Influence of Abutment Color and Mucosal Thickness on Soft Tissue Color

Marco Ferrari, MD, DMD, PhD[1]/ Michele Carrabba, DDS, PhD[2]/Alessandro Vichi, DDS, MS, PhD[3]/ Cecilia Goracci, DDS, MS, PhD[4]/Maria Crysanti Cagidiaco, MD, DMD, PhD[5]

Purpose: *Zirconia (ZrO_2) and titanium nitride (TiN) implant abutments were introduced mainly for esthetic purposes, as titanium's gray color can be visible through mucosal tissues. This study was aimed at assessing whether ZrO_2 and TiN abutments could achieve better esthetics in comparison with titanium (Ti) abutments, regarding the appearance of soft tissues.* ***Materials and Methods:*** *Ninety patients were included in the study. Each patient was provided with an implant (OsseoSpeed, Dentsply Implant System). A two-stage surgical technique was performed. Six months later, surgical reentry was performed. After 1 week, provisional restorations were screwed onto the implants. After 8 weeks, implant-level impressions were taken and soft tissue thickness was recorded, ranking thin (≤ 2 mm) or thick (> 2 mm). Patients were randomly allocated to three experimental groups, based on abutment type: (1) Ti, (2) TiN, and (3) ZrO_2. After 15 weeks, the final restorations were delivered. The mucosal area referring to each abutment was measured for color using a clinical spectrophotometer (Easyshade, VITA); color measurements of the contralateral areas referring to natural teeth were performed at the same time. The data were collected using the Commission Internationale de l'Eclairage (CIE) L*a*b* color system, and ΔE was calculated between peri-implant and contralateral soft tissues. A critical threshold of ΔE = 3.7 was selected. The chi-square test was used to identify statistically significant differences in ΔE between thin and thick mucosal tissues and among the abutment types.* ***Results:*** *Three patients were lost at follow-up. No statistically significant differences were noticed as to the abutment type ($P = .966$). Statistically significant differences in ΔE were recorded between thick and thin peri-implant soft tissues ($P < .001$). Only 2 out of 64 patients with thick soft tissues showed a ΔE higher than 3.7: 1 in the TiN group and 1 in the ZrO_2 group. All the patients with thin soft tissues reported color changes that exceeded the critical threshold.* ***Conclusion:*** *The different abutment materials showed comparable results in terms of influence on soft tissue color. Regarding peri-implant soft tissue thickness, the influence of the tested abutments on soft tissue color became clinically relevant for values ≤ 2 mm.* Int J Oral Maxillofac Implants 2017;32:393–399. doi: 10.11607/jomi.4794

Keywords: *customized abutment, gingival color, implant biotype, titanium, titanium nitride, zirconia*

In modern dentistry, an increasing demand for esthetics among patients and clinicians has led to the development of treatments and materials designed to be long lasting and also be esthetically pleasing. This is not without its challenges.[1–3]

In recent years, metal-free restorations have served as viable prosthetic solutions that imitate the optical properties of natural dentition.[4,5] Thanks to their intrinsic translucence and adequate mechanical properties, all-ceramic materials are now considered the most appropriate choice to mimic tooth function and esthetics.[6]

Simulation of natural esthetics in implant restoration is not limited to reproducing the color and optical properties of natural dentition; it involves peri-implant soft tissues as well.[7]The color of soft tissues is related to several factors, including the thickness of the keratinized epithelium, the quantity of blood vessels, and the quality and density of the collagen fibers.[8]

Structural changes to soft tissues, such as extraction-related blood vessel loss, placement of the

[1]Professor and Chair, Department of Prosthodontics and Dental Biomaterials, University of Siena, Siena, Italy.
[2]Visiting Professor, Department of Medical Biotechnologies, University of Siena, Siena, Italy.
[3]Assistant Professor, Department of Medical Biotechnologies, University of Siena, Siena, Italy.
[4]Assistant Professor, Department of Medical Biotechnologies, University of Siena, Siena, Italy.
[5]Visiting Professor, Department of Medical Biotechnologies, University of Siena, Siena, Italy.

Correspondence to: Prof Dr Marco Ferrari, School of Dental Medicine, Policlinico Le Scotte, Viale Bracci 1, 53100 Siena, Italy. Fax: +39 057 7233117. Email: ferrarm@gmail.com

Table 1 Inclusion and Exclusion Criteria

Inclusion criteria
Age ≥ 18 years
No systemic diseases or pregnancy
Smoking ≤ 10 cigarettes/day
No active periodontal disease with no site showing probing depth > 4 mm
Full-mouth plaque score (FMPS) and full-mouth bleeding score (FMBS) ≤ 15% (measured at four sites per tooth)
At least one missing tooth in maxilla or mandible
Adequate bone volume for implant insertion
Exclusion criteria
Heavy smokers (> 10 cigarettes/day)
Subjects requiring hard/soft tissue augmentation
Severe bruxism
Untreated periodontal disease/poor compliance

implant, and overall surgical procedures, can influence the color of mucosal tissues.[9,10] In particular, the peri-implant mucosa has been reported to be more translucent than gingival tissues because of reduced vascularization.[8,11,12]

In 2005, the pink esthetic concept was introduced as a factor influencing implant success by Fürhauser et al, with the pink esthetic score (PES),[13] and by Meijer et al, with the implant crown aesthetic (ICA) index.[14] The use of titanium for implants and abutments may cause color changes of the peri-implant soft tissues; the resulting esthetic deficiencies may be unacceptable to patients and clinicians.[15,16] To mitigate the gray tint of titanium abutments, a different solution was proposed: coating the surface with titanium nitride, which would reflect light better and provide the abutment with a "golden" appearance.[17–19]

With the development of computer-aided design and computer-assisted manufacturing (CAD/CAM) systems, zirconia was introduced to fabricate implant abutments.[20,21] The white esthetic of this ceramic material, which better matches the natural color of teeth, provides significant esthetic improvement.[22,23] Zirconia is a brittle material, and its long-term success as an abutment material has been reported in anterior regions up to the premolars.[24]

The purpose of the present randomized clinical trial was to assess whether zirconia and titanium nitride abutments could provide better peri-implant soft tissue esthetics than conventional Ti abutments. The following null hypotheses were tested: *(1)* There is no association between the abutment material and the color of the surrounding soft tissues, and *(2)* there is no association between the thickness of the peri-implant buccal mucosa and the color of the surrounding soft tissues.

MATERIALS AND METHODS

Study Population

The study, which was performed according to the CONSORT statement for improving the quality of reports of parallel-group randomized trials (ClinicalTrials.gov NCT02090647), was a parallel, randomized, and single-center clinical trial on the effects of different implant abutments on the color of peri-implant soft tissues. Three different types of abutments were compared: *(1)* titanium (Ti), *(2)* titanium nitride (TiN), and *(3)* zirconia (ZrO_2).

Subjects were recruited consecutively at the Department of Prosthodontics of the University of Siena, Italy, between September 2010 and December 2011. The ethical board of the same university approved the study protocol (ClinicalTrials.gov NCT02090647), and the researchers obtained informed written consent from all subjects included in the study. All principles reported in the Declaration of Helsinki on experimentation involving human subjects, as revised in 2000, were followed. Participants were recruited according to the inclusion and exclusion criteria described in Table 1. No limits were placed on the types of teeth to be replaced, but each patient could receive no more than four implants and abutments.

All surgical and prosthodontic procedures were performed by an experienced implant surgeon (MCC) and an experienced prosthodontist (MF), respectively, in the same dental clinic. A single calibrated examiner, blinded to the experimental procedures, assessed the clinical outcomes of all treatments.

Treatment Procedures

All the implants (OsseoSpeed, Dentsply Implant System) were positioned with a two-stage surgical technique. After 4 to 6 months (time 0), a second surgical procedure was performed to place transmucosal healing abutments. Two weeks after the surgical reentry (time 1), implant-level impressions were taken to fabricate screw-retained resin provisional restorations. The provisionals were screwed onto the implants 1 week later (time 2). The soft tissues were conditioned for 2 months, with periodic relining of the resin contours. The final implant-level impressions were taken with impression materials (EXA'lence Vinyl Polyether Silicone [VPES], GC) (time 3). The pick-up impression copings were customized using a flowable composite resin material (G-aenial

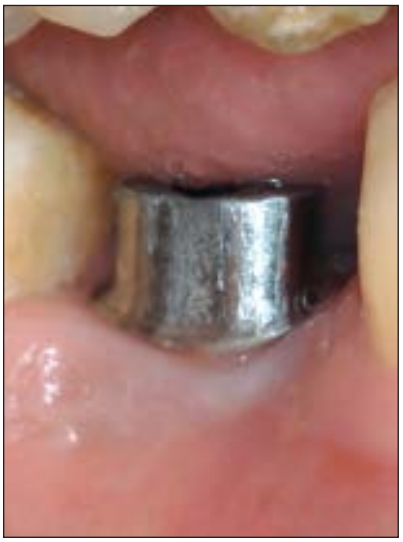

Fig 1 Clinical view of an experimental CAD/CAM titanium (Ti) abutment.

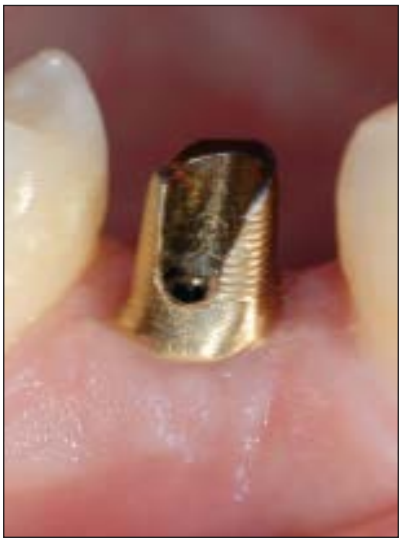

Fig 2 Clinical view of an experimental CAD/CAM titanium nitride (TiN) abutment.

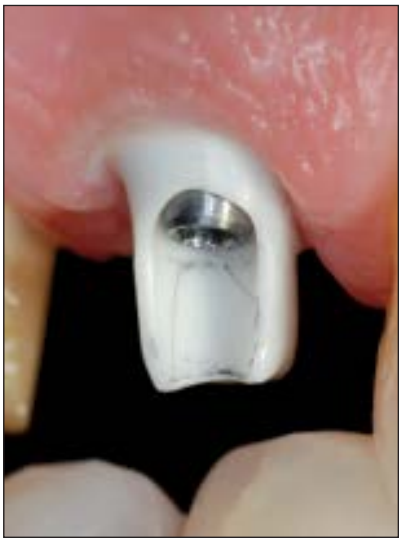

Fig 3 Clinical view of an experimental CAD/CAM zirconia (ZrO_2) abutment.

Universal Flo, GC) to transfer the emergence profiles of the provisionals to the master casts (type IV dental stone, New Fujirock, GC).

The patients were randomly allocated to three different experimental groups with different computer-aided design/computer-assisted manufacturing (CAD/CAM) abutments (ATLANTIS, Dentsply Implant System): *(1)* Ti (Fig 1); *(2)* TiN (Fig 2); and *(3)* ZrO_2 (Fig 3). The abutments were designed using ATLANTIS Virtual Abutment Design (VAD) software. The option "No Tissue Displacement" was always selected in order to reproduce the emergence profile as individualized with the provisional restorations.

Data Collection

A blinded examiner measured the thickness of the buccal keratinized peri-implant soft tissues horizontally using a dental thickness gauge (Iwanson Decimal Caliper, Asa Dental Spa) at the level of the implant neck. The peri-implant biotypes were then classified into two groups[25]: *(1)* thin biotype (tissue thickness $\leq$ 2 mm) and *(2)* thick biotype (tissue thickness $>$ 2 mm).

The final prosthetic restorations were implant-supported single crowns. Fifteen weeks after implant placement (time 4), the provisionals were removed and the final CAD/CAM abutments were screwed onto the implants. Full-coverage restorations were fabricated using either zirconia (Aadva, GC) or metal copings and stratified feldspathic porcelain, according to the allocation. The buccal margins of the final crowns were placed 1 mm subgingivally, while the interproximal and lingual margins were kept at the gingival margin. The final crowns were luted to the abutments with Link Ace cement (GC).

Randomization/Allocation Concealment/ Masking of Examiners

Each experimental implant/subject was randomly assigned to one of the three treatment regimens. Treatment assignment was noted and kept during the study. Allocation concealment was performed using opaque, sealed, and sequentially numbered envelopes containing the types of abutments. An experienced statistician generated the allocation sequence using a computer-generated random list and instructed a different operator to assign the envelopes containing the types of abutments. Each envelope was opened before abutment selection, and the treatment assignment was communicated to the prosthodontist. Blinding of the examiners was maintained throughout all the experimental procedures.

Color Assessment

To prevent the possibility of soft tissue compression and ischemia affecting the color assessments, the color measurements were performed 10 minutes after the abutments were torqued at 20 Ncm onto the implants. The color of the soft tissues at the abutment sites and contralateral teeth was measured in an area 1 mm apical to the gingival margin along the implant and tooth axes, respectively. A clinical spectrophotometer (VITA Easyshade, VITA Zahnfabrik) was used for color evaluation. The color was recorded using dedicated software (Shaderite 2HW, VITA Zahnfabrik) (Fig 4) involving the CIE L*a*b* color space coordinates, in which the L* value represents the brightness, the a* value represents the redness or greenness, and the b* value represents the yellowness or blueness. Even if L*, a*, and b* are individually relevant, the ΔE value is the most important

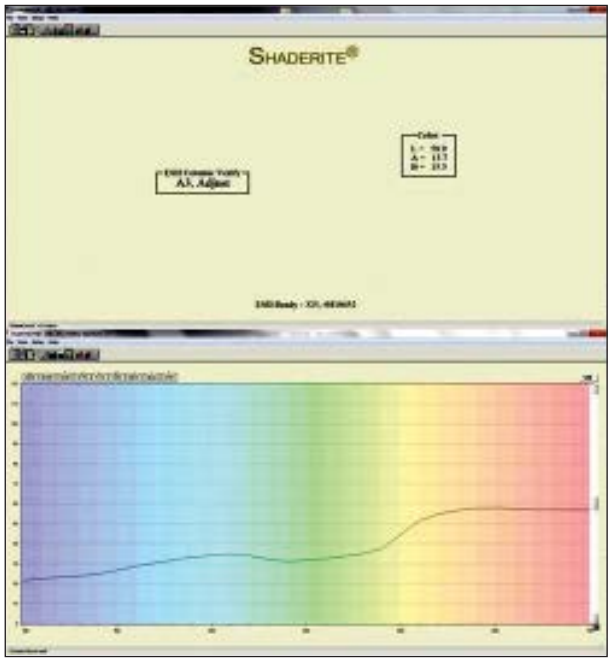

Fig 4 Screenshot of the VITA Shaderite software used for color measurements. Color was described by the CIE L*a*b* coordinates of the surface in contact with the tip of the recording instrument.

parameter for evaluating color differences.[26,27] This parameter, defined as the distance between the points representing the different colors in the color space with rectangular coordinates, can be calculated by applying the following equation:[28] $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$. ΔE was calculated between the peri-implant soft tissues at the site of each implant and contralateral tooth. The values were then classified into two groups: *(1)* clinically acceptable color differences and *(2)* unacceptable color differences, with a critical threshold of $\Delta E = 3.7$.[29]

Statistical Analysis

The chi-square test was applied to identify statistically significant differences in soft tissue color between the thin and thick peri-implant soft tissues and among the abutment types. For all analyses, the level of significance was set at $\alpha = .05$. The Yates correction for continuity was used for analysis of variable tissue thickness, and SigmaPlot 11.0 software (Systat Software Inc) was used to perform the statistical calculations.

RESULTS

The abutment materials did not show statistically significant color differences ($P > .05$), but statistically significant differences were seen between thin and thick peri-implant soft tissues ($P < .05$).

Color changes in peri-implant soft tissues were seen in all patients in the thin biotype group. In the thick biotype group, only 2 of 62 patients showed clinically relevant soft tissue color modifications at the control sites. The results are summarized in Table 2.

Among the thin biotype group, the mean ΔE was always over the threshold of 3.7, regardless of the type of abutment material used; conversely, in the thick biotype group, the mean ΔE values of the tested abutment materials did not exceed the threshold. The mean ΔE and standard deviations are described in Table 3.

DISCUSSION

On the basis of the results of the statistical analyses, null hypothesis 1 was accepted, since the abutment material did not influence the color of peri-implant soft tissues. Null hypothesis 2 was rejected, as the thickness of the buccal mucosa surrounding the implant neck affected the color of the soft tissues.

Clinical assessment of the perceptibility and acceptability threshold in soft tissue color evaluation is still under investigation. In a recent laboratory study, Sailer et al[30] compared two gingival images with calibrated color differences and identified the gingival color perceptibility threshold as $\Delta E = 3.1$. Most of the literature refers to a 1989 study by Johnston and Kao[29] that defined the tooth shade acceptability threshold for dental composite resins as $\Delta E = 3.7$. In 2009, Johnston clarified that the thresholds of perceptibility and acceptability are dependent on observed color characteristics,[26] and, accordingly, the threshold identified for tooth shade cannot match that of gingival tissues. A literature review recently reported an acceptability threshold of $\Delta E = 3.7$ as the most common value reported for color evaluation in dentistry,[31] so the same value was selected for this study in order to better compare its results with those of previous investigations.

The three abutment materials tested led to color differences of marginal soft tissues of similar magnitude when compared to the contralateral natural teeth—findings that are in general accordance with those of other clinical trials.[32–35] The implant biotype, which was intended to be the buccal thickness of peri-implant mucosa, was reported to be the main factor responsible for the influence of abutment materials on the perceived color of soft tissues around implants. These findings were in agreement with those of several other studies, which reported 2 mm as the soft tissue thickness threshold required to mask the appearance of prosthetic materials on implant-supported restorations.[35–37]

Table 2 Results and Statistical Significance (Chi-Square Test, $P < .05$)

Gingival biotype	TiN		Ti		ZrO_2		Significance
	ΔE < 3.7	ΔE > 3.7	ΔE < 3.7	ΔE > 3.7	ΔE < 3.7	ΔE > 3.7	
Thin	0	9	0	8	0	8	b
Thick	22	0	21	1	19	1	a
Significance	A		A		A		

Different capital letters indicate statistically significant differences for the factor "abutment material," while different italic letters indicate statistically significant differences for the factor "soft tissue thickness."

Several strategies have been proposed to thicken the peri-implant soft tissues. Narrowing the abutment emergence profile was reported to increase the connective tissue and optimize the orientation of collagen fibers around implant abutments—thus reducing the "graying effect" of titanium.[38–40] ATLANTIS VAD software offers the possibility to shape a concave abutment design that could help improve esthetics in thin gingival biotypes.

Happe et al[41] reported discoloration in the peri-implant mucosa around a single tooth restored with a zirconia abutment and an all-ceramic crown. After 1 year of service, the color of the peri-implant mucosa compared to that of the contralateral tooth showed a ΔE beneath the critical threshold of 3.7.

Sailer et al[36] indicated the use of zirconia abutments and all-ceramic crowns associated with connective tissue grafts in cases with high esthetic demands. Even if the magnitude of peri-implant mucosa color change was reported to be similar in zirconia and metal abutments, the quality of modifications caused by zirconia abutments was reported to differ from the grayish color of titanium, resulting in a satisfactory acceptance by patients.[35] These findings suggest that, in cases involving thin gingival biotypes, abutment color could help restore the correct color match between peri-implant mucosa and natural teeth, thus avoiding additional surgery. Clinicians should carefully evaluate the peri-implant biotype and consider it as a predictor of mucosal discoloration.

It was recently reported that the implant biotype differs from the gingival biotype, since it is influenced by the position of the implant and also the amount of hard and soft tissues surrounding it.[42] In cases involving thin gingival biotypes, soft tissue augmentation and/or colored and concave abutments should be considered in order to provide the desired esthetics.

By interpositioning different color strips between abutments and buccal peri-implant mucosa, Ishikawa-Nagai et al[43] showed that the soft tissue esthetics coloring the implant neck could be improved; the most effective color strip was light pink. In a randomized clinical trial, Happe et al[44] colored zirconia abutments with fluorescent light-orange ceramic and concluded that this approach made the peri-implant soft tissues appear brighter and more similar to natural gingiva.

Table 3 Mean ΔE and Standard Deviations (SD)

Gingival biotype	TiN		Ti		ZrO_2	
	ΔE	SD	ΔE	SD	ΔE	SD
Thin	6.4	0.9	8.2	1.3	6.4	0.6
Thick	2.2	0.8	1.3	0.5	2.0	1.0

Veneering of zirconia abutments is an easy way to influence the anatomy and color of peri-implant mucosa, but further investigation is needed to assess their long-term success and biocompatibility. In a recent case series, Sumi et al[45] investigated the esthetic outcome of anodic-oxidized titanium abutments on thin peri-implant mucosa (≤ 1 mm). The anodic oxidation of titanium produced a superficial dark-pink color in abutments but did not influence the biocompatibility of the titanium surface.[46]

Gingival color analyses have been performed using a spectroradiometer set up in an optical configuration, with 0 degrees for the observation and 45 degrees for the D65 illuminant,[47–49] or with a non-contact spectrophotometer (SpectroShade Micro, Medical High Technologies [MHT] SpA) connected to the proprietary software.[50,51] This software identifies the CIE L*a*b* color coordinates of a selected area. In the present study, a clinical spectrophotometer (Easyshade Compact, VITA) was used to measure soft tissue color. This device usually identified the correct tooth shade according to the VITA Classical and VITA 3DMaster shade guides. If the device is connected to a computer running dedicated measurement software (Shaderite, VITA), the CIE L*a*b* color coordinates of the object in contact with the intraoral tip of the instrument can be captured. The Easyshade spectrophotometer had high interdevice agreement,[52] excellent reproducibility, and superior compliance with the CIE L*a*b* reference system, compared with other color measurement devices.[53]

CONCLUSIONS

Within the limitations of the present trial, it can be concluded that:

- The three tested abutment materials (titanium, titanium nitride, and zirconia) performed similarly in terms of quantitative influence on soft tissue color.
- When peri-implant mucosal thickness was recorded as $\leq$ 2 mm, all abutment materials influenced the color of the peri-implant soft tissues. Conversely, when the mucosal thickness was $>$ 2 mm, only 2 out of 64 measurements showed color changes beyond the ΔE clinical threshold.

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