Interproximal Papilla Stability Around CAD/CAM and Stock Abutments in Anterior Regions: A 2-Year Prospective Multicenter Cohort Study

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The aim of this study was to compare the interproximal papilla stability of restorations supported by computer-aided design/computer-assisted manufacture (CAD/CAM) abutments to those supported by prefabricated stock abutments in anterior areas over a 2-year follow-up. Abutments were selected depending on implant inclination and thickness of buccal peri-implant soft tissues from the following: zirconia stock, titanium stock, zirconia CAD/CAM and titanium CAD/CAM. Differences between the height of the papilla tip were measured (REC). Results: REC values of titanium and zirconia CAD/CAM abutments were significantly lower than those of titanium and zirconia stock. The use of titanium and zirconia CAD/CAM abutments is related to better interproximal papillae stability. Int J Periodontics Restorative Dent 2017;37:657–665. doi: 10.11607/prd.3184

Esthetic demand in implant dentistry has increased in terms of both white and pink esthetics. While improvements in white esthetics mainly depend on the development of new ceramics for abutments and frameworks, pink esthetics are related to different aspects: proper surgical procedures, loading protocols, patient selection, and implant characteristics.1,2 The presence of a complete interproximal papilla between an implant and the adjacent tooth in demanding areas is one of the most challenging and least predictable issues to manage. Papilla loss can lead to cosmetic deformities, so-called black triangle disease, phonetic problems due to air or saliva passage, and lateral food impact.3 For these reasons, papillary integrity should be respected during all dental procedures and papilla loss must be minimized as much as possible.

Some factors related to the presence or absence of a complete interproximal papilla and the influence of the fixture’s three-dimensional position are widely studied. The implant-to-tooth distance and the distance of the bone peak to the prosthetic contact point are considered interproximal recession predictors.4–11 For implants with a platform-switched abutment connection, a vertical distance from the interproximal bone peak and the
contact point of ≤ 5 mm and a horizontal distance between the implant and the adjacent tooth of ≥ 1.5 mm were significantly associated with the presence of a complete interproximal papilla.11

Some authors have reported that smoking habits might significantly affect the presence of a complete interproximal papilla between an implant and the adjacent tooth.12,13 In a prospective cohort study, Raes et al12 concluded that smokers failed to demonstrate papilla regeneration and showed more midfacial recession following single implant treatment when compared to nonsmokers.

The role of the implant-to-abutment connection for hard and soft peri-implant tissue stability has been studied. Interproximal and midfacial hard and soft tissue recession around implants might be prevented by internal conical connection and platform-switching abutments.14–17 However, available data is lacking regarding the influence of abutment type and geometry on the presence of a complete interproximal papilla in highly demanding areas. In fact, positive soft tissue behavior with particular transmucosal component designs has already been described by some authors.18,19 Nevertheless, no comparison was performed between different abutment designs.

As the second part of a prospective multicenter cohort study,20 the aim of the present report is to compare the interproximal papilla stability for restorations supported by computer-aided design/computer-assisted manufacture (CAD/CAM) abutments to those supported by stock abutments in anterior areas over a follow-up period of 2 years.

Materials and Methods

Patient Selection

Patients with a single gap in the anterior region (from the second premolar forward) of the maxilla or mandible were consecutively treated from September 2010 to June 2011 by means of implant-supported single-tooth dentures (ST). Single dental implants (OsseoSpeed, Astra Tech, Dentsply) were placed for each patient. Treatments were performed at the Dental Clinic of Biomedical Sciences Institute, S. Paul Hospital, University of Milan, Italy, and at the Dental Clinic, Department of Medicine, Surgery and Dentistry, University of Padova, Italy. Written informed consent was obtained from all the subjects included in the study.

In obtaining the informed consent and conducting the study, investigators adhered to the principles outlined in the Declaration of Helsinki as revised in 2000 on experimentation involving human subjects. Patients were informed about the purpose of the study, the clinical procedures, and the materials to be used. Inclusion criteria were as follows: single edentulism in the anterior maxilla or mandible (from first premolar forward), absence of local inflammation, absence of oral mucosal disease, adequate oral hygiene, extraction at least 6 months earlier, and adequate bone volume at the implant site (for placement of an implant at least 3.5 mm in diameter and 8 mm in length) as evaluated on intraoral periapical radiographs and during clinical evaluation.

The exclusion criteria were as follows: patients with systemic diseases (such as heart, coagulation, and leukocyte diseases or metabolic disorders); history of radiation therapy in the head and neck region; current treatment with steroids; neurologic or psychiatric status that could interfere with the treatment; immunocompromised status, including infection with HIV; severe clenching or bruxism; smoking habit (more than 15 cigarettes per day); drug or alcohol abuse; and inadequate compliance.

Treatment Procedures

For all patients, a two-stage surgical technique was planned. An implant was placed after the raising of a mucoperiosteal flap without vertical releasing incisions. A submerged healing followed. No guided bone regeneration (GBR) procedures were performed, and no additional soft or hard tissue grafts were used. When requested by the patient, the edentulous gaps were temporarily restored with removable or provisional fixed prostheses during the healing phases. After 4 months, the implants were uncovered and transmucosal healing abutments (Astra Tech) were inserted. At 2 weeks after surgical reentry, an implant-level impression was taken for the fabrication of a screw-retained temporary restoration. At 1 week...
after the implant-level impression, a provisional restoration was placed.

The abutment selection for each patient was performed as described by Lops et al. in the first part of the present prospective study. As the manufacturer final stock abutments (Dentsply Implants, Astratech Dental, TiDesign, and ZirDesign abutments) are provided with a maximum inclination of 15 degrees, two different type of abutments were selected for the final restorations: stock and CAD/CAM abutments, for implants with an inclination within the ideal implant axis of 15 degrees or exceeding 15 degrees, respectively.

After 8 weeks of soft tissue conditioning by means of the provisional restoration, a final impression at implant level was taken; a precise record of the soft tissue dimensions was recorded on the cast models. The thickness of the facial peri-implant soft tissue was measured on the master cast at the level of the implant neck using a caliper (Iwanson Decimal Caliper, Asa Dental). Zirconia was selected as an abutment material where the buccal mucosal thickness was within 2 mm; titanium was selected where buccal thickness exceeded 2 mm, as previously described by Lops et al. For this reason, no randomization was possible for the abutment material selection in anterior areas. Therefore, considering the fixture inclination and the thickness of the facial peri-implant soft tissues, the patients were treated as follows: Group 1—patients with zirconia prefabricated stock abutments (Fig 1); Group 2—patients with titanium prefabricated stock abutments (Fig 2); Group 3—patients with zirconia CAD/CAM abutments (Fig 3); and Group 4—patients with titanium CAD/CAM abutments (Fig 4).

The system for CAD/CAM abutments milling (Atlantis) uses computer-aided technology to create the abutment contours. The contour of CAD/CAM abutments was juxtagingival, following the mucosal margin profile after the soft tissues remodeling provided by the provisional restoration.

Definitive cemented prostheses were positioned 4 months after implant placement. These restorations were metal-ceramic and zirconia-
ceramic. Juxtagingival emergence profiles were provided for all the implant-supported restorations. Zinc oxide cement (Temp Bond, Kerr) was used for fixation.

Parameters Analyzed

The main outcome variable, interproximal papilla stability (PS) was assessed at baseline and after 1 and 2 years of follow-up. To evaluate the modification of the interproximal soft tissues, digital photographs were taken for each patient at baseline and after 1 and 2 years of follow-up (Fig 5). A computerized analysis (ImageJ image processing software) was performed for the photograph measurements.\textsuperscript{20,24} A frontal projection was used to avoid any image distortion.

Two setting parameters were chosen to check the reproducibility of each picture,\textsuperscript{20,24} an apicocoronal vertical line from the most apical point of the buccal gingival margin to the most coronal portion of the crown edge (a) and a mesiodistal horizontal line at the widest part of the crowns adjacent to the treatment site (b). One of the teeth adjacent to the treatment site was used for these measurements. Furthermore, a calibrated plastic probe (TPS probe, Ivoclar Vivadent) was used on the same tooth to compare the values of a and b with those measured via computerized analysis. Only differences of ≤ 0.5 mm were accepted for data calculation.

To measure the interproximal papilla stability adjacent to the restored implant-supported crown, different lines were drawn on each photograph (Fig 5): a guide line (CP) joining the contact points between the crown and the adjacent tooth, a second line parallel to CP (PT) indicating the most coronal point of the interproximal papilla, and a third vertical line (CPP) representing the distance between CP and PT. This procedure was performed for both distal and mesial papillae. For each time point, the median CPP value was calculated by considering the distal and mesial papillae scores, respectively. The difference between CPP at baseline and after 2 years of follow-up represented interproximal papilla stability. Negative CPP scores were considered as a papilla recession (REC). Only apical shrinkage of ≥ 0.5 mm was considered as soft tissue recession. Measurements were made by one of the study authors (L.S.) and rounded to
the nearest half millimeter. Intraexaminer variability was evaluated by triplicate measurements of three soft tissue margins to detect a maximum of 5% of the coefficient of variation for soft tissue recession and linear evaluation. Any adverse event or biologic or technical complication present at any time point was recorded. Data regarding implant and prosthetic survival rates were previously reported by Lops et al.20

Statistical Analysis

A total of 36 patients for stock and CAD/CAM abutments groups were considered after power calculation; a mean difference of interproximal REC of 0.4 mm (SD 0.6 mm) was expected. Power was set at 80% and significance level \( \alpha \) at .05. True randomization was not possible for ethical reasons, as a zirconia abutment could be considered a compulsory choice in the esthetic zone. The initial REC value was introduced in the model to evaluate potential differences. The normal distribution of data was first analyzed and confirmed with Shapiro-Wilk normality test \( (P < .001) \). Subsequently, a general linear model was used to evaluate each group in relation to papilla stability after 2 years. A one-way analysis of variance model was used. By means of Tukey post hoc test, the mean REC indexes of each group of abutments were compared. Initial REC values for all groups of abutments were tested to evaluate an eventual influence on the 2-year soft tissue REC values. The null hypothesis of no difference between the four groups was tested with significance level \( P < .05 \). Furthermore, correlation analysis between the initial mucosal thickness and amount of REC was provided. The Pearson correlation coefficient was used to measure the strength of the linear relationship between the two aforementioned variables.

Results

Data on implant distribution as reported in the first part of this study20 are given in Table 1. A total of 72 patients were included in the study. Of these, 46 were treated at the Dental Clinic of
As reported in the first part of the study, no framework fracture or chipping of ceramic veneering was detected; a prosthetic cumulative survival rate of 100% was calculated for abutments in Groups 1, 2, and 4 (zirconia and titanium stock abutments and titanium CAD/CAM abutments). The survival rate for zirconia CAD/CAM abutments (Group 3) was 95% due to a fracture of an implant 4 mm in diameter and 11 mm in length placed at the site of the maxillary left central incisor. Two complications were observed in the form of abutment unscrewing; after crown removal the abutments (one titanium and one zirconia stock) were torqued down to 25 Ncm as recommended by the manufacturer, and occlusal contacts were checked again.

All the included patients were followed up at each consecutive annual examination. Therefore, no implant was classified as a drop-out; 72 patients were consecutively followed up during the 2-year period.

### Clinical Evaluation

Values recorded for REC after 2 years of follow-up are reported in Table 3. Initial recession values for all groups of abutments did not influence the 2-year soft tissue recession values ($P = .1$). The mean REC was 0.52 (SD 0.6) mm and 0.53 (SD 0.42) mm, for zirconia and titanium stock abutments (Groups 1 and 2), respectively. Furthermore, the REC of zirconia and titanium CAD/CAM abutments (Groups 3 and 4) was $-0.46$ (SD 0.54) mm and $-0.56$ (SD 0.68) mm, respectively (Table 3).

### Table 1 Stock Abutment Distribution by Implant Site and Diameter

<table>
<thead>
<tr>
<th>Area</th>
<th>3.5 mm diameter</th>
<th>4.0 mm diameter</th>
<th>4.5 mm diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxillary incisors/canines</td>
<td>Zr: 3 Ti: 2</td>
<td>Zr: 1 Ti: 2</td>
<td>Zr: 0 Ti: 0</td>
</tr>
<tr>
<td>Maxillary premolars</td>
<td>Zr: 2 Ti: 8</td>
<td>Zr: 4 Ti: 8</td>
<td>Zr: 0 Ti: 0</td>
</tr>
<tr>
<td>Mandibular incisors/canines</td>
<td>Zr: 0 Ti: 0</td>
<td>Zr: 0 Ti: 0</td>
<td>Zr: 0 Ti: 1</td>
</tr>
<tr>
<td>Mandibular premolars</td>
<td>Zr: 3 Ti: 1</td>
<td>Zr: 0 Ti: 1</td>
<td>Zr: 0 Ti: 0</td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
<td>11</td>
<td>5</td>
</tr>
</tbody>
</table>

Zr = zirconia; Ti = titanium.

### Table 2 CAD/CAM Abutment Distribution by Implant Site and Diameter

<table>
<thead>
<tr>
<th>Area</th>
<th>3.5 mm diameter</th>
<th>4.0 mm diameter</th>
<th>4.5 mm diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxillary incisors/canines</td>
<td>Zr: 6 Ti: 1</td>
<td>Zr: 4 Ti: 1</td>
<td>Zr: 0 Ti: 0</td>
</tr>
<tr>
<td>Maxillary premolars</td>
<td>Zr: 3 Ti: 8</td>
<td>Zr: 3 Ti: 3</td>
<td>Zr: 0 Ti: 0</td>
</tr>
<tr>
<td>Mandibular incisors/canines</td>
<td>Zr: 1 Ti: 0</td>
<td>Zr: 0 Ti: 0</td>
<td>Zr: 0 Ti: 1</td>
</tr>
<tr>
<td>Mandibular premolars</td>
<td>Zr: 1 Ti: 1</td>
<td>Zr: 2 Ti: 1</td>
<td>Zr: 0 Ti: 0</td>
</tr>
<tr>
<td>Total</td>
<td>11</td>
<td>10</td>
<td>9</td>
</tr>
</tbody>
</table>

Zr = zirconia; Ti = titanium.

Biomedical Sciences Institute, S. Paul Hospital, University of Milan, Italy, and 26 at the Dental Clinic, Department of Medicine, Surgery and Dentistry, University of Padova, Italy.

A total of 72 implants (Osseo-Speed, Astra Tech) were placed. For the 36 patients who received prefabricated stock abutments, 13 zirconia (ZirDesign) and 23 titanium (TiDesign) were used.

Moreover, 36 patients received CAD/CAM abutments: 20 zirconia (Atlantis) and 16 titanium (Atlantis) abutments were used, respectively. Abutment distribution is reported in Tables 1 and 2. All patients (39 men and 33 women) were aged between 26 and 58 years (mean age: 46 years) and presented good general health and an absence of local inflammation and mucosal diseases at the time of the surgical procedure. The minimum follow-up was 24 months after the start of prosthetic loading. All inserted implants were restored, and a 100% implant survival rate was observed at the 2-year follow-up.
REC values for titanium and zirconia CAD/CAM abutments were significantly lower ($P = .04$ and $P = .03$, respectively) than those of titanium and zirconia stock abutments (0.98 mm and 1.06 mm, respectively).

When mean REC index of all the CAD/CAM abutments ($-0.52$ mm, SD $0.61$ mm) was compared to that of all the stock abutments ($0.53$ mm, SD $0.48$ mm), the difference was significant ($P = .04$).

REC values were also compared by considering the same type of abutment material to avoid comparisons between different buccal mucosal thicknesses. The difference of $-1.1$ mm between mean papilla REC index of CAD/CAM titanium abutments (Group 4) was significantly lower ($P = .001$) than that of stock titanium abutments (Group 2). Similarly, the difference of $-0.97$ mm between mean REC index of CAD/CAM zirconia abutments (Group 1) was significantly lower ($P = .001$) than that of stock zirconia abutments (Group 3) (Table 4).

As reported by Lops et al\textsuperscript{20} in the Part 1 of the study, the mean buccal gingival thickness was found to be 1.75 and 2.75 mm for zirconia and titanium CAD/CAM abutments, respectively. The mean values for zirconia and titanium standard abutments were 1.72 and 2.91 mm, respectively. The correlation between initial mucosal thickness and REC was not statistically significant ($P = .3$). The Pearson correlation coefficient was used to measure the strength of the linear relationship between the two aforementioned variables. The difference of $0.1$ mm between the mean REC index of CAD/CAM zirconia abutments (Group 3) was not significantly different ($P = .9$) from that of CAD/CAM titanium abutments (Group 4). Similarly, the difference of $0.01$ mm between mean REC index of stock zirconia abutments (Group 1) was not significantly different ($P = 1$) from that of stock zirconia abutments (Group 3).

### Table 3 Papilla Recession Values

<table>
<thead>
<tr>
<th>Abutment</th>
<th>Stock zirconia</th>
<th>Stock titanium</th>
<th>Custom zirconia</th>
<th>Custom titanium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (mm)</td>
<td>0.52</td>
<td>0.53</td>
<td>$-0.46$</td>
<td>$-0.56$</td>
</tr>
<tr>
<td>Median (mm)</td>
<td>0.50</td>
<td>0.50</td>
<td>$-0.15$</td>
<td>$-0.35$</td>
</tr>
<tr>
<td>SD (mm)</td>
<td>0.60</td>
<td>0.42</td>
<td>0.54</td>
<td>0.68</td>
</tr>
</tbody>
</table>

Negative values indicate papilla growth.

### Table 4 Comparison of Papilla Recession by Type of Abutment

<table>
<thead>
<tr>
<th>Abutment</th>
<th>Compared abutment</th>
<th>Mean difference</th>
<th>SE</th>
<th>$P$</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Custom zirconia</td>
<td>Custom titanium</td>
<td>0.106</td>
<td>0.154</td>
<td>.901</td>
<td>$-0.313$ $0.525$</td>
</tr>
<tr>
<td></td>
<td>Standard zirconia</td>
<td>$-0.975^*$</td>
<td>0.171</td>
<td>.000</td>
<td>$-1.442$ $-0.509$</td>
</tr>
<tr>
<td></td>
<td>Standard titanium</td>
<td>$-0.989^*$</td>
<td>0.149</td>
<td>.000</td>
<td>$-1.395$ $-0.582$</td>
</tr>
<tr>
<td>Custom titanium</td>
<td>Custom zirconia</td>
<td>$-0.106$</td>
<td>0.154</td>
<td>.901</td>
<td>$-0.525$ $0.313$</td>
</tr>
<tr>
<td></td>
<td>Standard zirconia</td>
<td>$-1.082^*$</td>
<td>0.163</td>
<td>.000</td>
<td>$-1.527$ $-0.637$</td>
</tr>
<tr>
<td></td>
<td>Standard titanium</td>
<td>$-1.095^*$</td>
<td>0.140</td>
<td>.000</td>
<td>$-1.477$ $-0.713$</td>
</tr>
<tr>
<td>Standard zirconia</td>
<td>Custom zirconia</td>
<td>0.975*</td>
<td>0.171</td>
<td>.000</td>
<td>0.509 $1.442$</td>
</tr>
<tr>
<td></td>
<td>Custom titanium</td>
<td>1.082*</td>
<td>0.163</td>
<td>.000</td>
<td>0.637 $1.527$</td>
</tr>
<tr>
<td></td>
<td>Standard zirconia</td>
<td>$-0.013$</td>
<td>0.159</td>
<td>1.000</td>
<td>$-0.447$ $0.420$</td>
</tr>
<tr>
<td></td>
<td>Standard titanium</td>
<td>0.989*</td>
<td>0.149</td>
<td>.000</td>
<td>0.582 $1.395$</td>
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<tr>
<td></td>
<td>Custom zirconia</td>
<td>1.095*</td>
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<tr>
<td></td>
<td>Standard zirconia</td>
<td>0.013</td>
<td>0.159</td>
<td>1.000</td>
<td>$-0.420$ $0.447$</td>
</tr>
</tbody>
</table>

$^*$Significant difference.

Independent variable: recession index. Error (quadratic mean) $= 0.212$.
Negative values indicate papilla growth.
SE = standard error; CI = confidence interval.
Prosthetic Evaluation

Data on performance of abutments and crowns were reported in Part I of the study.20

Discussion

The 2-year follow-up data on peri-implant soft tissue stability for restorations supported by CAD/CAM and stock abutments were reported in the present study.

Significant differences were found. For restorations supported by stock abutments, the mean REC index was higher than for CAD/CAM abutments for both titanium and zirconia abutments. After 2 years of follow-up, slight papilla regrowth was measured for zirconia and titanium CAD/CAM abutments (−0.46 and −0.56 mm, respectively). Custom CAD/CAM abutments combine most of the advantages of stock and cast custom abutments. In addition to a predictable fit and durability, all the prosthetic parameters are modifiable, including the emergence profile, thickness, finish line location, and external contour. A custom abutment design could improve the support for the papilla and avoid excessive compression of the interproximal tissue. These aspects may explain the results of the present study.

Regarding the abutment material, no significant difference in REC index was found between titanium and zirconia for CAD/CAM (0.10 mm) or stock (−0.013 mm) abutments after 2 years of follow-up. This agrees with in vitro data available in the literature. Linkevicius and Apsė25 confirmed the well-documented biocompatibility and mechanical properties of these materials reported in the literature.

A limitation of the outcomes reported could be the reduced follow-up of 2 years; nevertheless, the trend agrees with the results of Zembic et al26 after 11 years of observation for 54 single implants positioned in anterior areas. No other data are present in the literature comparing papillae stability for restorations supported by different type of abutments. More studies with a medium- to long-term follow-up are required to confirm the findings of the present prospective report.

The favorable clinical results for CAD/CAM abutments and the adjacent interproximal papillae are also supported by promising data on biomechanical properties. Even if CAD/CAM was initially used to fabricate implant components from titanium and titanium alloy, to date CAD/CAM is the only way to produce implant components from high-strength ceramics such as partially stabilized zirconia. Furthermore, CAD/CAM abutments have been reported to consistently fit better than conventional cast components. Vertical gaps for titanium and zirconia abutments were reported to be comparable to stock implant abutments by Yüzügüllü and Avcı.27 When comparing the fracture resistance of titanium and zirconia abutments in vitro, CAD/CAM abutments were durable enough to withstand an applied occlusal load in the range of 300 to 460 N.28 Since these values are above the maximum physiologic occlusal forces on the anterior teeth, these abutments could be recommended for use with anterior implant restorations.29

Regarding the measurement procedures, the same method used in the first part of the study20 was used in the second part. A digital standardized method6,24 was effective for giving a numeric representation of interproximal papilla height modifications. The widely cited classification proposed by Jemt30 could describe the interproximal soft tissue as simply fully, partially, or not present. Nevertheless, the aim of the present study required a numeric measurement of papilla stability for adequate comparisons between groups of abutments.

Conclusions

In the anterior area, use of titanium and zirconia CAD/CAM abutments is related to a better interproximal papillae stability. For implant-supported restorations supported by stock abutments, the REC index was significantly higher than that for restorations supported by CAD/CAM abutments.

Acknowledgments

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References


