**) and the UCLA group (**C** and **D**).

Creation of the prosthetic bar

A specimen was included (sectioned) by using a #4 silicone ring for inclusion, with 90-g capacity (Metalsul, Santa Catarina, Brazil). On the free surface, four wax feeding channels were tied (Dentaurum, Ispringen, Germany), approximately 2 mm in diameter. These channels, in turn, were connected to the crucible forming base by a bar, which was made of the same wax, with 5-mm diameter. To avoid bubbles, Calibra-Express® (Protechno, Girona, Spain) was manually spatulated for 15 seconds, and mechanically spatulated by vacuum for 60 seconds (Polidental Multivac 4, Degussa, Hanau, Germany). Subsequently, the inclusion ring was filled under vibration. One hundred grams of a nickel-chromium-molybdenum alloy (Remanium CSe, Dentaurum, Ispringen, Germany), containing 61% Ni, 26% Cr, 11% Mo, 1.5% Si and less than 1% Fe, Co and Ce, were used. The cluster was placed in an electric oven (7000 – 5P, *EDG Equipamentos e Controle Ltda*, São Paulo, Brazil) that had been preheated to a temperature of 900°C, and the wax, once volatilized, generated the mold that was filled with molten metal (melting point of approximately 1260°C to 1350°C). The injection of the liquefied metal was accomplished using a centrifuge. After cooling of the cluster, welding was

Table 1: Analysis of the gap (average ± standard deviation (μm).

GROUP	Average ± Standard Deviation (μm)
UCLA	10.8 ± 2.2 ^{A}
MINI	3.1 ± 1.3 ^{B}
	p < 0.0001

Different letters (capital letters in columns) indicate statistically significant differences between the groups, according to the Student's t-test ($p < 0.05$).

performed using an electric arc (Kernit®, Compact, São Paulo, Brazil). The piece was finished with a aluminum oxide disc (Talmax, Paraná, Brazil) and then polished with a rubber disc (Dedeco, New York, USA).

Evaluation of the I-A interface

The level of adaptation between the implants and abutments was evaluated using SEM (Model JSM-6390LV/GS) immediately after the screws had been inserted at three equidistant points on the lingual and vestibular faces of each I-A interface, in a standardized manner. A magnification of 1000x was used. The obtained images were measured using a computer-based measurement system (Jeol Scanning Electron Microscope).

Statistical analysis

First, the data were evaluated for normality according to the Shappiro-Wilk test. After this evaluation, a comparison was performed between the groups, using Student's non-paired

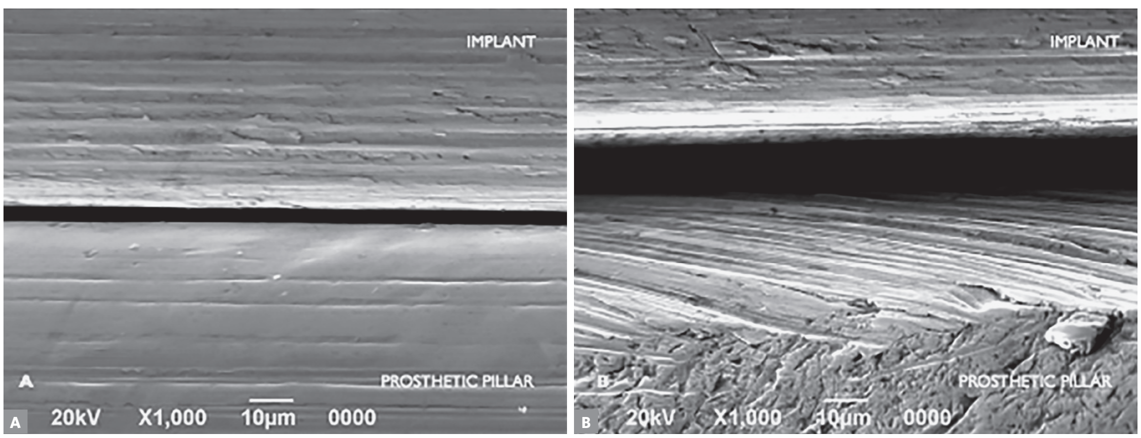

Figure 3: Images corresponding to the gap observed with SEM: **A**) MINI group and **B**) UCLA group (1000x magnification).

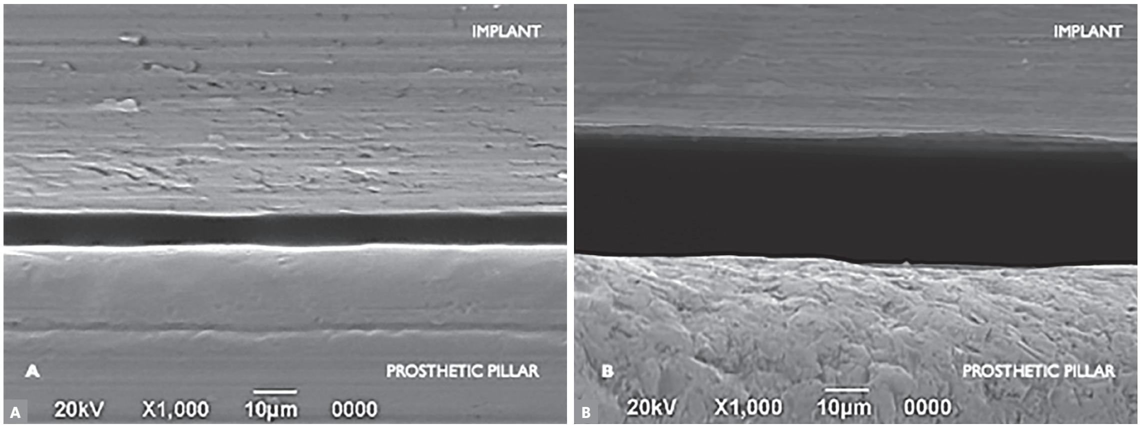

Figure 4: Implant-abutment interface misfitting, observed with scanning electronic microscopy, showing the most critical scenario in the **A**) MINI group (7 μm) and **B**) UCLA (27 μm) group (1000x magnification).

t-test (SAS v. 9.01, Cary, NY, USA). A post-hoc calculation was performed to consider the average deviation pattern of the gap, and a power of 94% was determined for the study (GPower 3.1, Universität Kiel, GR). A 5% significance level was considered for all the analyses.

RESULTS

In the analysis of the averages in all of the regions, a statistically significant difference was detected between the UCLA group and the MINI group ($p < 0.05$), and significantly greater maladjustment was observed in the UCLA group than in the MINI group (Table 1).

Figure 3 shows the gap between the implant and the prosthetic component in the evaluated groups: the images correspond to the average vertical gap in each group. Figure 4 indicates the most critical vertical placement found in the MINI group (7 μm) (Fig 4A), as well as in the UCLA group (27 μm) (Fig 4B).

DISCUSSION

Since the introduction of osseointegrated dental implants in Dentistry, their use in partially or totally edentulous patients has required an improvement in biomechanical principles. The gap at the I-A interface is an important factor to be considered for the longitudinal success of rehabilitating treatments.[6] The results of the present study support the assertions that UCLA castable abutments present greater vertical marginal discrepancies among the surfaces of the I-A interface, and that machined abutments are more precise than castable abutments —which are more prone to technical and laboratory sensitivity that can cause problems due to contraction during melting, inclusion technique, melting method, type of dental alloy used, and contraction of the alloy.[16,20,21] Considering researches that corroborate the present results, the selection of mini-abutments in the control group was based on the best adaptation of machined components.[16,20,21]

The present study did not simulate clinical procedures for building the infrastructure, so certain factors were eliminated —such as procedures for molding, materials for printing, crystallization expansion of the special plaster and the confection of the master model—, which could have influenced the adaptation of the I-A interface.[22] By eliminating these factors, we could confirm that the greatest vertical maladjustment presented in the UCLA group was related to the process of melting. It is known that the maladjustment of melted pieces, especially large and curved ones, tends to occur because the infrastructure fuses into only one piece, thereby causing greater distortion.[22,23]

Nevertheless, when discussing adaptation, as well as the methods of compensation for the distortion of the infrastructure, it is also necessary to evaluate the geometry and disposition of the implants in the dental arch because they can also influence the mechanical components of implant-supported prostheses.[6] A standardized model in aluminum, with a similar disposition of the implants for all the groups, as well as the creation of standardized melted bars, was used with the objective of eliminating these possible variables in the comparisons between the groups. The use of four implants for fixed implant-supported rehabilitation in edentulous mandibles in the present study was based on previous research in which such procedures provided high survival rates with low-cost implants.[18,19] Based on these findings, the use of four implants has been increasingly indicated for the rehabilitation of edentulous mandibles, reinforcing the importance of the present study.

The analyzed SEM images showed that the abutments that had undergone the process of melting exhibited very irregular surfaces, compared to the prefabricated abutments. The images showed that the process of melting promoted an irregular surface and created an interface that favored the development of peri-implantitis.[24]

The parameters for adaptation of prostheses on implants are a controversial topic; there has been difficulty in establishing acceptable values, the best method for verifying maladjustments and their clinical implications.[23] Despite the difficulty in establishing an acceptable pattern for maladjustment at the I-A interface, the literature has demonstrated an inverse relationship between the magnitude of maladjustment and the biomechanical commitment of the implant-supported rehabilitations.[4,10,11] In the same manner, this study demonstrated that the UCLA group presented the greater average of vertical maladjustment between the evaluated groups, thereby suggesting unfavorable biomechanical behavior.

CONCLUSION

The present *in vitro* study showed that UCLA castable abutments, used for the creation of inferior protocol-type prosthesis on four implants with external hexagon connection, presented greater vertical marginal discrepancies between the surfaces of the I-A interface; and that machined abutments were more precise. Moreover, this study reinforces the need to re-evaluate the use of castable UCLA abutments in implant-supported prosthesis, with a view to achieving greater longevity of rehabilitation treatments.

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