MULTIPARAMETRIC EVALUATION OF FITTING ACCURACY FOR DIFFERENT COMBINATIONS OF IMPLANT-ABUTMENT COUPLING AT MARGINAL INTERFACE

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SUMMARY

Objectives. This study describes a method for the measurement of the marginal gap between abutment and prosthetic crown and analyses the influence of different variables influencing the fitting precision.

Methods. The extent of marginal gap between titanium or dental abutment with different implant types composed of sintered titanium, milled titanium alloy, zirconia and translucent zirconia was evaluated.

The gap at implant-abutment interface was analysed by optical stereomicroscope observation. To optimise measurement precision, samples were oriented with a specific inclination angle and properly stained to limit reflection phenomena. Captured images was processed by ImageJ virtual measuring instruments. The correlation between various factors including type of tooth (molar, canine), stump type (artificial, natural), prosthesis type (sintered titanium, titanium, zirconia and translucent zirconia), and gap type (proximal, distal) was statistically evaluated performing the study of variance (ANOVA).

Results. There was a significant correlation between the type of abutment and the different materials used for implant on fitting accuracy. The variables type of tooth and gap type do not significantly correlate with the marginal gap size.

Results of the ANOVA test demonstrated that the association titanium abutment and titanium implant represent the best fitting with a minimum level of marginal gap at the junction interface.

Conclusions. The measurement of marginal gap with stereoscopic observation associated with the analysis of variance has been demonstrated to be a valuable method for marginal gap evaluation. This approach demonstrated that the best abutment-implant fitting is represented by the association between titanium abutment and titanium implant.

This model could be used to perform preliminary evaluation in order to help the clinician to select the best match of components for prosthetic implant.

Key words: marginal gap, prosthetic crown, implant surface.

Introduction

Fitting precision is an exceptionally important condition for the maintenance of implants integrity and for the prevention of bacterial infection.

A misfit between crown and abutment may generate initial strains and stresses on implant and potentially could led to mechanical complications, such as the fracture of the prosthetic framework.

Therefore, in order to achieve the best fit, of course, accurate implant prosthodontic procedures are necessary, and first of all it's important to take a proper choice of the impression technique.

Digital impressions performed by using an intraoral scanner have shown a number of advan-

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tages, compared to conventional impression techniques. The precision of the impression depends on different factors, such as the materials used (1), the impression tray types (2), the water/powder *ratio*, *vacuum versus* hand-mixing (3), and the type/compatibility of dental tissues with the impression material and the impression techniques (4). Each step in the procedure is subjected to operator's bias and/or to several other material errors (5).

Digital impression and scanning systems allow to overcome all these bias, and it could ensure speed and potential cost and time-effectiveness, in addition to an important reduction of the distortion of impression materials.

Moreover, digital impression has further advantages, such as 3D planning of tooth preparations, a faster transfer of the digital images from dental office to dental technicians and the possibility to indefinitely store the achieved data.

Following the acquisition of dental impression, there are a number of prosthetic implant-abutment combinations, among which the dentist has to select the most predictable and effective one.

The detection of marginal-gaps at the implant-abutment interface is a common clinical task in prosthodontics treatment. Various methods have been suggested for the monitoring of such fit, including macroscopic observation, periotest (6), probing with dental explorers and intraoral radiography (that has been shown to be the prevalent method for marginal gap investigation) (7). These techniques are not specific and carry some limitations that may conduce to a not correct clinical diagnosis.

Therefore, the searching for new imaging and detection modalities for this purpose would be extremely helpful in implant dentistry.

The aim of our study was to investigate a new method for the measurement of marginal gap and to analyse the best match between two different type of abutments, artificial and natural, coupled with 4 different implant options, consisting of sintered titanium, titanium, zirconia and translucent zirconia.

Methods

Preparation of the samples

Abutments used as samples were made of 4 materials: 1) sintered titanium and 2) milled titanium alloy (Pressed), 3) zirconia and 4) translucent zirconia (Katana). The investigations were performed on a plaster cast of a lower-jaw where the titanium implants and natural teeth in 3.3/4.3 and 3.6/4.6 positions were appropriately positioned.

Detection and image processing

Optical stereoscope (L6D, Leica) was used to visualize the gap at implant-abutment interface. To obtain an accurate measurement of the vertical gap, all the specimens were properly positioned on a support inclined of 50° with respect to the horizontal plane, and oriented towards the viewing axis of the stereoscope. Both the abutments and the implants have been properly painted to attenuate the reflection phenomena that could interfere with the correct measurement. At least 50 scans were performed for all samples investigated. For each scan, it has been recorded the measurement of the marginal gap by means of the software *ImageJ*, an image processing software.

Statistical analysis

All the measurements were elaborated using the statistical methods of analysis of variance (ANOVA) to analyse the effects of different factors on the quality of the fitting.

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Results

Marginal closure measurement

The measurements were performed along all the contour of the crown-abutment interface, following the path identified by the following dental regions: distal region - buccal region - mesial region and lingual region. For each coupling, analysis was performed on both canine and molar teeth (Figures 1-4).
It is important to highlight that such measurements were detected in some specific and repetitive points of the couplings, previously studied and identified; this premise justifies the slightly homogeneous behaviour of the graphic shown in the Figures. The data obtained revealed that there are regions in which the measurement of marginal closure reaches values of about 65-70 µm, and that, for all the cases analysed, the average value is of about 35 µm.

Study of variance

The study of variance (ANOVA) was performed on the obtained data, in order to analyse the effects of different factors on the quality of the coupling. In particular, the point-value of marginal closure was considered as our "variable of interest".
Different factors were identified and the effects on the outgoing variable, i. e. marginal closure, were evaluated. The factors identified, and their levels are shown in Table 1.
In accordance with the variance analysis method, the sums of the squares (SS) of each

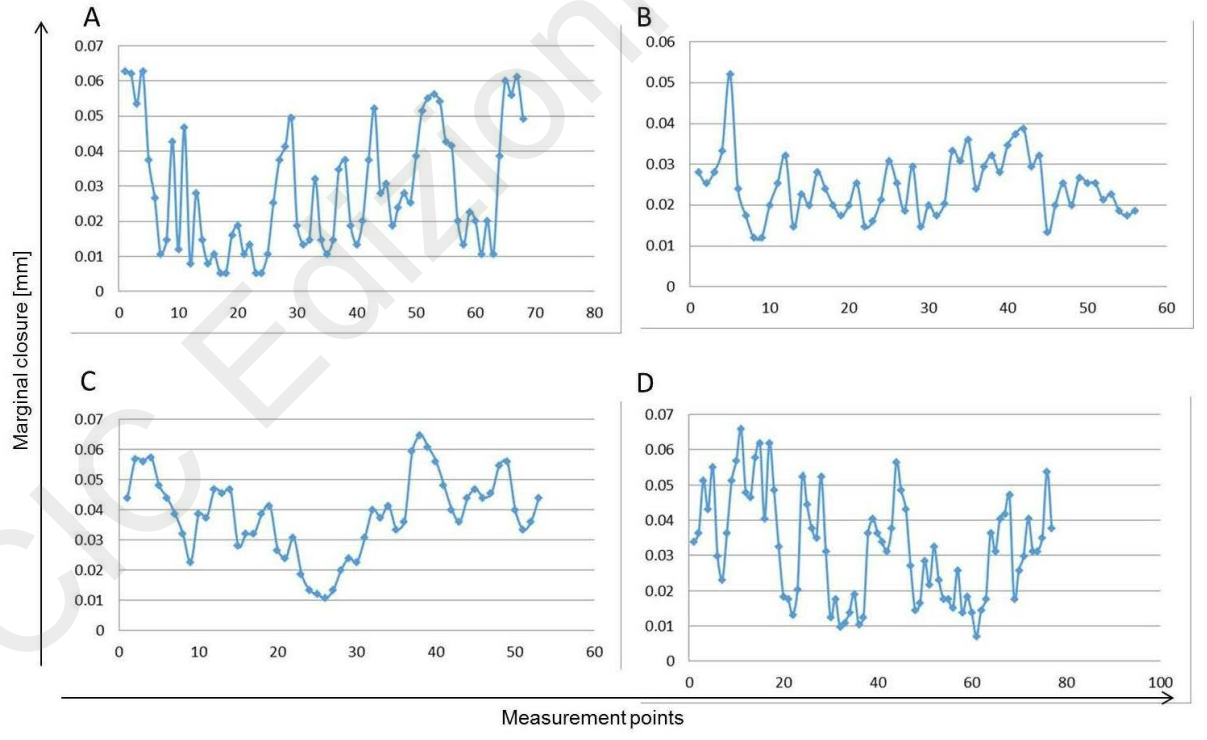

Figure 1
Measurements of marginal closure obtained on the canine for couplings made with titanium abutments and sintered titanium, titanium, zirconia and translucent zirconia capsules.

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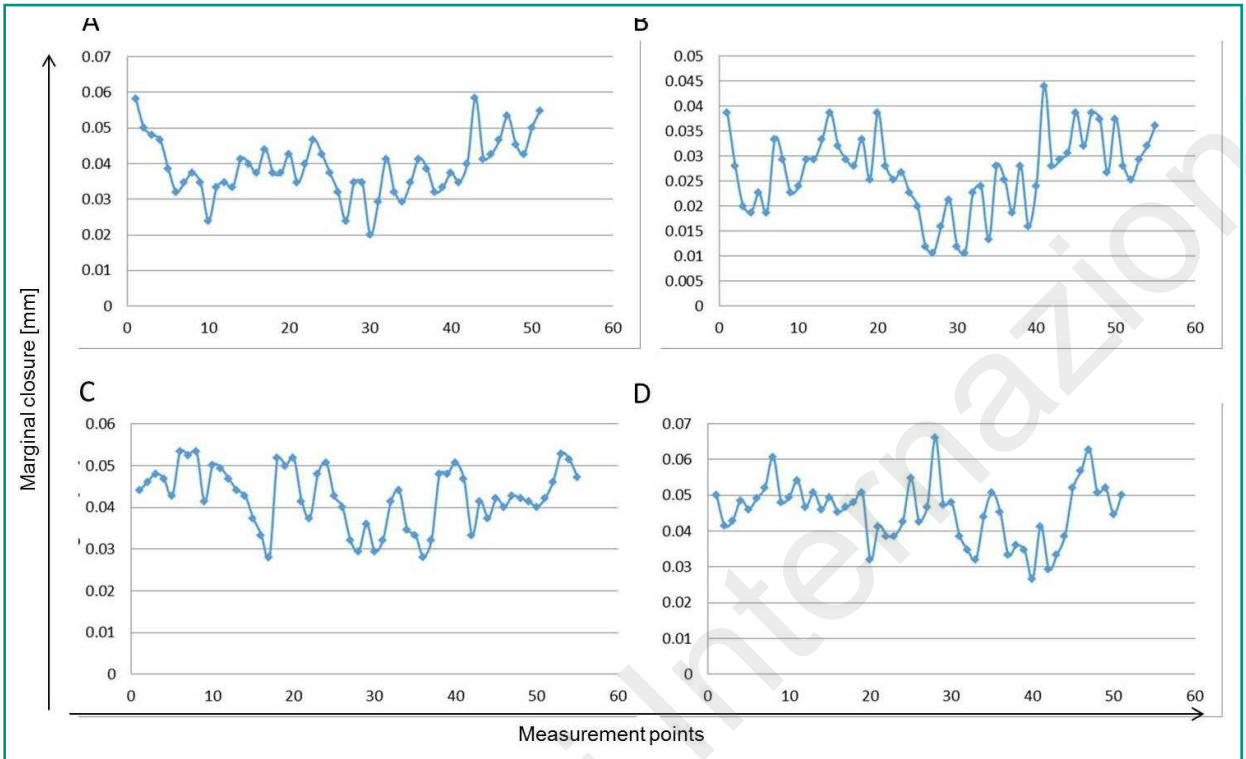

Figure 2
Measurements of marginal closure obtained on the molar for couplings made with titanium abutments and sintered titanium, titanium, zirconia and translucent zirconia capsules.

factor were calculated. It is important to consider that only the direct effects of the variables were considered, while the possible interaction between the different factors were neglected.
The sum of the squares of the error was determined as the difference between the sum of the total squares and the sum of the squares of all the factors. Furthermore, six different measures (n = 6) were made for each combination of input factors. The main results of the analysis of variance are shown in Table 2.
It is observed that the factors A (type of tooth) and D (type or measure side of the gap) have a statistically NOT significant effect on the quality of the coupling. For these two factors, in fact, the variance value (MSA and MSD) is lower than the variance associated with the error, i. e. the factor F0 (MSi / MSErr) is lower than 1.
On the contrary, the marginal gap is strongly influenced by the factor B (type of abutment), with a factor F0 greater than 40.
Also factor C (type of prosthesis) seems to have an influence on the quality of the couplings, albeit to a lesser extent than the factor B (F0~4).
The average values of the marginal closure according to the input parameters are shown in Table 3.
The graph shows a high difference between the mean values relative to the two levels of the factor B, hence, the artificial stump (level 2) allows to obtain significantly more precise couplings with respect to the natural stump, with average values of about 25 µm in the first case against about 35 µm in the second.
Similar variability, although less pronounced, is observed about the factor C, with minimum gap values in titanium prosthesis, near to 26 µm, and maximum values in zirconia prostheses, with average values of about 34 µm. The prostheses obtained by laser sintering and translucent zirconia

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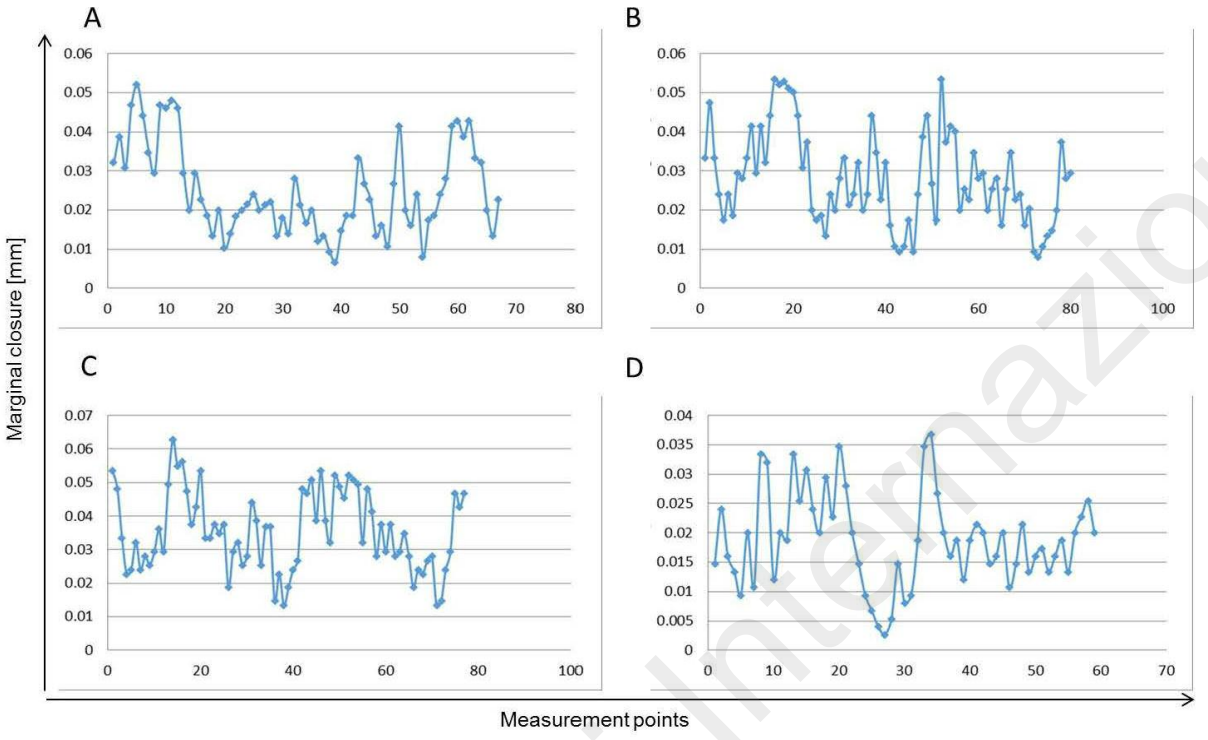

Figure 3
Measurements of marginal closure obtained on the canine for couplings made with natural tooth abutments and sintered titanium, titanium, zirconia and translucent zirconia capsule.

show a similar behaviour with average values of about 29 µm. The graphs of the factors A and D, instead, show almost flat trends with average values between 28 and 30 µm, confirming the limited dependence of the marginal gap on these parameters.

Discussion

The optimal fitting between abutment and prosthesis is an essential pre-condition for an effective and long-lasting implant outcome.

Table 1 - Factors and levels for the analysis of variance.

	Factors	Levels	
Identification	***Description***	***N°***	***Description***
A	Type of tooth	2	1. Canine 2. Premolar
B	Stump type	2	1. Natural 2. Artificial
C	Prosthesis type	4	1. Titanium 2. Laser sintering 3. Zirconia translucent 4. Zirconia
D	Gap Type	2	1. Distal 2. Lingual

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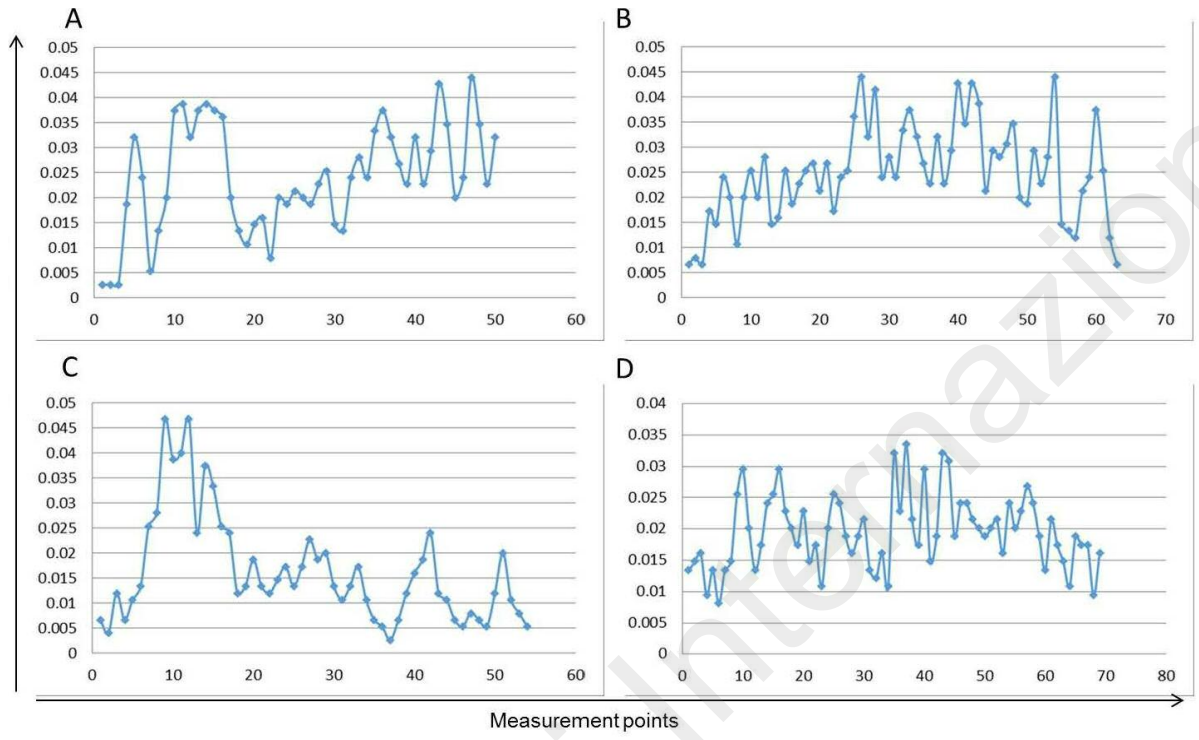

Figure 4
Measurements of marginal closure obtained on the molar for couplings made with natural tooth abutments and sintered titanium, titanium, zirconia and translucent zirconia capsule.

Table 2 - Analysis of variance.

Source of variation	Sum of squares (SS_i)	DOF (DOF_i)	Mean square ($MS_i=SS_i/DOF_i$)	F_0 (MS_i/ MS_{Err})
A	SS_A=2.43877E-05	1	MS_A=2.43877E-05	0.215790959
B	SS_B=4.820487E-3	1	MS_B=4.820487E-3	42.65334222
C	SS_C=1.31371E-3	3	MS_C=4.37903E-4	3.874722016
D	SS_C=1.03887E-4	1	MS_D=1.03887E-4	0.919230709
Err	SS_{Err}=1.8082473E-2	160	MS_{Err}=1.13015E-4	
Tot	SS_{Tot}=2.4344945E-2	191	MS_{Tot}=1.27460E-4	

Table 3 - Average values of the marginal gap (μm) according to the input parameters.

	Factors			
	A	B	C	D
Levels	**Type of tooth**	**Stump type**	**Prosthesis type**	**Gap Type**
1	29.316	24.662	26.417	28.937
2	30.029	34.683	28.785	30.408
3			29.820	
4			33.667	

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Tight closure of the marginal boundary between the abutment and implant is critically important; instead, microleakage produced by a fissure between the components of implant could led to passage of acids, bacteria and their metabolic products (8). Several studies show that microorganisms are present outside, between and within the implant components (9).
These bacteria and their metabolites directly affect the periodontal tissue, causing bleeding and swelling (10); potentially triggering the development of inflammations such as perimplantitis with subsequent implant loss (11).
In addition to biologic issues, it has been shown that marginal misfit could initiate the transmission of high stresses to the alveolar bone and dental implant components (12), causing screw loosening and promoting the risk of abutment fracture (13).
Owing to the fact that a minimum misfit is clinically acceptable, accurate prosthodontic procedures such as exact impression making are necessary to achieve optimal fit (14). Precise 3-dimensional virtual impression, acquired by intra oral scanning permit to transfer accurate abutment positions from the mouth to working casts and allow to obtaining the maximum fit between the stump and the implant structure during fabrication (15).
The detection of marginal gaps at the interface between implant and abutment is an important clinical task in implant dentistry. Several methods have been described for these purpose, these techniques include macroscopic optical control, dental exploring using specific probes, use of periotest devices, etc. (6, 7). Nevertheless, intraoral radiography has been shown to be the most popular method for the verification of the implant-abutment marginal connection. Intraoral radiography, however, shows certain limitations and false diagnosis of the X-ray may occur (16), in addition embrace the risks connected to radiation exposure. Therefore, a new imaging and detection method for this purpose would be extremely advantageous for prosthodontics treatments.
In this work, the marginal fit of two stump types, made with titanium or deriving from natural tooth, coupled with four different types of crown, composed of sintered titanium, titanium, zirconia and translucent zirconia, has been investigated.
Images were obtained by optical stereoscopic observation, to simulate a clinically-relevant imaging setting, the casts were specifically oriented (angle of 50°) on an inclined support. Image processing has been done using virtual measurement tasks of ImageJ software.
Measurements were perceived around all abutment-implant coupling border (distal to lingual region direction), in specific points characterised by sudden closure extent changes.
The results of gap investigations revealed, for all the cases analysed, an average value of marginal closure of about 35 µm, with regions characterized by measures that reaching values of about 65-70 µm.
Despite most Authors empirically accept a maximum tolerable misfit value of 120 µm (17, 18). Previous studies have only discussed the deleterious effects caused by marginal misfit of the implant-abutment interface, but there are no evidences about the acceptable range of misfit.
Thus, marginal gaps should be clinically detected and corrected; for this purpose, our approach could be considered an accurate and sensitive method.
The acquired data has been statistically elaborated by the analysis of variance (ANOVA), in order to investigate the effects of different factors on the quality of the coupling. For this purpose, different variables were identified and their effects on marginal closure were assessed. The results of these tests demonstrated that the factors more influencing the extent of marginal closing are the abutment type and the prosthesis type. Moreover, the artificial stump allows to obtain significantly more precise couplings with respect to the natural abutment, with average values of about 25 µm in the first case against about 35 µm in the latter. Similar variability, albeit less pronounced, is observed about the type of prosthesis, with minimum gap values in titanium prostheses, equal to about 26 µm, and maximum values in zirconia prostheses, with average values of about 34 µm. The prostheses obtained by

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laser sintering and translucent zirconia show a similar behaviour with average values of about 29 µm. The data of the factors "type of tooth" (canine or molar) and "typology of gap" (distal or proximal) shown instead, average values between 28 and 30 µm, confirming the weak dependence of the marginal gap on these two parameters.

The analysed parameters may also be depending from other variables, for example related to infections on the bone level, creating a hostile environment (19, 20) as well as a local condition that could impair the tissue reply to physiological stimuli (21, 22). It's quite usual to treat patients with some systemic disease, such as oral cancer (23), syndromic conditions (24), infections (25) or a simple unavailability to collaborate with dentist: such patients should be differently approached, as the technique used is not so important at all to obtain a good final result.

Tissue engineering has been also investigated to overlap a proper function with a good aesthetic in prosthetics. Several tissues (26-28) have been investigated as scaffolds, and also specific *in vitro* studies (29-32) have been committed to better understand the role of scaffolds in implant dentistry and in prosthetic dentistry. The main suggestion to avoid complications is related to the smoking habits, preferring at least the e-smoking and limiting the traditional cigarettes (33).

All such considerations will improve the peri-implant tissues maintenance and the clinical success (34-37).

Conclusion

The evaluation of the optimal fit of the implant to abutment has been considered as an important prerequisite for long-term clinical success, indeed an excessive level of gap could cause pain, plaque accumulation and stress in the cervical area of the implant.

In this study a new method is proposed for the evaluation of the marginal gap, based on the acquisition of optical images with stereoscopy followed by image processing through specific software. Thus, these processes could be considered as a new useful tool to evaluate the implant-abutment interface.

Furthermore, the statistical analysis of the data obtained with this protocol shown that artificial abutments allow to obtain significantly more precise couplings and that the type of prosthesis, which determines minimum gap values, is represented by titanium implants. Concluding the best results in terms of abutment-crown coupling could be obtained on titanium stump combined with titanium prostheses.

Funding

None.

Competing interests

None.

Ethical approval

Not required.

Patient permission

Not required.

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