CLINICAL RESEARCH

A 4-Year Prospective Study to Assess Peri-Implant Hard and Soft Tissues Adjacent to Titanium Versus Gold-Alloy Abutments in Cemented Single Implant Crowns

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Purpose: **The purpose of this prospective clinical study was to compare titanium and gold-alloy abutments when used with cemented, implant-supported single-tooth crowns. For 4 years following prosthodontic rehabilitation, these abutments were evaluated with respect to peri-implant marginal bone levels and peri-implant soft tissue parameters.**

Materials and Methods: **During the years 1998 to 2000, 20 patients were selected from a patient population receiving treatment in the Implantology Department at the University of Padova, Italy. They all presented with single-tooth bilateral edentulous sites in the premolar/molar region with adequate bone width, similar bone height on each side, and an occlusal scheme that allowed for the establishment of identical occlusal cusp/fossa contacts on each side. Each subject received two identical implants (one in each edentulous site). One was randomly selected to be restored with a titanium abutment and a cemented implant-supported single-tooth crown, and the other was restored with a gold-alloy abutment and a cemented implant-supported single tooth crown. Data on peri-implant marginal bone levels and soft tissue parameters were collected for 4 years after abutment and crown insertion placement and analyzed to determine whether there was a significant ($p < .001$) difference with respect to the type of abutments (titanium vs. gold alloy) used.**

Results: **All subjects completed the study. All 40 implants survived, resulting in a cumulative implant success rate of 100%. Statistical analysis revealed no significant differences between the two groups with respect to peri-implant marginal bone levels and soft tissue parameters.**

Conclusions: **Within the limitations of this study, the results indicate that there was no evidence of different response with the peri-implant marginal bone and soft tissue when titanium or gold-alloy abutments were used in conjunction with the cemented, single-tooth implant restorations provided for this limited patient population. There was no evidence of different behavior of peri-implant marginal bone and of peri-implant soft tissue when titanium abutments or gold-alloy abutments were used for cemented single-tooth implant restorations in this limited patient population.**

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INDEX WORDS: single implant cemented restorations, titanium abutments, gold-alloy abutments

SINGLE-TOOTH replacement with implant-supported crowns has become routine at many clinics. Various studies have reported on the predictability of single implant restorations.[1-7] Prosthodontic reconstruction with cement-retained, implant-supported, single-tooth crowns may involve abutments made from several materials, which are directly connected to endosseous dental implants made of titanium.

In single-tooth restorations, a widely used solution is the UCLA abutment.[8-10] This abutment is designed to engage the implant directly and it is usually cast in gold alloys.[11] In 1990, NobelBiocare (Göteborg, Sweden) developed the Procera system, based on computer-assisted design and manufacture (CAD/CAM) technology.[12-14] Implant abutments created with the Procera system were

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introduced in 1998. The Procera abutments can be made of commercially pure titanium—concerns about dissimilar metals and about interfaces between machined and cast components are eliminated.[15] Lang et al[16] showed the high precision standards of this type of abutment.

Few studies have investigated the different responses of the peri-implant marginal bone and peri-implant soft tissue when various abutment materials were used on titanium implants. In an experimental animal study, Abrahamsson et al[17] investigated whether the material used for an abutment with an implant system influenced the quality of the mucosal barrier that formed following implant placement. The findings demonstrated that the material used in the abutment portion of an implant system influenced the location and the quality of the mucosal attachment that occurred between the peri-implant mucosa and the implant. Abutments made of commercially pure titanium or ceramic allowed the formation of a mucosal attachment that was about 2 mm and 1 to 1.5 mm high, respectively. At sites where abutments were made of gold alloy or dental porcelain, no proper attachment formed at the abutment level, but the soft tissue margin receded and bone resorption occurred. In an animal study, Zitzmann et al[18] investigated reactions of the peri-implant mucosa to plaque accumulation on titanium implant abutments designed with either a rough or a smooth external surface. The authors concluded that the different surface characteristics of abutments made of commercially pure titanium failed to influence plaque formation and the establishment of inflammatory cell lesions in the peri-implant mucosa. In an in vitro study, Taylor et al[19] analyzed the effect of titanium endosseous dental implants coupled with dissimilar materials on the capacity of preosteoblasts in bone marrow culture to differentiate, form alkaline phosphatase-positive colonies, and to mineralize. It was concluded that the presence of these commonly used implant abutment biomaterials, coupled with titanium endosseous dental implants, had no adverse effects on the in vitro capacity of preosteoblasts in marrow to differentiate and to form mineralized bone nodules, despite measured differences in solution potentials.

In two prospective randomized controlled studies, Andersson et al[20,21] evaluated the long-term clinical function of CerAdapt ceramic abutments compared to titanium abutments on Brånemark implants for single-tooth replacement and supporting short-span fixed partial dentures (FPDs). The two types of abutments demonstrated no differences regarding measurements of various indices of peri-implant tissue health and bone loss measurements.

In a clinical study, Barclay et al[22] compared the superficial tissue responses to titanium and ceramic surfaces of transmucosal elements of established IMZ implants. In this split-mouth study on 14 patients with two mandibular implants and a bar-retained complete mandibular denture, a conventional titanium and a newly developed ceramic-coated transmucosal element were placed. A range of clinical parameters were recorded before transmucosal-element replacement and at 1, 4, and 12 weeks postplacement. A comparison of the recorded soft tissue responses revealed no significant differences between a group of implants fitted with ceramic-coated transmucosal elements and a group of contralateral implants fitted with titanium transmucosal elements. Similar results were demonstrated in a study by Bollen et al.[23]

There is scarcity of evidence in dental literature regarding the evaluation of abutment material and its relationship to peri-implant marginal bone and soft tissue. The purpose of this prospective clinical study was to compare titanium abutments and gold-alloy abutments when used with cemented, implant-supported, single-tooth crowns and observed for 4 years following prosthodontic rehabilitation with respect to peri-implant marginal bone levels and peri-implant soft tissue parameters.

Materials and Methods

From 1998 to 2000, 20 patients were selected from a patient population desiring treatment in the Implantology Department at the University of Padova, Italy, according to the following criteria:

1. Lack of systemic contraindication for oral surgical therapy;
2. Single-tooth bilateral edentulous sites in the premolar/molar region;
3. Presence of adequate bone width precluding the need for bone augmentation procedures;
4. Similar bone height at both implant sites of each patient, allowing for the placement of implants of identical height and diameter;

Table 1. Single-Tooth Bilateral Edentulous Sites Treated with Implants

Type of Rehabilitations	*Number of Implants*
Premolar maxillary region	16
Molar maxillary region	16
Molar mandibular region	8

5. Occlusal scheme allowing for the establishment of identical occlusal cusp-fossa contacts in the same patient.

The study was approved by the Clinical Medical Ethical Committee. The consent of patients was obtained prior to implant placement. A controlled clinical trial with split-mouth randomization was carried out.[24] According to a list of randomization,[25] in each subject, one edentulous site was randomly chosen to receive a cemented, implant-supported, single-tooth crown on a titanium Procera abutment (NobelBiocare, Göteborg, Sweden);[12-16] in the contralateral edentulous site, a cemented, implant-supported single-tooth crown on a gold, machined UCLA abutment (SGUCA1C, 3i/Implant Innovations, Palm Beach Gardens, FL) was placed.[8-11] Forty standard-size implants (3i/Implant Innovations) were surgically placed by the same practitioner with the use of a surgical template. All implants were placed at the bone crest level. The edentulous sites treated and the length and diameter of the implants used are summarized in Tables 1 and 2. At second-stage surgery, 4 months after placement of the implants, titanium-healing caps were connected. The master cast impression was made 3 weeks after second-stage surgery, and a single impression[26] served for both implants simultaneously. For the impression phase, 2-mm-thick custom impression trays were fabricated with Palatray light cure (LC) resin (Heraeus Kulzer, Wehrheim, Germany), in accordance with the manufacturer's instructions. The impression trays had two windows to allow access for both coping screws and were previously coated with tray adhesive (Dental-Medizin, 3M ESPE, Seefeld, Germany). Prior to each impression procedure, a square impression coping (pick-up type, IIC12, 3i/Implant Innovations) was secured to the implant. The elastomeric impression material (Impregum Penta, 3M ESPE) was machine-mixed (Pentamix, 3M ESPE), and syringed around the impression copings to ensure complete coverage. Five minutes were allowed for setting of the impression material, after which the coping screws were unscrewed and the impression was removed. An implant replica (ILA20, 3i/Implant Innovations) was connected to the impression coping for each implant, and the impression was poured with Type IV stone (New Fujirock, GC Corp, Tokyo, Japan). All laboratory procedures were performed by the same technician, and all prostheses were provided by the same prosthodontist.

Table 2. Length and Diameter of Implants Used (Implant Innovations)

Length (mm)	*Diameter (mm)*	*Number of Implants*
13	3.75 (OSS 313)	14
15	3.75 (OSS 315)	10
13	4.00 (OSS 413)	10
15	4.00 (OSS 415)	6

For the cemented, implant-supported, single-tooth crowns on titanium abutments, custom Procera abutments made of commercially pure titanium were fabricated for all 20 implants. A machined base cylinder was fixed to the implant analogue, and wax was applied to build the abutment to full contour. The waxed abutment was cut back and checked for position and contour; the amount of space available for the restoration was also verified. The pattern was then removed from the master cast and positioned in the Procera Scanner (NobelBiocare) to obtain a digitally scanned image of the waxed abutment. The resulting wire mesh digital design was reviewed on a monitor and sent electronically to the production facility (NobelBiocare). The custom abutments were screwed to implants clinically using a titanium screw (NobelBiocare) and torqued to 35 Ncm (Torque Driver CATDO, 3i/Implant Innovations).

For the cemented, implant-supported, single-tooth crown on the gold-alloy abutments, the gold UCLA-type abutments (SGUCA1C, 3i/Implant Innovations) were screwed to implant replicas using waxing posts, and wax was added directly to the gold cylinders following standard waxing procedures. The waxed cylinders were then invested in a carbon-free phosphate-bonded investment (Ceramicor, Cendres & Métaux SA, Biel-Bienne, France) and cast using a noble alloy (Esteticor Plus, Cendres & Métaux SA; composition: Au 45.0%, Pd 38.9%, Ag 5.0 %, and In 8.6%). The fabricated custom abutments were screwed to implants clinically in the same fashion as before.

Porcelain-fused-to-metal definitive crowns with porcelain occlusal surfaces were fabricated for all 40 abutments. A noble alloy (Esteticor Plus) was used for the metal copings, and porcelain was added (Noritake EX-3, Noritake, Nagoya, Japan) (Fig 1).

Radiographic assessments were accomplished during all prosthetic phases (impression phase, abutment try-in, final try-in). For esthetic reasons, for both types of abutments, the crown/abutment margin was placed 1 mm subgingival on the buccal surfaces; the crown/abutment margin was placed for both types of abutments at the gingival level in the mesio-disto-lingual surfaces where esthetic concerns did not exist.

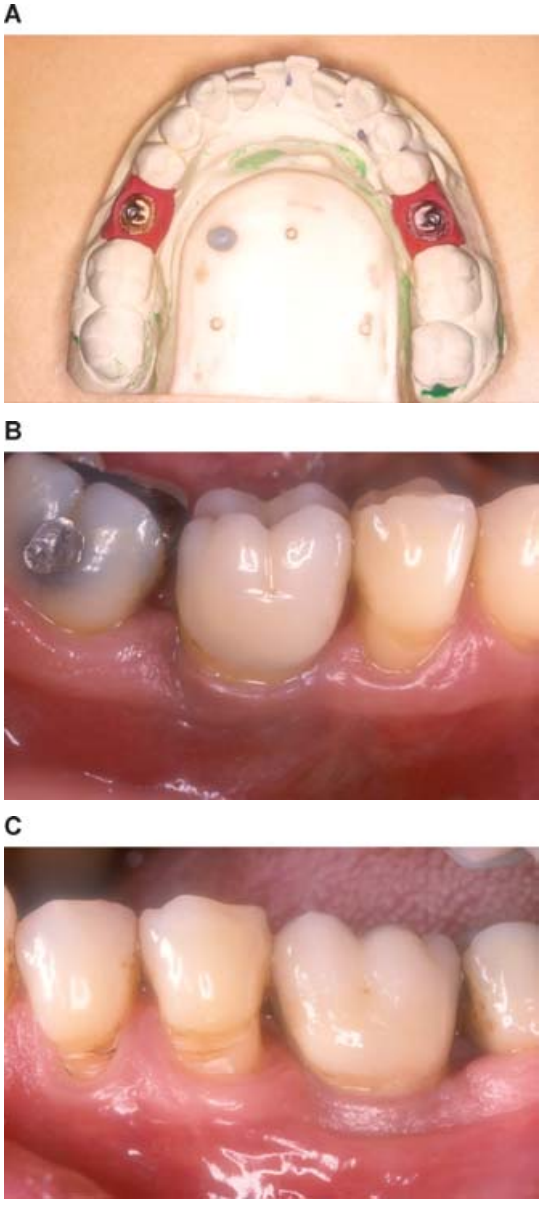

Figure 1. *(A)* Master cast with titanium abutment (right side) and gold-alloy abutment (left side). *(B)* Buccal view of implant-supported single-tooth crown (first mandibular right molar region) cemented on titanium abutment. *(C)* Buccal view of implant-supported single-tooth crown (first mandibular left molar) cemented on gold-alloy abutment.

Careful handling was carried out for both types of abutments in the laboratory phase to avoid further contamination of the abutment surfaces.[27] Within both groups, the occlusal surfaces of the restorations were designed to avoid premature contacts during lateral and protrusive movements. All definitive restorations were cemented with temporary cement (Temp Bond NE, Kerr Italia, Scafati, Salerno, Italy). A follow-up recall included patient assessments every 3 months during the first year and every 6 months in subsequent years. All patients regularly returned to the office for recall. The implant survival was judged on the following criteria:[28]

- Absence of mobility;
- Absence of painful symptoms or paresthesia;
- Absence of peri-implant radiolucency during radiographic evaluation;
- Absence of progressive marginal bone loss.

During the 4 years following prosthetic rehabilitation, disconnection and reconnection of the abutments was avoided to prevent bone loss as described in previous animal studies.[29] Four years after abutment and crown insertion placement, all patients were seen and periodontal parameter data were compiled for the peri-implant mucosal response (records for four surfaces of each restoration type)—supragingival plaque, gingival inflammation, bleeding on probing, amount of keratinized gingiva around abutment, and probing depth from the gingival margin. Bleeding of the peri-implant mucosa and gingiva[30] was diagnosed by gently moving a blunt periodontal probe in the marginal part of the peri-implant/gingival sulcus around the implant. Supramucosal/gingival plaque was recorded around implants. All cemented crowns were carefully removed using GC removal pliers (Type KY, GC Corp., Japan) to avoid damaging the porcelain. The custom abutments were unscrewed to allow measurement of the mucosal channel; a periodontal probe was used to record the length from the marginal gingiva to the head of the implant. Periapical radiographs were taken for each implant using an individual stent and the long-cone technique, which gives standardization of consecutive radiographs as suggested by previous studies.[1,31] The radiographic films were evaluated using a 6× magnifying lens, which permitted the measurement of marginal bone resorption with an accuracy of ±0.3 mm. The initial measurement of the marginal bone level, taken with the same standardized intraoral radiographic method, was recorded as baseline at the time of abutment and crown insertion (Fig 2). The apical end of the smooth collar of the implants was considered the coronal reference point.

Occlusal relationships and all complications were recorded. All evaluations were performed by the same examiner who carried out all prosthodontic procedures. Statistical analysis was performed using a paired Student's *t*-test to determine whether there was a statistically significant difference in peri-implant marginal bone levels and soft tissue parameters between the cemented, implant-supported, single-tooth crowns on titanium abutments and on gold-alloy abutments.

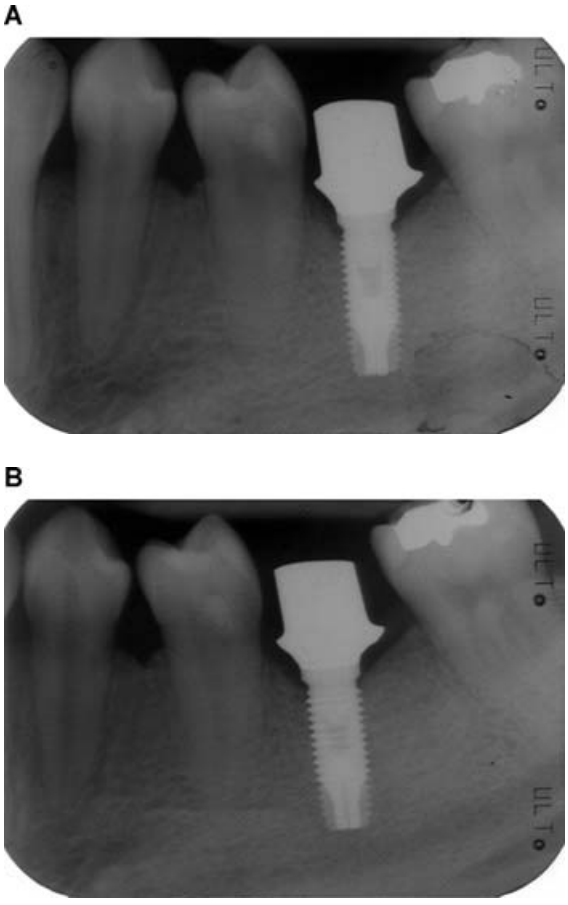

Figure 2. *(A)* Radiograph of titanium abutment at the time of abutment insertion. *(B)* Radiograph of titanium abutment 4 years after abutment placement.

Results

The study had a 100% subject retention rate. All 40 implants survived the second surgical phase and loading with the definitive restoration. This demonstrates the safety of single-tooth replacement when accepted treatment concepts are followed and documented components are used. No patient reported any prosthetic complications, such as loosening of the custom screwed abutment, fracture of the porcelain, or loosening of provisionally cemented definitive crowns.

Bone quality at the implant sites was estimated at the time of implant placement. Twenty-two implants were placed in type 1 bone, and 18 implants were placed in type 2 bone.[32] Clinical evaluation of the peri-implant mucosa using periodontal indices revealed similar satisfactory results for the implant-mucosa interfaces (Table 3). The status of the soft tissue around crowns and adjacent teeth remained stable over the evaluation period. At the 4-year evaluation dental plaque was present on 16% of the considered surfaces on both types of restorations, and gingival inflammation involved only 4.7% of the cemented crowns on titanium abutments and only 4.5% of the cemented crowns on gold-alloy abutments. Keratinized attached gingiva was not present at 8.7% of the buccal surfaces and 7.8% of the lingual surfaces for both types of restorations. A mean probing depth of 2.8 mm was recorded for both types of restorations, which is less than that reported in other studies.[1,33,34] Probing was carefully accomplished and a low percentage of sites (6.8%) had bleeding on probing for both types of restorations. The mean marginal bone resorption at 4 years after abutment and crown insertion, as measured with the intraoral radiographic examination method [1,31] from the apical end of the smooth collar of the implants, was 0.4 mm, with a range of 0.3 to 0.8 mm, for both types of restorations. The paired Student's *t*-test was used to analyze the numeric data obtained from the examination of peri-implant marginal bone levels and soft tissue parameters. This analysis revealed no significant differences between the two groups ($p < 0.001$).

Discussion

This 4-year prospective study provided the results from 40 implants (20 patients) used for single-tooth crowns cemented on either titanium or gold-alloy abutments. The comparison of these two types of restorations with respect to peri-implant marginal bone levels, peri-implant soft tissue, and prosthetic complications did not reveal any clinically significant differences in outcomes at the end of the evaluation period. No screw loosening was found with the crowns cemented on either titanium or gold-alloy abutments. Accurate evaluation of the occlusal scheme and the provision of appropriate variations to the occlusal contacts, both static and dynamic, may also explain the lack of prosthetic complications, such as porcelain fracture and loosening of provisionally cemented definitive crowns.

For esthetic reasons, the crown/abutment margins were not placed too deeply in the gingiva. For both types of abutments, the crown/abutment margin was placed 1 mm subgingivally on the

Table 3. Periodontal Parameters Recorded by Dichotomic Records (Presence or Absence) at the 4-Year Time Period

Periodontal Indices Records	*Percentage in Cemented, Implant-Supported, Single Tooth Crowns on Procera Titanium Abutments*	*Percentage in Cemented, Implant-Supported, Single Tooth Crowns on Gold Machined UCLA Abutments*
Plaque presence	16.0	16.0
Gingival inflammation	4.7	4.5
Bleeding on probing	6.8	6.8
Amount of facial keratinized gingiva	91.3	91.3
Amount of lingual keratinized gingiva	92.2	92.2

buccal surfaces; the crown/abutment margin was placed for both types of abutments at the gingival level in the mesio-disto-lingual surfaces where esthetic concerns did not exist. Furthermore, it should be noted that the cemented crowns of both groups required particular attention to the removal of all subgingival cement at the cementation phase, so problems associated with peri-implant gingival tissues could be minimized.

The results of this clinical study refute the results of a previous animal study.[17] The small number of dogs included in that study (only five) and the fact that the implants were inserted in recently extracted areas may have influenced the final outcome of that research. In the 20 patients of this study, for both types of abutments, proper attachment formed at the abutment level, the soft tissue margin did not recede, and bone resorption did not occur with respect to the initial measurement of the marginal bone level, recorded at the first recall 3 months after abutment and crown insertion. It should be noted that in this study the mean probing depth was 2.8 mm for both types of restorations, and the titanium and the gold-alloy abutment surfaces were carefully handled in the laboratory phase to avoid additional contamination of the abutment surfaces. Further investigations should be carried out to evaluate the soft tissue and the bone response to different abutment materials in case of deeper probing depths. The results of the present clinical study indicate that the choice of titanium versus gold-alloy abutments remains primarily the clinician's preference. Within the limitations of this study, there was no evidence that one method of restoration was clinically or biologically superior to the other.

Conclusions

Within the limits of this study, the following conclusions may be drawn:

1. All 40 implants survived, and no prosthetic complications occurred.
2. No statistically significant differences on peri-implant soft tissues and marginal bone loss were observed between the two study groups.
3. The choice of titanium versus gold-alloy abutments can remain as the clinician's preference. There was no evidence that one method of restoration was superior to the other in this limited study.

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