CLINICAL ORAL IMPLANTS RESEARCH

Eriberto Bressan
Gianluca Paniz
Diego Lops
Boris Corazza
Eugenio Romeo
Gianantonio Favero

Influence of abutment material on the gingival color of implant-supported all-ceramic restorations: a prospective multicenter study

Authors' affiliations:
Eriberto Bressan, Department of Periodontology, Dental Clinic, School of Dentistry, University of Padova, Padova, Italy
Gianluca Paniz, Department of Prosthodontics and Operative Dentistry, Tufts University, Boston, MA, USA
Gianluca Paniz, Boris Corazza, Department of Prosthodontics, Dental Clinic, School of Dentistry, University of Padova, Padova, Italy
Diego Lops, Department of Periodontology, Dental Clinic, School of Dentistry, University of Milan, Milan, Italy
Eugenio Romeo, Gianantonio Favero, Department of Prosthodontics, Dental Clinic, School of Dentistry, University of Milan, Milan, Italy

Corresponding author:
Gianluca Paniz
Department of Prosthodontics
Dental Clinic
School of Dentistry
University of Padova
Via Cesarotti 31
35100 Padova
Italy
Tel.: +39 049 8751455
Fax +39 049 8776791
e-mail: panizg@hotmail.com

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Abstract

Purpose: The aim of this clinical research on implant-supported restorations is to analyze, through spectrophotometric digital technology, the influence of the abutment material on the color of the peri-implant soft tissue.

Material and methods: Twenty patients received an endosseous dental implant in the anterior maxilla. At the time of each definitive prosthesis delivery, an all-ceramic crown has been tried on gold, titanium and zirconia abutment. After the insertion of each single abutment, the peri-implant soft tissue color has been measured through a spectrophotometer. Also, the thickness of the facial peri-implant soft tissue was measured at the level of the implant neck through a caliper. A specific software has been utilized to identify a specific tissue area and to collect the data before the statistical analysis in *Lab** color space. The normality of the quantitative variables was verified by means of the Shapiro–Wilk test. Simple linear correlation between quantitative variables was evaluated by using Pearson's coefficient. The results on the performance of the abutment materials with regard to the color measurements and the overall measurement ΔE were described by computing the least-square means. The significance of differences among types of abutment was verified by means of the Scheffe test for multiple comparisons.

Results: For all the abutments used, the color of the peri-implant soft tissue appeared to be significantly different from the one of the contra-lateral tooth ($\Delta E > 8.5$). Significantly higher ($P < 0.05$) difference were present with the use of titanium abutments (11 ± 0.4) when compared with the results of gold (8.9 ± 0.4) and zirconia (8.5 ± 0.4) abutments. No correlation has been demonstrated between soft tissue thickness and degree of color difference ($P > 0.25$).

Conclusions: Within the limitation of the present study, the peri-implant soft tissue color appears to be different from the soft tissue color around natural teeth, no matter which type of restorative material is selected. When titanium abutment was selected, significantly higher differences were present than those obtained with gold or zirconia abutments. The thickness of the peri-implant soft tissue did not appear to be a crucial factor in the abutment impact on the soft tissue color.

The preservation or reproduction of a natural mucogingival architecture surrounding dental implants placed in the anterior maxilla is esthetically challenging for the restorative dentist, particularly when patients present with a high lip line when smiling. The challenge arises from the loss of muco-gingival tissue as a result of bone loss after extraction of traumatically injured or periodontally compromised teeth, or is due to a traumatic surgical extraction or congenital defects (Buser et al. 2004).

The selection of a dental implant system that allows a proper biological response of the hard and soft tissues, represents the first step for the achievement of an adequate esthetic result (Sykaras et al. 2000). Besides, a proper surgical technique, implant positioning and soft tissue management are necessary for a natural outcome (Choquet et al. 2001; Kan et al. 2003; Grunder et al. 2005; Quirynen et al. 2007). Finally, the selection of the proper prosthetic solution, which is often overlooked, contributes significantly in the achievement of a proper shade and shape of the gingival tissue (Bichacho & Landsberg, 1997; Tarnow & Eskow 1996). The utilization of customized emergence profiles and abutments is critical for the achievement of proper esthetic results (Gallucci et al. 2004).

Most recently, all-ceramic restorations have become increasingly popular for restoring teeth and implants. The advantages of all-ceramic restorations cemented over metal abutments are questionable, especially when the abutment choice is for a highly translucent heat-pressed

ceramic restoration (Nakamura et al. 2002). All-ceramic abutments, made of aluminum oxide or yttrium-stabilized zirconium oxide, have been produced in an effort to overcome this esthetic problem (Prestipino & Ingber 1993a; Wohlwend et al. 1996; Heydeck et al. 2002; Rompen et al. 2007).

The esthetic benefit of ceramic abutments over metal abutments has been well documented in a recent clinical study by (Jung et al. 2008). Anyway, increased thicknesses of alumina and zirconium oxide could compromise the esthetic result due to an increased opacity and reduced translucency (Hefferman et al. 2002a, 2002b); therefore, the benefit might be controversial.

The presence of different abutment closer to the soft tissue might affect the esthetic appearance of the peri-implant soft tissue and alter its color and appearance. In a recently published study by (Jung et al. 2008), with the utilization of titanium or gold abutment with PFM Crown or aluminum oxide abutment with all-ceramic crown, clinically noticeable differences were present in comparison with the contra-lateral tooth; all-ceramic restorations revealed a significantly better color match to the un-restored neighboring teeth than porcelain-fused-to-metal restorations on titanium or gold abutments.

The purpose of this clinical trial on implant-supported restorations is to analyze, through spectrophotometric digital technology, the influence of the abutment material on the color of the peri-implant soft tissue. Moreover, the correlation between soft tissue thickness and digital evaluation will be analyzed in order to verify possible esthetic implications for the utilization of different types of abutment material related to different clinical situations.

Material and methods

Twenty patients have been included in this prospective multicenter study. All patients have been treated at the University of Padova Dental School and at Dental Clinic of Biomedical Sciences Institute, St. Paul Hospital, University of Milan, Italy. The study protocol was approved by the University of Padova and Milan Institutional Ethics Committees. Informed consent was obtained from all subjects.

Each single patient received an endosseous dental implant (Osseospeed 4.0s, Astra Tech Dental Implant, Astra Tech AB, Molndal, Sweden), which has been placed in the anterior maxilla (area from tooth 1.5 and 2.5).

To be included in the study, all patients presented: (i) controlled periodontal condition (no PPD index superior to 4 mm, no bleeding on probing and plaque index inferior to 20%); (ii) no active intraoral or systemic disease; (iii) healed single edentulous site; and (iv) tooth contralateral to the placed implant: the natural tooth had to be present, vital and not restored.

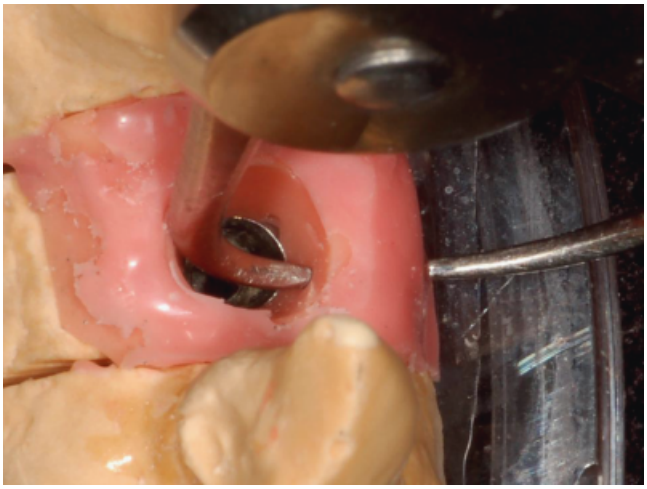

Fig. 1. Thickness of the facial peri-implant soft tissue replica on the master cast (siliconic replica). Measurement performed at the level of the implant neck through a caliper.

Exclusion criteria were: (i) patients with systemic diseases (such as heart, coagulation and leukocyte diseases or metabolic disorders); (ii) history of radiation therapy in the head and neck region; (iii) current treatment with steroids; (iv) neurological or psychiatric handicap that could interfere with good oral hygiene; (v) immuno-compromised status, including infection with human immunodeficiency virus; (vi) severe clenching or bruxism; (vii) smoking habit (>15 cigarettes/die); (viii) drug or alcohol abuse; and (ix) inadequate compliance.

A two-stage surgical technique and no additional soft or hard tissue graft were planned for all the implants. All implants were submerged and all parts of the defects were covered by mucosal tissue. Removable prostheses or provisional fixed bridges were adjusted.

Four months after implant placement, surgical re-entry occurred; implant stage 2 was performed by the same operator and a trans-mucosal healing abutment (Healing Abutment 3.5/4.0, Astra Tech Dental Implant) was inserted [Time 0].

Two weeks after surgical re-entry, an implant-level impression was taken for the fabrication of a screw-retained temporary restoration [Time 1]. The provisional restoration was inserted 1 week after implant level impression [Time 2]. After 8 weeks of soft tissue conditioning by means of the provisional restoration, a definitive implant level impression was taken; a precise record of the soft tissue dimensions [Time 3] was recorded. The pick-up impression coping was modified by adding a self-polymerizing resin (Duralay, Chicago, IL, USA) in order to reply the emergence profile of the provisional restoration in the definitive cast (type IV dental stone, New Fuji-Rock, GC Corp., Tokyo, Japan). The thickness of the facial peri-implant soft tissue was measured at the level of the implant neck through a caliper (Iwanson Decimal Caliper, Asa Dental spa, Lucca, Italy) (Figs. 1 and 2). The peri-implant mucosa was replied by using a light-consistance siliconic material around the implant analog before the dental stone application so that an eventual inaccuracy of the soft tissue reproduction steps could be reduced at least.

The definitive prosthesis was an implant-supported single crown cemented on a customized abutment. One full coverage restoration was fabricated for each single implant with the utilization of a zirconia coping (Lava, 3M ESPE, Seefeld, Germany) and feldsphatic porcelain stratification (Ziro X veneering ceramic, Wieland Dental + Technik GmbH & Co. KG, Pforzheim, Germany).

The customized abutment was the variable of the present study and three different materials have been utilized: titanium, gold-alloy and zirconia as shown in Table 1. The facial and interproximal margin level were kept 1mm subgingival while the palatal margin was left equigingival. CAD-CAM technology (WizBlade, Nextec Technologies 2001 Ltd., Tirat HaCarmel, Israel) was used to create the same morphology for all the 3 types of abutments using a milling machine (MIKRON HSM 400U ProdMed, Angie Charmilles International SA, Geneva, Switzerland).

Fourteen weeks after implant stage 2 [Time 4], the temporary restoration was removed and definitive customized abutments were screwed (Ratchet Wrench, Astra Dental Implant). The definitive all-ceramic crown (Lava, 3M ESPE) was temporarily placed on the abutment with a

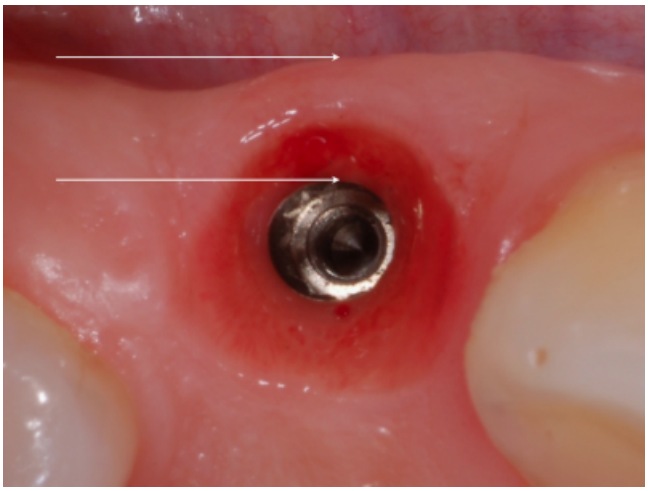

Fig. 2. Correspondent occlusal view of the dental implant and the facial peri-implant soft tissue.

Table 1. **Abutment type**

Abutment type	Abutment material
Type 1	Cast-to abutments 3.5/4.0 (Astra Tech Dental Implant) Keramit Eco LF, Micro Fine Grain Alloy (Au 57%, Pd 10,6%, Ag 29,2%) (NobilMetal S.p.A., Villafranca d'Asti, Italy)
Type 2	Titanium abutment: platform 3.5/4.0 (Astra Tech Dental Implant)
Type 3	Zirconia abutment: platform 3.5/4.0 (Astra Tech Dental Implant)

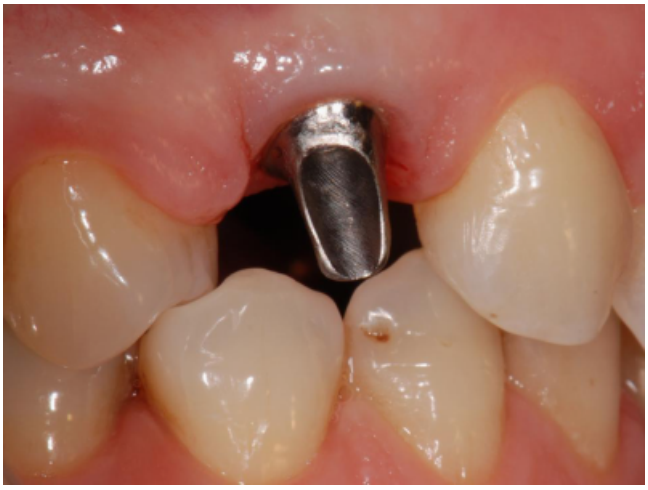

Fig. 3. Titanuim abutment screwed into position.

try-in paste (Variolink trial base, Ivoclar Vivadent, Ivoclar Vivadent AG, Schaan, Liechtenstein).

Each type of abutment (Table 1) was left in the mouth for 10 min, with the correspondent crown positioned, before proceeding with the color measurement of the peri-implant soft tissue. Immediately after the first color measurement, the all-ceramic restoration was removed, the first abutment was unscrewed and the second one was positioned in the same manner of the first one. Even if without altering the shape of the definitive prosthesis from the final one, no pressure on the soft tissue was noticed, 10 min were left between the prosthesis insertion and the color measurement in order to have a stable tissue color. After the completion of the color measurement of the second abutment, the peri-implant soft tissue around the third one was measured in the same manner (Figs. 3–5). The sequence of choice of the type of abutment was randomly selected on each single case. The measurement of the contra-lateral soft tissue area (control site), adjacent to a natural tooth, was also performed in order to obtain a standard reference measurement.

The color measurement has been obtained using a spectrophotometer (Spectroshade ''Micro'' Device, MHT S.p.A., Medical High Technologies, Arbizzano di Negrar, Verona, Italy). The device was managed by a single operator who captured an area of about 5 mm around the gingival margin of the selected tooth or crown. Each selected area was measured for three times. After all the measurements, an evaluation of the esthetic outcome was also performed by the operator and by the patient and the best solution was delivered to the patient.

The selected abutment was torqued down to 25 N/cm (Abutment Screw, Astra Tech Dental Implant) with a torque wrench (Torque Wrench, Astra Tech Dental Implant) and the definitive all-ceramic crown was cemented with a temporary cement (Temp-Bond Clear, Kerr Corporation, Orange, CA, USA).

All the measured areas were analyzed through the spectrophotometer software (Spectroshade 3.01, MHT S.p.A.) which identified a specific area. The selected area extended from the gingival level to 4 mm sub-gingival and from the long axis of the tooth 2 mm on each side as shown in Fig. 6. The results of each measured area were recorded through *Lab** color scale and the values from the three measurements were averaged before proceeding with the statistical analysis. The comparison between the peri-implant soft tissue and the contra-lateral gingival tissue was performed with the use of the following ΔE formula:$\Delta E = (\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2$. A critical threshold of ΔE 3.7 for intraoral color distinction by the naked eye was considered (Munsell, 1923; Hunt 1987; Johnston & Kao 1989; Berns 2000).

Statistical analysis was performed to investigate the performance of the abutment materials. The normality of the quantitative variables was verified by means of the Shapiro-Wilk test. Simple linear correlation between quantitative variables was evaluated by using Pearson's coefficient. The results on the performance of the abutment materials with regard to the color measurements and the overall measurement δE were described by computing the least-square means as well as their standard errors (SE). To obtain the adjusted least-square means, general linear models were applied with types of abutment and patients as main fixed effects.

This method also provided the 95% confidence intervals (95% CI) for the mean values. The significance of differences among types of abutment was verified by means of the Scheffe test for multiple comparisons, or by the Dunnett test when the not-treated teeth (control sites) characteristics were used as reference.

The significance level was fixed at 0.05, and all tests were two tailed. All the analyses were performed using the SAS statistical software rel. 9.1 (SAS Institute, Cary, NC, USA).

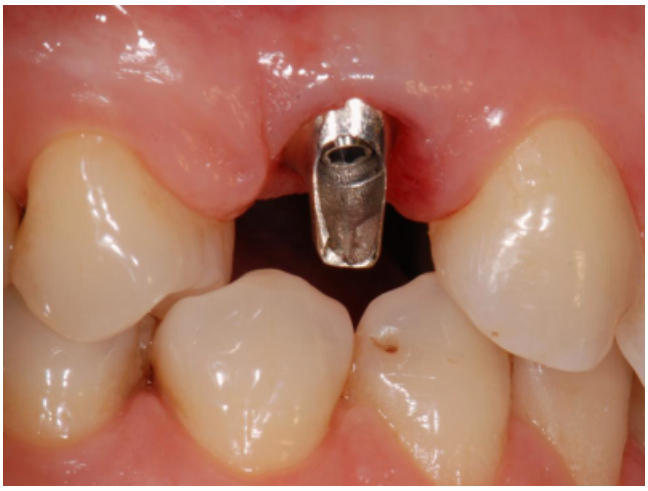

Fig. 4. Gold-alloy abutment screwed into position.

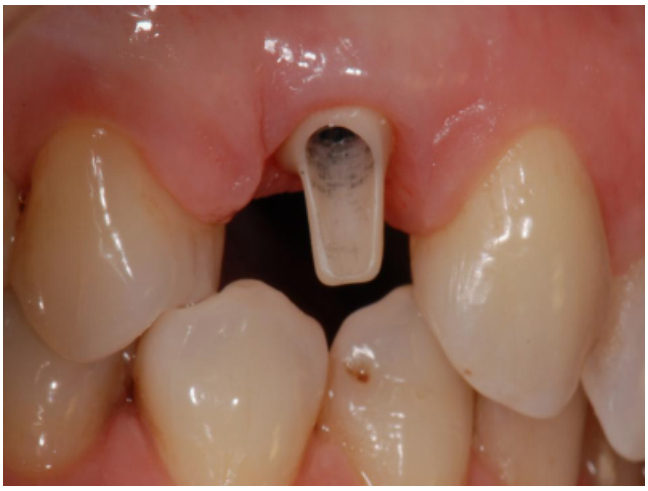

Fig. 5. Zirconia abutment screwed into position.

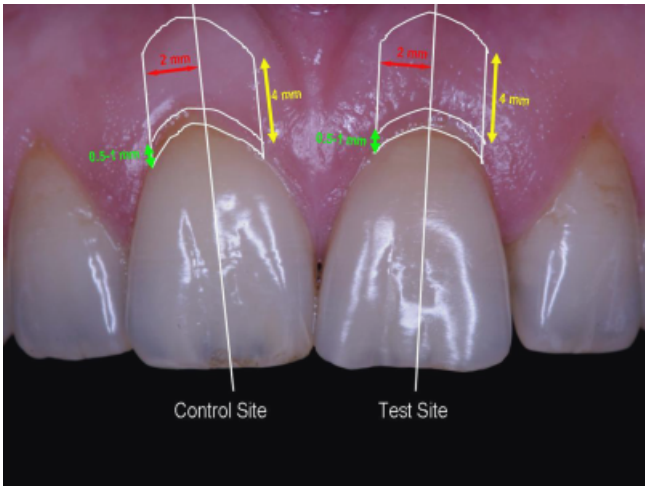

Fig. 6. Selected area identified through spectrophotometer software: 2 mm in thickness (red arrow) and 4 mm in apico-coronal direction (green arrow).

Results

The peri-implant soft tissue color was different from the soft tissue color around natural teeth, no matter which type of restorative material was selected (Table 2). Measurements relative to all the abutments were above the critical threshold of ΔE 3.7 for intraoral color distinction by the naked eye. When the crown was placed over the abutment, the ΔE mean value between the peri-implant soft tissue and the contra-lateral gingival tissue was similar for gold and zirconium abutment (8.9 and 8.5, respectively), but it was significantly greater with the titanium abutment (11).

***Table 2*. Estimated least square mean ± standard errors (SE) and 95% confidence intervals (95% CI) of ΔE by abutment materials**

	Mean ± SE	95% CI
Gold	8.9^{a} ± 0.4	8.1–9.7
Titanium	11^{b} ± 0.4	10.2–11.9
Zirconium	8.5^{a} ± 0.4	7.6–9.3

Different superscript letters indicate significantly ($P<0.05$) different mean values (Scheffe's test for multiple comparison).

The calculated *Lab* (*L*, *a*, *b*) values of the measured areas around abutments and natural teeth were summarized on Table 3. For each feature, natural teeth mean values were significantly higher than those of the different types of abutment. In addition, gold and titanium abutments provided no significantly different mean values both for *L* and *b* color measurement, while titanium abutment always provided lower mean values. For the *a* color measurements, no differences were evident among the three types of abutment. Gold, titanium and zirconia abutment measurements were significantly different ($P<0.001$) from contra-lateral teeth (control sites) measurements.

Calculated *Lab* values of different abutments with correspondent 95% CI are reported in Fig. 7; control sites were considered as reference. All the differences evaluated by using paired data were statistically significant, as shown by 95% CIs (zero value not included). Fig. 7 also showed that titanium abutment exhibited worse color performances than gold and zirconium abutments. The zirconia results were likely to achieve the best color matching with natural teeth, but the differences with gold performance were never statistically significant.

To verify the role of soft tissue thickness on the color measurements with the different abutment types, a stratified analysis was performed by dichotomizing the thickness on 2 mm (thin ≤ 2 mm; thick > 2 mm). Seven patients were included in the "Thin" group and the other 13 patients made up the "Thick" group, respectively. The ΔE mean value did not depend on the soft tissue thickness (Table 4), and thickness might only relate to the Ä*b* color aspect (Table 5).

Discussion

The present study evaluated the color-change effect on marginal peri-implant soft tissue of all-

Table 3. **Estimated least square mean ± standard errors (SE) of *Lab* values: measured areas around abutments and natural teeth by abutment materials**

	Gold	Titanium	Zirconium	NT
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
L^*	$47.1^{a,b} \pm 0.6$	$45.6^{a} \pm 0.6$	$48.1^{b} \pm 0.6$	$52.9^{c} \pm 0.6$
a^*	$22.1^{a} \pm 0.5$	$21.5^{a} \pm 0.5$	$22.9^{a} \pm 0.5$	$25.5^{b} \pm 0.5$
b^*	$14.9^{a,b} \pm 0.3$	$13.9^{a} \pm 0.3$	$15.4^{b} \pm 0.3$	$18.4^{c} \pm 0.3$

Different superscript letters indicate significantly different mean values.

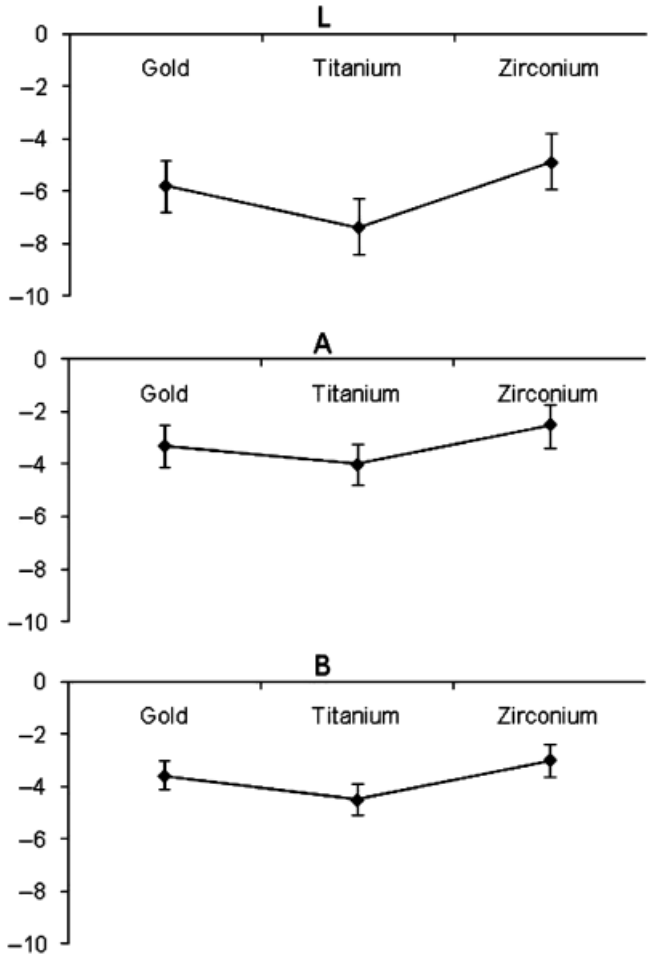

Fig. 7. Calculated *Lab* values with correspondent 95% confidence interval represented by type of abutment: taking not treated teeth (control site) taken as reference.

Table 4. **ΔE mean values and standard errors (SE) by soft tissue thickness and abutment materials**

	Soft tissue thickness (mean ± SE)		*P*
	≤ 2 mm (7 pt)	> 2mm (13 pt)	
Gold	8.6 ± 1.4	9.1 ± 0.8	0.74
Titanium	9.5 ± 1.4	11.9 ± 1.2	0.25
Zirconium	7.5 ± 1.4	8.9 ± 0.7	0.38

Table 5. **Correlation coefficients between soft tissue thickness (mm) and the difference for the *Lab* values of the measured areas around abutments and natural teeth or ΔE, by abutment materials**

	Gold	Titanium	Zirconium
ΔL	0.2 (0.38)	− 0.06 (0.81)	− 0.04 (0.87)
ΔA	− 0.3 (0.19)	− 0.26 (0.26)	− 0.2 (0.38)
ΔB	− 0.45 (0.05)	− 0.4 (0.08)	− 0.4 (0.08)
ΔE	0.08 (0.74)	0.09 (0.71)	0.13 (0.6)

Significance in brackets.

ceramic restorations based on zirconium oxide, gold-alloy and titanium abutments. The peculiarity of this trial was that measurements were performed for all three abutment materials in each patient; therefore, important patient-related and material-related biases were avoided. Moreover, different from previous studies, only one type of crown was utilized, relating the results only to the abutment variable.

In accordance with the data available in the international literature by (Sailer et al. 2009) and (Zembic et al. 2009), the results of the present study showed a significant difference between the color of the peri-implant soft tissue and the color of the gingival around natural teeth no matter which type of prosthesis is used. As described on Table 2, ΔEs were always higher than the critical threshold of 3.7 (Johnston & Kao 1989). This value, described as higher value for color matching between natural teeth and restored teeth, might have only a relative impact on the analysis of the soft tissue but represent the most reported reference in the literature (Ishikawa et al. 1988; Jung et al. 2008; Lops et al. 2008; Romeo et al. 2008). Other values reported in the tooth color matching literature are even lower (Douglas, 1997; Douglas & Brewer, 1998). The absence in the literature of a reference for soft tissue color matching may represented a limitation in the analysis of present results, but the ΔE values obtained are significantly higher than the reported color differences between the soft tissues of contra-lateral natural teeth, which were within 2.7 (Zembic et al. 2009).

As described on Table 3, significantly different mean values have been found between titanium on one side and gold and zirconia on the other side. While no differences were present in the color performance of gold and zirconium oxide abtments, the color of the soft tissue around titanium abutment was significantly more different from the gingival color around natural teeth.

In addition, all the single values (L^*, a^*, b^*) were different from the values obtained around natural teeth. Among the different type of abutments, no significant differences were present in considering the red and green scale of a values, confirming a trend already reported in the literature (Hermann et al. 2001). In the analysis of L^* and b^* values, significantly differences were present among the abutment. The peri-implant soft tissue around zirconium oxide abutments appeared to be significantly closer to the color of natural teeth gingival than titanium and gold abutment provided interposed results. Also, (Jung et al. 2008) noticed clinically gingival color differences between around peri-implant soft tissue in comparison with the contra-lateral tooth. Nevertheless, their results suggested that all-ceramic restorations on aluminum oxide abut-

ments provide a significantly better color match to the un-restored neighboring teeth than porcelain-fused-to-metal restorations on titanium or gold abutments. Unfortunately, no specification on the number of gold or titanium abutment nor a description on the possible different outcome present between these two types of abutment has been made. Moreover, considering the properties of zirconium oxide vs. aluminum oxide, zirconium oxide should be referred on implant-supported restorations (Butz et al. 2005; Canullo, 2007; Garine et al. 2007).

Another *in vitro* study by (Jung et al. 2007) reported a decrease of the color change related to an increasing of the mucosa thickness over zirconia and titanium. In situations with a mucosal thickness of 1.5 mm, both materials demonstrated ΔE values above the critical threshold of 3.7 (Park et al. 2007), with a score of 3.87 for zirconium oxide and 5.06 for titanium. With a mucosa thickness of 2 mm, the color change induced by zirconia was below the threshold of 3.7 (3.17), whereas titanium still caused a visible difference (4.32). With a 3 mm thickness, all the abutment scored within the limit of 3.7 (titanium 2.14 and zirconia 2.47).

For this reason, the present study also tried to assess possible *in vivo* implication of the thickness of peri-implant mucosa by dichotomizing it at 2 mm: 7 patients with thin and 13 with thick peri-implant soft-tissues were observed. As shown on Table 4, no statistically significant differences were present in the color of the mucosa between thick and thin tissue. Even if a trend of higher values of differences was noticed, especially with titanium abutment, in the thick group, this study did not confirm that mucosa thickness mucosa is a crucial factor in terms of discoloration as concluded by (Jung et al. 2007). Most probably this result differed from the previous literature due to the reduced sample size. Another reason for this trend could be that no soft tissue thickness $\geq$ 3 mm was found in the group classified as ''Thick.'' Further researches on more representative patient samples are requested to confirm or refuse this trend.

Regarding an eventual shortcoming of the thickness measurement by means of a caliper applied to the study cast), the authors considered that a customized pick-up was able to permit a precise reproduction of the trans-mucosal soft tissue cone, and a light-consistence polyether material could not interfere in the soft tissue thickness re-production. Probably, the subsequent step of the gingival re-construction on the master cast by means of a siliconic material could add some degree of inaccuracy (maybe fraction of millimeter) in the peri-implant mucosa re-production. It could be interesting to compare the accuracy of this method with that used by (Sailer et al. 2009) and (Zembic et al. 2009). They recorded the soft tissue thickness in the region of esthetic assessment both at implants and teeth using an endodontic file (ISO #20) with a rubber stop.

Conclusions

Within the limitation of the resent study, the following conclusions can be drawn:

- the peri-implant soft tissue color is different from the soft tissue color around natural teeth, no matter which type of restorative material is selected.
- titanium abutments are associated with significantly higher differences than those obtained with gold or zirconia abutments.
- no significant differences are present between the color of peri-implant soft tissue around zirconia abutment and the one around gold abutment.
- the thickness of the peri-implant soft tissue does not appear to be a crucial factor in the abutment impact on the soft tissue color.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Supporting information in accordance with the CONSORT Statement 2001 checklist used in reporting randomized trials.

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