Experimental Zirconia Abutments for Implant-Supported Single-Tooth Restorations in Esthetically Demanding Regions: 4-Year Results of a Prospective Clinical Study

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Purpose: This prospective clinical study evaluated an experimental implant abutment made of densely sintered zirconia with respect to peri-implant hard and soft tissue reaction as well as fracture resistance over time. ***Materials and Methods:*** Twenty-seven consecutively treated patients with 54 single-tooth implants were included. Zirconia abutment ingots were individually shaped and set on the implants with gold screws. All-ceramic (Empress I) crowns were cemented using a composite cement. At the 1- and 4-year examinations, reconstructions were evaluated for technical problems (fracture of abutment or crown, loosening of abutment screw). Modified Plaque and simplified Gingival Indices were recorded at implants and neighboring teeth, and peri-implant bone levels were radiographically determined. ***Results:*** All but 1 of the 27 patients with 53 restorations could be evaluated at 1 year, and 36 restorations in 18 patients were evaluated 4 years after abutment and crown insertion. The median observation period for the reconstructions was 49.2 months. No abutment fractures occurred. Abutment screw loosening was reported for 2 restorations at 8 months and 27 months, respectively. Mean Plaque Index was 0.4 (SD 0.6) at abutments and 0.5 (SD 0.6) at teeth; mean Gingival Index was 0.7 (SD 0.5) at abutments and 0.9 (SD 0.5) at teeth. Mean marginal bone loss measured 1.2 mm (SD 0.5) after 4 years of functional loading. ***Conclusion:*** Zirconia abutments offered sufficient stability to support implant-supported single-tooth reconstructions in anterior and premolar regions. The soft and hard tissue reaction toward zirconia was favorable. *Int J Prosthodont 2004;17:285–290.*

In esthetically demanding anterior regions, restoring a single-tooth gap with an implant-supported crown is a major challenge to the clinician.[1–3] In patients with a high lip line, implant-supported reconstructions demand a superior esthetic outcome because the exposed position enables a direct visual comparison of the restored gap with adjacent natural teeth. Therefore, in this part of the jaw, success is not only defined by established osseointegration, but also by the presence of natural soft tissue and crown contours.[4]

From an esthetic point of view, one crucial factor influencing the individual appearance of the restoration is the emergence profile. As the cross-sections of implant shoulder and natural tooth at the gingival level differ, the transformation of the implant shoulder's circular section to an individualized anatomic section of the corresponding crown has to be performed either by the abutment or by the crown. Consequently, establishing the desired contours by means of the crown requires a short prefabricated abutment. This abutment design does not follow the scalloping of the soft tissue. Therefore, the crown margin ends up deeply submucosal,[5] leading to cementation difficulties (ie, removal of excess cement) in most cases. To avoid this, the crown margin is preferably located slightly submucosal; thereby, the emergence profile is created by the abutment

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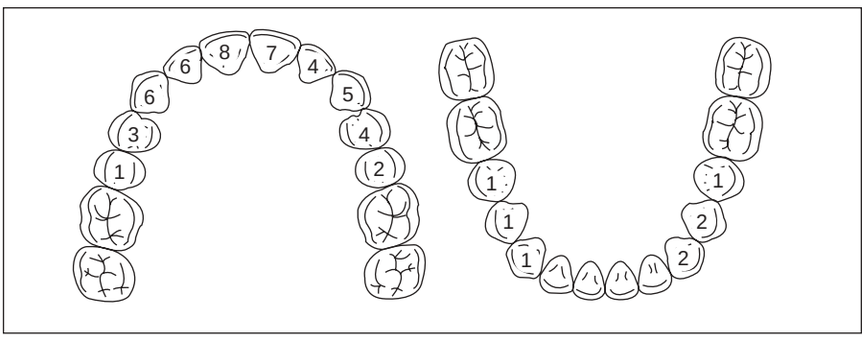

Fig 1 No. of abutments/crowns per tooth position.

itself. Consequently, the abutment has to be individualized because of the patient's mucosal situation.[6]

A second crucial factor influencing the clinical appearance of an implant-supported reconstruction is the color of the surrounding mucosa. Today, dental implants and abutments usually are fabricated out of commercially pure titanium because of its well-documented biocompatibility and mechanical properties.[7] However, from an esthetic point of view, titanium abutments may cause an unnatural bluish appearance to the soft tissue. Hence, for achieving optimal mucogingival esthetics, there is a need for a tooth-colored individualized abutment.

In 1993, a novel ceramic abutment (CerAdapt, Nobel Biocare) made of densely sintered alumina was introduced for Brånemark system implants (Nobel Biocare).[8–10] The proposed indications (ie, single crowns and fixed partial dentures [FPD] in both anterior and premolar regions) were documented by encouraging results of prospective clinical studies.[11,12] Furthermore, abutments made of densely sintered yttrium-stabilized zirconia have been introduced to support implant-supported single-tooth crowns.[6,13] Alumina as well as zirconia are characterized by good tissue compatibility,[14] low corrosion potential, low thermal conductivity, and superior mechanical properties compared to conventional ceramics.[15–17] Moreover, zirconia has a flexural strength and fracture toughness almost twice as high as alumina.[18] Through its common use in orthopedics (eg, hip joint replacements) for many years, the biocompatibility of zirconia has been extensively documented.[19,20]

In the field of restorative dentistry, zirconia has been used for root canal posts since 1989,[21] for implant abutments since 1995,[13] and for all-ceramic posterior FPDs since 1998.[22] Its versatility and material properties seem to be adequate for use in restorative dentistry. However, no clinical long-term studies on either of the above-mentioned prosthetic indications are available so far.

The purpose of the present prospective study was to evaluate the peri-implant hard and soft tissue reaction to experimental zirconia abutments supporting single crowns in the esthetic zone and to document technical problems related to the abutment material during the first 4 years of function.

Materials and Methods

Study Design and Patients

Patients scheduled for implant-supported single-tooth restorations were consecutively included in this prospective clinical study, provided that they fulfilled the following criteria:

- Missing tooth/teeth in an esthetically demanding region (ie, maxillary or mandibular incisor, canine, or premolar).
- Absence of any disorders at the implant site, such as previous tumors, chronic bone disease, or previous irradiation.
- Brånemark system Mk II Regular Platform implants (Nobel Biocare) had been selected and placed according to a standard, submerged protocol.
- Following uneventful healing, abutment connection had been performed and the implant was classified as successfully osseointegrated according to the success criteria defined by Albrektsson et al.[23]
- Informed consent for participating in the study was given by the patient.

From October 1995 to October 1997, of all patients scheduled for implant-supported single-tooth restorations at the authors' clinic, a total of 27 patients fulfilled the above-mentioned criteria and subsequently were included in the study. In particular, 16 women (mean age 42 years, range 26 to 65 years) and 11 men (mean age 46 years, range 27 to 75 years) received a total of 54 implants, experimental zirconia abutments, and all-ceramic crowns. Overall, the 54 implant-supported reconstructions replaced 25 missing incisors, 11 canines, and 10 premolars in the maxilla, and 3 canines and 5 premolars in the mandible (Fig 1).

The experimental all-ceramic abutments selected for all study implants were obtained by an individualization process of densely sintered yttrium-stabilized zirconia ingots (Wohlwend) (Fig 2).

Fig 2 Experimental zirconia abutment ingots with different diameters available for the study.

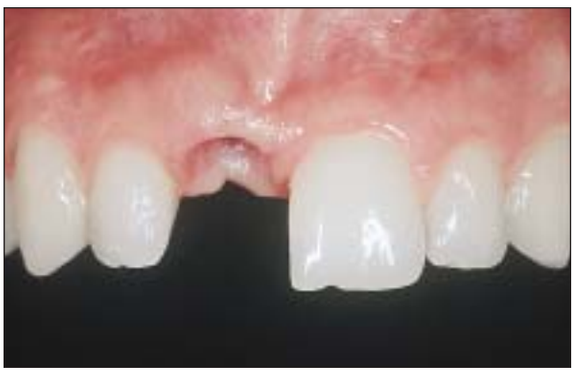

Fig 3 Peri-implant soft tissue contours 2 months following insertion of provisional crown.

Fig 4 Impression taking using a modified impression coping.

Fig 5 Regular impression coping *(left)*, modification *(center)*, and proabutment built up in resin material *(right)*.

Restorative Procedures

Following second-stage surgery, the peri-implant soft tissues were conditioned by means of a provisional crown for 2 to 3 months (Fig 3). Subsequently, an impression was taken at implant level using a modified impression coping (ref 28376, Brånemark system) according to a previously described technique[24] to transfer implant position as well as the established soft tissue contours to the master model (Fig 4).

Based on a clinical try-in of a treatment wax-up, the prospective abutment (ie, proabutment; Fig 5) was modeled in a resin material (Pattern Resin, GC) on the master cast. Subsequently, the most appropriate of the different industrially fabricated, densely sintered zirconia abutment ingots (Fig 2) was selected by the dental technician. Using the proabutment as a guide, the ingot was individually shaped (a minimum material thickness of 0.5 mm was fulfilled in all cases) by diamond instruments mounted in a manually guided copy-milling system (Wohlwend). Based on a clinical abutment try-in, corrections of preparation margin and emergence profile were either intra- or extraorally performed using diamond burs. Subsequently, the abutment was finished in the laboratory, and an all-porcelain crown (Empress I, Ivoclar Vivadent) was fabricated (Fig 6). Clinically, the zirconia abutment was definitively seated on the implant with a gold screw (DCA 1045, Brånemark system) at a torque level of 32 Ncm. To ensure controlled cementation of the crown, the abutment screw access channel was filled with a layer of gutta percha and composite material. Finally, the restoration was completed by cementing the all-ceramic crown using a resin cement (Panavia TC, Kuraray).

Follow-up Examinations

Follow-up visits were scheduled at 1 and 12 months and at 4 years following abutment and crown insertion (Fig 7). Clinical evaluation included an assessment of plaque accumulation and bleeding tendency at implants and neighboring teeth using a modified Plaque Index (mPII)[25] and a simplified Gingival Index (GI).[26] Furthermore, all restorations were examined for technical failures, ie, fracture of implant, abutment, or crown; loosening of components (abutment screw, crown); or chipping of porcelain. Standardized intraoral radiographs were taken using the long-cone parallel technique[27] at crown insertion and at the 12-month and 4-year examinations.

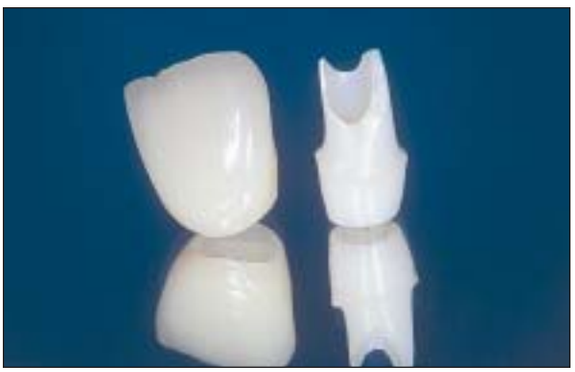

Fig 6 Individually shaped zirconia abutment and corresponding all-ceramic crown.

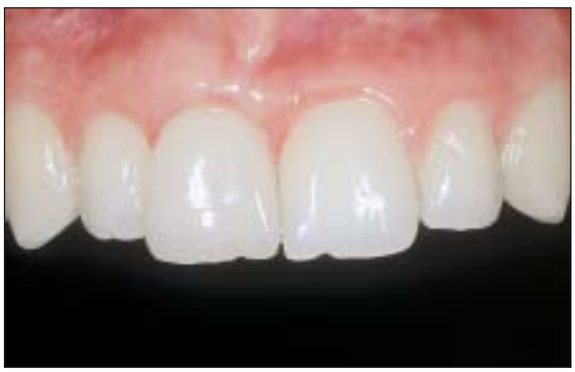

Fig 7 Clinical 4-year follow-up.

Table 1 Plaque and Gingival Indices over Time

Parameter	Following crown insertion		1-y follow-up		4-y follow-up	
	Mean	SD	Mean	SD	Mean	SD
Modified Plaque Index						
At abutments	0.2	0.1	0.4	0.3	0.4	0.6
At teeth	0.3	0.2	0.4	0.2	0.5	0.6
Simplified Gingival Index						
At abutments	0.6	0.2	0.7	0.3	0.7	0.5
At teeth	0.7	0.3	0.8	0.3	0.9	0.5

SD = standard deviation.

Marginal bone level changes were assessed radiographically at 4× magnification, using the standardized distance between implant threads (0.6 mm) as the measuring unit. Marginal bone loss was calculated from level of abutment-implant junction to first bone-implant contact.

Statistical Analysis

Descriptive statistics (mean values and standard deviations [SD]) were used for evaluation of the data. Marginal bone level changes over time were evaluated using the Student's *t* test. The cumulative survival rate was calculated using Kaplan-Meier statistics. Statistical analyses of changes in mPII or GI over time were performed using the sign test.

Results

During the course of the study, 53 restorations in 26 patients could be examined at 1 year, and 36 restorations in 18 patients were examined 4 years following abutment and crown insertion. The 8 missing patients (18 restorations) at the 4-year follow-up had either moved from the area or did not show up for examination in spite of two or more reminders. The mean observation period for the 36 followed restorations was 49.2 months (range 48 to 54 months).

Neither fractures nor chipping were observed during individualization or clinical incorporation of any zirconia abutment. No abutment fractures were observed during clinical loading, resulting in a cumulative survival rate of 100% for the followed abutments. Loosening of the abutment screw was reported for two restorations at 8 months and 27 months, respectively. In one case, the abutment screw could be retightened by creating an access through the crown, with no further complications reported so far. In the second case, the abutment screw was also retightened, but a new crown had to be manufactured because of an unfavorable location of the access hole. Minimal incisal porcelain chipping was reported for two crowns at the 1-year follow-up and for one crown at the 4-year follow-up. In these cases, polishing of the fractured area was adequate.

The mean mPII was 0.4 (SD 0.6) on abutments and 0.5 (SD 0.6) on teeth at the 4-year examination. The mean GI after 4 years was 0.7 (SD 0.5) on abutments and 0.9 (SD 0.5) on teeth (Table 1). There were no statistically significant differences ($P > .05$) regarding mPII or GI when implant sites and neighboring teeth were compared at baseline or at the 1- and 4-year follow-ups. The mean marginal bone loss was 1.1 mm (SD 0.5) at the 1-year examination and 1.2 mm (SD 0.5) at the 4-year follow-up (Fig 8).

Discussion

During the course of the present study, no abutment fractures were observed, and the peri-implant mucosa was

healthy with regard to both mPII and GI. However, because of an overall patient/restoration dropout of 33% at the 4-year follow-up time point, the results must be carefully interpreted. Since there are no comparable follow-up studies on zirconia abutments available so far, the current findings have to be compared to the results of scarce studies conducted with all-ceramic abutments made of alumina.

A comparative study documenting alumina abutments used for single-tooth reconstructions reported 7% abutment fractures within the first year of clinical loading (cumulative survival rate 93.3%).[12] Using alumina abutments to support FPDs, 1 of 53 abutments fractured during the first year of loading, leading to a cumulative survival rate of 98.1% after both 2- and 5-year follow-up periods.[11,28] In the present study, no abutment fracture was recorded, resulting in a cumulative survival rate of 100% for the 36 abutments followed for up to 4 years. Hence, it may be speculated that by using zirconia instead of alumina as an abutment material, adverse technical events such as abutment fractures are reduced. Nevertheless, further studies are needed to support this speculation.

With regard to further technical problems at the abutment level in the present study, abutment screw loosening was reported for two restorations. One screw became loose after 8 months, and another loosened 27 months following abutment and crown insertion. The incidence of abutment screw loosening in the present study of 1.8% for the first year and 3.7% for 4 years of loading is in agreement with similar studies on titanium abutments. In an investigation on all-ceramic crowns on titanium abutments (CeraOne, Nobel Biocare), 1 of 65 titanium abutment screws (incidence 1.5%) became loose after the first year of clinical loading.[29] Furthermore, a study on single-tooth implant restorations demonstrated that the use of a gold abutment screw reduces screw loosening.[30] However, an incidence of abutment screw loosening of 4% during a 5-year follow-up period was reported by those authors.

In general, abutment screw loosening because of functional loading of the reconstruction may be favored by a slight rotational freedom between implant head and abutment base resulting in a relative motion between these two components. Several in vitro studies demonstrate that an elimination of rotational freedom between abutment base and implant hexagon results in a screw joint that is more resistant to loosening.[31–33] On the other hand, elimination of rotational freedom may result in a press fit, thereby causing shear stresses within a ceramic material and possibly inducing fractures. Unfortunately, there is a lack of information concerning an adequate fit for ceramic abutments, including the experimental zirconia abutment tested in the present study. Hence, further studies are needed to document the fit and ensure the stability of screw joints at ceramic abutments.

In the present investigation, three crowns exhibited minimal incisal chipping of the veneer porcelain during the observation period, but no crown fracture was reported. This frequency of porcelain chipping is in accordance with results published for all-ceramic crowns supported by natural abutments.[34] On the other hand, in a prospective clinical study including 62 implant-supported all-ceramic crowns cemented on titanium abutments, 2 crowns (3.2%) fractured.[29] An investigation including 81 implant-supported all-ceramic crowns reported 7 crown fractures (8.6%).[30] In contrast to these two studies using a conventional cementation procedure for all-ceramic crowns, the present investigation included an adhesive cementation technique. The current results indicate that adhesively cemented all-ceramic crowns may also exhibit superficial porcelain chipping but may be less prone to complete fracture.

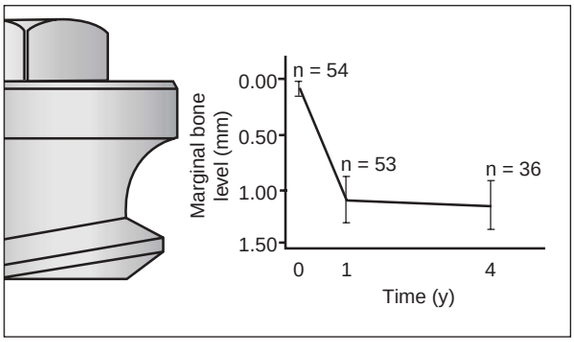

Fig 8 Mean marginal bone level.

The mPII and GI indicated healthy mucosal conditions at both neighboring teeth and zirconia abutments, with no statistically significant difference at any of the examination time points. This favorable soft tissue reaction toward ceramic (ie, zirconia) abutments is in line with similar studies reporting on implant-supported single-tooth restorations.[29,35]

The radiographic evaluations revealed only minor changes of marginal bone levels between the 1- and 4-year follow-ups. With reference to the abutment-implant junction, the mean marginal bone level decreased from 1.1 mm (SD 0.5) after 1 year to 1.2 mm (SD 0.5) after 4 years of loading and was thereby well within the limits set for successful implants.[23]

Overall, the clinical and technical experiences from the present study indicate that the use of yttrium-stabilized zirconia for abutment fabrication displays several material-related advantages and disadvantages. First, compared to other available ceramics, the material is characterized by superior physical properties.[18] In contrast to alumina, zirconia allows radiographic visualization of the abutment because of its higher radiopacity. On the other hand, depending on the restorative procedures and mucogingival embrasure, the white color inherent to zirconia can result in a too-bright appearance of the final reconstruction. In such cases, the surface can be colored with a corresponding veneering ceramic material to match the natural dentition.

Compared to prefabricated abutments, the individualization procedure is more demanding and time consuming and often requires an additional clinical try-in before the final crown is fabricated. Therefore, by using an individualized zirconia abutment, the overall treatment costs are increased. Future developments in the field of computer-aided design/manufacturing technology may overcome this disadvantage. Nevertheless, creating an individualized ideal abutment emergence profile with respect to the local mucogingival findings by using a high-strength ceramic material introduces a new restorative era.

Conclusions

Within the limitations of this study, the following conclusions can be drawn:

- Zirconia abutments offer sufficient stability to support implant-supported single-tooth reconstructions in incisor and premolar locations.
- Healthy mucosal conditions and stable marginal bone levels documented at zirconia abutments indicated a favorable soft and hard tissue reaction toward this ceramic material.

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