A Multi-faceted Treatment Approach for Anterior Reconstructions Using Current Ceramics, Implants, and Adhesive Systems

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Abstract

Of all developments in dental technology, to fulfill the esthetic and functional demands of the patient, especially regarding anterior reconstructions, is still a challenge for both dentists and dental technicians. This becomes more difficult for patients with a previous treatment history that is not ideal. This case presentation demonstrates reconstruction of anterior zirconia resin-bonded fixed-dental prosthesis (RBFDP) for the mandible with a combined treatment approach utilizing veneers for harmonized space distribution on the abutment teeth and an implant-supported zirconia FDP in the anterior segment of the maxilla. Adhesive cementation of the restorations is also presented in a step-by-step approach based on the current state of the art.

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Introduction

Today, prosthetic and operative treatment concepts could be categorized as non-invasive (reversible), minimally invasive (partially reversible), and (more) invasive strategies (non-reversible), using various materials.\(^1\) Dentistry, perhaps, has the unique distinction of using the widest variety of materials, ranging from metals and metal alloys to resin-based composites and ceramics. Developments, especially in the field of polymers and ceramics, have largely eliminated the use of metals in the mouth. In spite of all the advances, clinicians should realize the drawbacks before selecting the most appropriate material for a particular situation. Concentrating only on the material's properties is not sufficient; they should be mindful of the best application method. As the esthetic aspect of dental care becomes increasingly important to patients, the dental practitioner should be aware of the applications and limitations of the various tooth-colored restorative materials or systems and balance these with the ethical aspects of the invasive applications.\(^1\)

Fortunately, the dental profession has profited from remarkable technological advances in the substitution of missing dental tissues and teeth. However, we are still faced with the challenge of replicating the tooth tissues, mechanically, physically, biologically, and optically. With the increased options, the choice of material is also becoming more difficult. When a qualified ceramist is engaged, pressed ceramics provide outstanding results for single anterior fixed-dental prosthesis (FDP), more so than almost all other restorative options, with suitable marginal fit, minimal abrasion, and conservative tooth preparation. Yet they are not as effective as reinforced ceramics in preventing premature failure. On the other hand, reinforced all-ceramic FDP can be achieved using milled aluminous or zirconia copings.\(^2\) However, the presence of the relatively opaque internal ceramic core may provide an impediment to matching some tooth colors.

Although minimally invasive applications are possible using direct composites, sensitivity of technique is an issue; the drawbacks of composites are problems regarding loss of surface lustre. This may require repolishing, refinishing, or relayering.\(^3\) This is commonly found to be the case after several years of clinical function, and therefore the maintenance of the surface characteristics of composites, even after finishing and polishing, is an ongoing issue.

Minimally invasive applications are also possible using ceramic veneers. According to the majority of studies, it is clear that from the mechanical point of view, retention of laminates is not seen to be problematic.\(^4\) Clinical studies rarely report debonding, indicating that the adhesion of the luting cement, not only to dental tissues but also to the hydrofluoric-etched and silanized ceramic, is very reliable. Therefore the choice of full-coverage FDPs over laminates for mechanical retention reasons cannot be justified.\(^1\) Similarly, resin-bonded FDPs (RBFDPs), which are all-ceramic, are surely preferable to metal ceramics, due to their being minimally invasive, and also for esthetic reasons. Nevertheless, generally, teeth surrounded by healthy periodontal tissues have a very high longevity, up to 99.5% over 50 years.\(^5\) Therefore, the
utmost care should be taken to preserve the cementoenamel junction. This may not always be achieved, however, due to required tissue sacrifice for esthetic reasons. In addition, patient-related factors will continue to dominate when choosing one restoration type over another or the most suitable restorative materials for the patient. ¹

The situation becomes even more complex where the patient has a history of several treatment concepts that have failed. This case presentation could be considered an example of the most minimally invasive and durable approach being practiced, according to the state of the art, considering the patient’s demands.

**Materials and methods**

A 30-year-old female patient presented with an implant placed alio loco at tooth 21 by her previous dentist and a temporarily rehabilitated situation in the maxilla and mandible (Fig 1). She asked for a permanent rehabilitation in both the maxilla and the mandible as quickly as possible. Since she had already been through extensive therapy, her explicit wish was to limit therapy as much as possible, but at the same time accomplish the best possible result. Among others, the previous treatments involved implantation and explantation in the region of 31 as well as repeated soft tissue augmentation in the region of 11 and 21. The patient described herself as very sensible, nervous, critical, and unsure about the treatment outcome.

**Baseline situation in the maxilla**

In the maxilla, both bone loss and soft tissue loss were observed. The implant was positioned correctly. However, despite the previously accomplished soft tissue augmentation, the implant shoulder was located labially, being approximately 0.5 mm below the gingiva (Fig 2). For this reason, an individualized ZrO2 ceramic abutment with fired-on ceramic and a short external hex connector of small diameter (Brånemark System® NP) was made. The problem of this approach is uncertain long-term resistance against loading of the connection. During cyclic loading, vibrations and oscillating micro-movements or wear of the two participating materials occurs with the consequence of material loss at the surface. For the wear process, not only the roughness but also the hardness of the material plays a role. ZrO2 has a

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Knoop hardness value of 1200 kg/mm², being relatively harder than that of titanium (250 kg/mm²). For external hex connectors, 1 to 4 degrees of rotational loose fit between the implant body and various tested abutments were determined.

With non-conical self-blocking connections, a micro-movement at the interface can never be avoided. Also in this case, wear of the titanium surface on the ZrO₂ was noticed (Fig 3). The food debris and biofilm on the inner surface of the abutment were indicators of the presence of an insufficient connection.

The high rotational forces of the cantilever pontic are other unfavorable factors in such a material combination. Changing the implant geometry by grinding must be considered a major complication since, in the case of a repair, the new restoration would require a direct impression followed by manufacturing and insertion of an individually cast abutment. In the described case, the fired-on ceramic characterization was clearly visible beyond (cervically) the finishing line of the temporary crown (Fig 1). Moreover, the long-term, temporary FDP exhibited an adequate form, and the egg-shaped pontic showed a correct contact surface to the gingiva.

The therapy concept

Based on the above-mentioned situation, it was decided to construct a new all-ceramic ZrO₂ abutment bonded onto a titanium base, and to thin the titanium base on the labial side to the minimum thickness possible. In such difficult cases, the crown margin should be positioned labially and cervically, as much as possible, in order to avoid any exposure of the zirconium abutment. If further recession occurs, the finishing line between crown and abutment would be visible.

To accomplish a perfect harmony from the esthetic standpoint is more difficult when fewer teeth are subject to treatment in a given segment of the dental arch. In the presented case, the baseline situation exhibited asymmetric...
positions of the lateral incisors due to soft tissue loss and the rotation of the lateral incisors. In order to fulfill the high esthetic demands of the patient, it was decided to involve these two teeth in the reconstruction. On tooth 22, a classical labial veneer was made (Fig 10). For tooth 12, a crown as an abutment tooth was planned (Fig 5). This relatively invasive treatment option was chosen for two reasons: (1) the long-term stabilization of the extension bridge seemed questionable, and (2) a harmonious optimal closure of the interdental gaps between 12 and 11 was possible. In such a case, with several extracted neighboring teeth, the papilla loss, in this case between 12 and 11 as well as 11 and 21, presented a major esthetical problem. Because 12 was a sound tooth, the crown reduction was kept to 1 mm for preservation of the pulp. In the anterior area, it is considered a successful clinical practice to reduce the zirconium oxide framework to 0.3 mm. In so doing, it is possible to achieve a good esthetic outcome even with minimal space available. With
FDPs, the bisquit try-in is one of the most important steps of the treatment and should be practiced several times if necessary. During bisquit try-in, the following aspects should be taken into consideration:
- fit of the abutments
- proximal contacts
- basal shape and contact of the pontics with the gingiva
- occlusion
- perception of the reconstruction with the tongue
- phonetics
- esthetics.

**Fig 8** The labial surface of the ZrO2 coping of 12 was reduced to 0.3 mm in order to achieve room for the maximum thickness of the veneering ceramic.

**Fig 9** During bisquit try-in of the 3-unit FDP, it was noticed that leaving the tooth 22 unchanged, which is too narrow and tilted distally, is an esthetic compromise. With the consent of the patient, a labial veneer was achieved to improve the esthetics.

**Fig 10** The finished individualized ZrO2 abutment luted on a titanium base (Medentika, Baden-Baden, Germany). Preparation of 12, as minimal as possible, and veneer on tooth 22.

**Fig 11** Temporarily cemented FDP (bridge) for several days with 22 having the veneer. View of the temporary restoration in the mandible.
The control of the position of the pontics in relation to the gingival is especially important. Corrections can be made by removing ceramic or by adding material, and the correct relationship should be communicated to the dental technician. In this case, the try-in showed that the veneer option for 22 significantly improved the general esthetics (Figs 9,10). The veneers had to be made twice since the form did not suit the clinical requirement at the first attempt and the color was too light. (With veneers, the color of the ceramic should be correct right away; a later correction with the luting composite gives only very limited scope for change.\textsuperscript{12} For this reason, it is preferred to remake a veneer if the color is in doubt.) Because the patient did not feel sure about the final treatment outcome, despite intensive care and individual adjustments, the finished work was, exceptionally, cemented temporarily (Fig 11). Such a procedure is rarely performed due to possible damage occurring during the temporarization period or during removal of the restoration. It is, however, sometimes necessary if the patient particularly requests it.

Baseline situation in the mandible

The missing tooth could be replaced with an all-ceramic RBFDP with lingual wings using a more tissue-saving approach. The question is which design would be best. Extension of the wings over more than one abutment tooth has yielded clinically unfavorable outcomes, the distally connected tooth showing a delamination after a while. The question of whether a two-wing design would be better than a one-wing design has been answered by Kern.\textsuperscript{13} Clinical data have clearly shown the superior longevity of one-winged RBFDPs. In the maxilla, one-unit extension RBFDPs are clearly preferred. However, it is our experience that in the mandible, the two-wing design functions very well. For this reason a two-wing design was chosen. In the mandible, the gap was significantly larger than the usual width of the mandibular incisors. In such cases, the best esthetics are achieved when the width is distributed equally to each tooth. As to how this can be realized, the theoretical possibilities are as follows:

- to enlarge the abutment teeth with composite
- to enlarge the abutment teeth with ceramic as an integrated part of the bridge
- to make separate additional veneers.

The therapy concept

In order to close the proximal gap as much as possible towards the cervical, our preference was the last option. The second option would have required firing on veneering ceramic without an adequate supporting substructure, which seemed questionable from a technical point of view. Furthermore, the required insertion path would have created problems cervically. The possible aging of the composite was the reason for rejecting the first option. The contact points of the veneers to the RBFDP were precisely determined using a laboratory paralelometer. Additional veneers are virtually invisible on teeth as long as the finishing line is oriented cervico-incisally (Fig 18).

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\textsuperscript{13} Clinical data have clearly shown the superior longevity of one-winged RBFDPs.
However, finishing lines perpendicular to the tooth’s long axis may be visible in some cases. After adhesive cementation of the veneers, a new impression was made. The construction of the ZrO2 framework was achieved using an established CAD/CAM system (Fig 19).

The surface treatment of the ZrO2 for adhesive cementation can be achieved using air abrasion with 50 µm alumina particles at 2.5 bar for 15 s together with a phosphate monomer (MDP)-containing primer and the corresponding cement.14, 15 Of all possible alternatives, grit blasting has the best surface-cleaning effect.16-18 Because zirconium oxide is not etchable, a clean and rough surface is obtained that would ensure wetting of the surface, which is a prerequisite for adhesion. Another possibility is to sili-
cacoat the cementation surfaces with CoJet™ or Rocatec™ (3M™ ESPE™, Seefeld, Germany) silanization and then use a Bis-GMA-based cement19 (Figs 22 to 24). Currently, there is no long-term clinical study available on the effect of surface conditioning of non-etchable ceramics on clinical behavior.20 Aging was reported to have a detrimental effect on long-term adhesion.14,20

In the case presented, the whole lingual surfaces of the teeth and the proximal cementation surfaces of the veneers were cleaned using micro-abrasion with 25 μm alumina slurry under water (Prep K1 Max, EMS, Nyon, Switzerland) and the surfaces were roughened (Fig 24). Finally, the teeth were etched with 35% phosphoric acid (Ultra-Etch®, Ultradent Products, Inc., South Jordan, UT, USA)

**Fig 16** The already accomplished lingual preparation is completed with additional veneers. The sharp finishing line is placed backwards, behind the middle in order to enable a smooth adaptation between the etched feldspathic ceramic and the ZrO2 framework. Central positioning grooves in the preparation make cementation easier.

**Fig 17** Proximal veneers.

**Fig 18** Adhesively cemented veneers on 32 and 41. As a rule, vertical transitions are incorporated quite invisibly.

**Fig 19** Digital design of the RBFDP.
Fig 20  Finished all-ceramic RBFDP on the model.

Fig 21  RBFDP with two wings (two bonded retainers). ZrO2 framework was veneered with Creation Z1-F ceramic but the retainers were not veneered.

Fig 22  Silica coating of the cementation surfaces of the wings with the CoJet system (3M ESPE, Seefeld, Germany).

Fig 23  Application of the silane coupling agent (Monobond S, Ivoclar Vivadent, Schaan, Liechtenstein). It takes one minute to evaporate the solvent.

Fig 24  Application of the dual-cured luting composite (Variolink II, Ivoclar Vivadent, Schaan, Liechtenstein) on the cementation surfaces of the RBFDP.

Fig 25  Cleaning the surface with airflow (Prep K1 Max, EMS).
Fig 26  Cementation of the ZrO2 RBFDP and photo polymerization.

Fig 27  RBFDP after the adhesive cementation in situ.

Fig 28  The final treatment result.
and conditioned, followed by the application of a classical etch-and-rinse adhesive system (Syntac, Ivoclar Vivadent, Schaan, Liechtenstein). The cementation was achieved using dual-cured adhesive cement (Variolink® II, Ivoclar Vivadent, Schaan, Liechtenstein) (Figs 24 to 26). Figs 27 and 28 show the final treatment result.

Discussion

Unfortunately, there is rarely a single solution for all problems in dentistry and dental technology. In most cases, dentists find solutions for individual situations and individual complications. The presented case involved several such challenges and indicates that esthetics in reconstructive dentistry is an extremely demanding discipline requiring experience and knowledge, and the potential to apply both. The esthetic aspect of treatment always adds an additional requirement to the medical basics, and sometimes competes with them, making the whole treatment more difficult. Good esthetics do not happen necessarily as a consequence of correct dental and medical treatment. Often there is a need to do more. Furthermore, the individual patient’s wishes need to be taken into consideration. Patients with high esthetical demands require good management, which can create challenging situations.

The present case illustrates, from different angles, the demanding daily task of the practicing dentist to apply modern and advanced methods and at the same time assess their benefits and risks. With the increasing complexity of cases, the responsibility of the clinician is increasing. The solutions demonstrated should not be considered the most correct treatment; instead they illustrate the thought process during the planning of such complex cases. Whilst almost two decades ago the missing teeth in such cases were restored with metal-ceramic FDPs, with the preparation of at least four abutment teeth, today we have the possibility of using implants and zirconium oxide frameworks, but these also require more experience and know-how. In considering hard and soft tissue augmentation and the indications for implants, their number, position, system, design, and the dental material itself need to be considered in the treatment planning, as well as time management on the part of the dental professional.

The statement “High-tech dentistry is high-risk dentistry” was an accepted saying a decade ago but it is not true any more. CAD/CAM milled ZrO2 frameworks and glass ceramic restorations (eg, lithium disilicate) are more reliable full-ceramic materials than manually produced ceramics. Today, the following statement is more valid: “High esthetics dentistry is high-risk dentistry.” The more esthetic the material is, or the more translucent the ceramic, the weaker it is. Moreover, the higher the esthetic demands, the more difficult it is to establish static and mechanically strong restorations. Today, ZrO2 implants and ZrO2 abutments that are screwed directly onto the titanium implants are still an experimental solution.

The pressure from the market is triggering sales of such untested medical products, and every practitioner needs to decide for him/herself how and when
such progressive alternatives should be applied in their own practice. With the presented adhesive abutment solution in the maxilla, it is clearly shown that even in such challenging situations it is possible to offer, in borderline cases, a relatively safe and clinically proven solution. The most probable risk here is the debonding of the ZrO2 restorations. In such a situation, a non-problematic intra- or extraoral rebonding would be an easy solution. Adhesion of ZrO2 abutments to titanium bases is successful in vitro\(^2\) and has become successful clinical practice for years in our office as well as in many others.

Regarding the mechanical stability of the components, the alternative titanium abutment in combination with metal frameworks is considered the most reliable option with the longest track record. The chosen material combination in the presented case must still prove its longevity in the clinic. However, experience with several such cases is promising.

The most difficult decision in this case was whether to consider a full-coverage single-unit FDP on tooth 12 or not. This issue was discussed intensively with the patient. A series of review articles tried to answer the question of whether implant-supported FDPs or combined implant-tooth-supported FDPs are prognostically in favor of the solely implant-supported restorations.\(^2\)-\(^5\) The analysis of 21 studies that met the inclusion criteria indicated an estimated survival rate for implant-supported FDPs of 95% after 5 years and 86.7% after 10 years of function.\(^2\) Against the high survival rates for implant-supported FDPs, frequent complications (38.7%) were reported within the first 5 years in the same study.\(^2\) These included chippings and loosening or fracture of screws. The term “success” is used when an FDP remained unchanged and free of all complications over the entire observation period. The reported complication rates indicate that implant-supported restorations generally carry a high risk of retreatment and require maintenance services.\(^2\) In a comparable metaanalysis of 13 studies that met the inclusion criteria, combined tooth–implant-supported FDPs showed a significantly lower estimated survival rate of 94.1% after 5 years and 77.8% after 10 years. The success rates for the implants were also lower with 90.1% and 82.1% after 5 and 10 years, respectively. However, the complication rates related to the implants alone ranged between 0.7% and 11.7%, depending on the type that presented a figure considerably lower than those of the implant-supported restorations.\(^2\)

In our case, the issue in question was whether a three-unit combined tooth–implant-supported FDP would have a higher survival and lower complication rate than a two-unit cantilever FDP supported by a single implant. Thus the decision made for this case deviates from the situations analyzed in the dental literature. Although trends can be observed, the literature cannot provide an answer. Nonetheless, tooth-supported cantilever FDPs show lower survival rates and higher complication rates than those of
conventional FDPs supported by at least two abutments.25 This indicates that the leverage forces created by a cantilever should, in general, be regarded as mechanistically problematic.

Due to the fact that the diameter of the implant and of the external hex was small and that the vertical dimension of the prosthesis was high, and that therefore strong leverage forces were to be expected, the conventional bridge solution was considered safer than a free-end pontic. This assessment was confirmed by the fact that the temporary restorations showed multiple debondings. The implant situation was given and, according to today’s possibilities, correct as well. The presence of two neighboring implants in the anterior region is an almost insoluble esthetic challenge for the prosthodontist, due to the soft tissue (ie, papillae) problems. In fact, an implant can only prevent a full-coverage crown on the abutment tooth and at the same time replace the missing tooth. Therefore the decision to incorporate a crown on tooth 12 in the present case could be justified from an ethical standpoint as well.

The situation in the mandible is a classic indication for an RBFDP. This is especially true after an already failed implant attempt. A conventional full-coverage FDP would require much hard tissue loss. In cases where there are soft tissue recessions in combination with small root diameters at the gingival level, a correct crown preparation is almost impossible. Such RBFDPs could be made with one or two wings on one or two abutments. One-wing RBFDPs made entirely of ceramics have been shown to be a successful treatment op-

tion.27,28 The disadvantage of the two-wing type is that, in a case where an unnoticed fracture, debonding, or delamination occurs, secondary caries on the abutment tooth could occur.23,29 Knowing that the one-wing RBFDP has a documented excellent clinical longevity record,30 other options are not justified in such a situation. The most common indication for RBFDPs is missing lateral incisors in the maxilla. Splinting the central incisor with the canine of the same side using an RBFDP was proved to be not physiologic. The experience of the authors regarding such RBFDPs in the maxilla has shown unilateral debondings in many cases. A possible reason for these debondings could be stress at the adhesive interfaces due to uneven tooth mobility of the anterior maxillary teeth under physiologic functional load. In contrast, during more than 10 years of observation, no unilateral debonding was observed in the mandible with all-ceramic RBFDPs made of lithium disilicate.31 Furthermore, these RBFDPs were made specially with proximal grooves but no wings. This indicates that in the mandible, the load is directed axially rather than lingu ally, which may explain why two-wing RBFDPs were more successful. Similarly, Kern et al. found all one-sided debondings exclusively in the maxilla.13 The question remains whether, under the assumption that in the mandible both options could function clinically, a second wing is necessary. Even if the potential danger of a connector fracture is present, in our opinion the two-wing design is favored, because it allows for thinner connectors.

The discussion above clearly underlines the difficulty of the practicing
dentist to make the right decisions to guarantee long-term clinical success. Also, the question regarding durability of the adhesive cementation with a non-etchable ceramic zirconium oxide ceramic remains unanswered. The longest clinical experience exists with glass-infiltrated aluminum oxide ceramics. The results with this material indicated that surface conditioning with air-abrasion using alumina, and the use of a primer and adhesive with bifunctional (MDP) monomers, yields a good clinical survival rate. However, in vitro microtensile tests showed unfavorable results for the adhesion of resin cements to In-Ceram® Alumina and In-Ceram Zirconia after artificial aging conditions. For pure zirconium oxide, such information is limited in the literature. In general, it can be anticipated that all kinds of non-etchable ceramics would behave similarly. Based on the information derived from in vitro studies, the aging effect on the adhesive interfaces and thereby the durability of the adhesion is the Achilles heel of such therapies.

A possible structural change through air abrasion in the stabilized zirconium oxide could be a concern. Limited information is available on the possible negative effects of air abrasion on zirconium oxide. The opinions on this aspect are controversial. Nevertheless, chairside application of silicatization was claimed to be less hazardous on the material properties of zirconium oxide than laboratory air abrasion utilizing alumina.

Air abrasion could be expected to create damage in the form of delamination or total fracture according to the current knowledge. However, it depends on several other parameters. Still, it was, however, claimed that the cleaning of cementation surfaces is best achieved with air abrasion. Since oxide ceramics do not contain silica, as an alternative to the adhesive cementation with MDP-containing cements, chairside silica coating and silanization could be considered in combination with dual polymerized Bis-GMA cement. Which method for the cementation of zirconium oxide would be clinically more successful needs to be determined. Therefore, such cases are currently under review in our practice.

Conclusions

Missing teeth can be restored both functionally and esthetically utilizing treatment modalities such as veneers and surface-retained RBFDPs coupled with implants and zirconia suprastructures. The durability of such restorations can be achieved through adhesive cementation, based on the current state of the art derived from both clinical and laboratory studies. This clinical example illustrates the particular challenge for any clinician when confronted with exceptional situations, where former experience or scientific evidence may not followed. It is important to learn from previous unfavorable applications and inappropriate assessments or decisions affecting the individual and to keep an open mind regarding treatment concepts in the light of new findings and experiences.
References


AUTHOR QUERIES:

1. Please check ALL text very carefully as it has been heavily edited for English – please ensure the correct meaning has been captured.

2. Please check the sentence in Discussion, para 6: “A series of review articles tried to answer the question of whether implant-supported FDPs or combined implant-tooth-supported FDPs are prognostically in favor of the solely implant-supported restorations.”

22-25