Inlay-retained Zirconia Fixed Dental Prosthesis: Clinical and Laboratory Procedures

Carlo Monaco, DDS, MSc, PhD
Division of Prosthodontics, Department of Oral Sciences, Alma Mater Studiorum, University of Bologna, Bologna, Italy

Paolo Cardelli, DDS
Division of Prosthodontics, Department of Oral Sciences, Alma Mater Studiorum, University of Bologna, Bologna, Italy

Michele Bolognesi, DT
Laboratorio Bonfiglioli-CCD, Bologna, Italy

Roberto Scotti, DMD, Prof
Division of Prosthodontics, Department of Oral Sciences, Alma Mater Studiorum, University of Bologna, Bologna, Italy

Mutlu Özcan, Prof Dr med dent, PhD
University of Zürich, Dental Materials Unit, Center for Dental and Oral Medicine, Clinic for Fixed and Removable Prosthodontics and Dental Materials Science, Zürich, Switzerland

Correspondence to: Carlo Monaco
Division of Prosthodontics, Department of Oral Sciences, Alma Mater Studiorum, University of Bologna, Via San Vitale 59, 40125 Bologna, Italy; Tel: +39-51-208-8186, Fax: +39-51-225-208; E-mail: carlo.monaco@unibo.it
Abstract

Many treatment options are currently available for single tooth replacement, such as metal-ceramic, all-ceramic, direct or indirect fiber-reinforced composite fixed dental prostheses (FDPs) or implants. Inlay-retained FDPs could be indicated especially when adjacent teeth have preexisting restorations and where implant placement is not possible or not indicated. In such cases, indication of both metal-ceramic and fiber-reinforced composite FDPs has certain disadvantages. This paper describes the use of all-ceramic inlay-retained FDPs with zirconia frameworks, veneered with a press-on technique. The retainer margins were made of pressed ceramic to make adhesive luting possible. In deep cavities, a full contour press-on ceramic all around the retainers increased the available surface area for the adhesive approach.

Introduction

Today, it is possible to replace a missing tooth in the posterior area of the mouth using different treatment modalities. During the past decade, dental implants have been the first choice, especially in cases when the abutment teeth were sound. In fact, when patients reject implant therapy, with or without previous reconstructive surgery, or in cases of already-restored teeth, the adhesive treatment approach and other minimally invasive procedures could also offer an alternative solution, as opposed to conventional full coverage fixed dental prosthesis (FDP). Moreover, the removal of large parts of dental tissues to gain macromechanical retention becomes problematic in young patients who have typically teeth with larger pulp chambers. Pre-existing fillings can minimize tooth structure removal and give retention to the inlay-retained FDP, transforming it into an ultraconservative option. These retainers enable greater preservation of healthy tooth structure and make periodontal assessment easier.

Although it is still accepted as the golden standard, the application of full coverage metal-ceramic FDPs has some disadvantages. These include loss of retention, soft tissue pigmentation or an opaque-to-darkish cervical appearance of the abutment teeth. Consequently, alternative materials have achieved a certain degree of popularity in prosthetics, such as high-strength pressed ceramics, fiber-reinforced composite (FRC), and recently, alumina and yttria-tetragonal zirconia polycrystal (Y-TZP) with ceramic veneering. However, these materials present some problems derived from their inherent properties namely, high-strength pressed ceramics have a potential for debonding with also insufficient fracture resistance. FRCs on the other hand, has risks of fiber exposure, delamination, and formation of hairline micro-cracks in the composite veneering material. A possible explanation for these phenomena could be the intrinsic flexibility of the fiber framework that may also play an important role in the marginal adaptation of the FRC FDPs. The mechanical properties of the zirconia, especially those related to its stiffness, could help to avoid the failures associated with FRC and high-strength pressed ceramics. However, zirconia still presents a challenge when used with adhesive techniques due to their single-phase tetragonal crystalline structure that is not etchable by commonly-used agents such as hydrofluoric acid.

In fact, when cementation problems can be overcome, inlay retained zirconia FDPs could be good alternatives to other materials and treatment options. The purpose of this article is to illustrate the technical and clinical procedures related to the placement of inlay-retained FDPs made out of zirconia framework that is veneered with a pressed ceramic veneering and luted with a completely adhesive approach.

Materials and methods

Indications and contraindications

Similar to other metal-free materials, the properties of the materials used in inlay-retained zirconia FDPs must be in-
dicated. Careful clinical evaluation and treatment planning should be performed prior to the rehabilitation procedure. Inlay-retained FDPs could be indicated in patients with good oral hygiene, less caries susceptibility, presenting coronal tooth height of a minimum 5 mm or higher, parallel abutments and maximum mesio-distal edentulous gap of 12 mm (Fig 1). Contraindications include severe parafunctions, the absence of enamel on the preparation margins, extensive crown defects and various degrees of abutment tooth mobility. Endodontically treated teeth should have their cusps included in the preparation for their coverage and protection. Otherwise, the clinician should consider a complete crown preparation. Unsolved periodontal pathologies or gingival bleeding should also be considered as an absolute contraindication, because gingival bleeding compromises the adhesive bonding between the prepared tooth and the resin.

Moreover, periapical radiographs of the selected abutment teeth should be made and model analysis conducted, starting with irreversible hydrocolloid impressions. Attention should be paid to generalized wear facets, antagonist contact positions, premature contacts, clinical crown height, horizontal extension of the edentulous ridge, and alignment of the abutment teeth. Canine guidance must be ensured to avoid torsional stress on the FDP. When canine guidance no longer exists, its reconstruction should be considered prior to tooth preparation for the inlay-retained FDP.
Pretreatment

Existing restorations adjacent to the pontic area were removed, and if caries was present, carefully excavated. The prepared dentin was then immediately sealed with an adhesive system to prevent contamination by bacteria, and components coming from the impression and provisional cementation materials. Moreover, this procedure reduces the hydrodynamic effect derived from the inadequate seal of temporary materials. Therefore, dentin bonding reduces the postoperative sensitivity.

The build-up was fabricated with composite materials to eliminate the undercuts and to compensate for the gap between the residual tooth structure and ideal preparation design.

Preparation

The cavity preparation for inlay-retained zirconia FDPs was performed according to the following guidelines:

- 2.5 mm occlusal depth (floor of isthmus to central groove)
- 3 mm vestibular-palatal/lingual width of the intercuspal isthmus
- 2 mm depth of proximal box (shoulder with rounded internal angle)
- 4.5 mm buccal vestibular width (3 mm of zirconia framework and 0.5–0.6 mm of ceramic veneering for each side)
- minimum dimensions of connectors: 3 x 3 mm
- inclusions of cusps in the preparation when the abutment tooth has a wide bucco-oral defect (>50%) or has been devitalized
- divergence angle of the cavity of approximately 6 degrees (Fig 2).

The recommended impression technique was based on silicone materials with a one-step technique (polyether or VPS) (Fig 3).

Laboratory procedures and options

The master impressions were developed with polyurethane resin (Exakto-Form®, Bredent, Senden, Germany) (Figs 4a, b). Zeiser model mounting was performed, and the fixed dental prosthesis waxed up (Sculpturing Wax Chip® (beige), Yeti Dental, Engen, Germany) (Fig 5). Laboratory putty VPS (Platinum 95, Zhermack SpA, Badia Polesine, Italy) could be used to create three templates of the fixed dental prosthesis area: buccal, occlusal, and palatal/lingual. The waxed-up fixed dental prosthesis was then removed from the preparations, and the model was powdered with a thin layer of TiO2 and scanned for CAD procedures (inEOS®, Sirona, Bensheim, Germany) (Fig 6). The master model was scanned again after repositioning and powdering the waxed fixed dental prosthesis. The two scans of the master model were superimposed, and preparation margins defined with the fixed dental prosthesis semi-transparent on the screen (Cerec® inLab 3D software, Sirona). The FDP framework is always designed with a connector surface of at least 3 x 3 mm, and a palatal/lingual bar on the medium third of the pontic, to hold the framework in the right position during press-on.

At this stage, based on the depth of the cavity preparations, two framework-design options were available that led to different surface conditionings of the
Fig 4  Details of the retainer preparation on the a) premolar, and b) molar on the master model.

Fig 5  Wax-up of the inlay-retained FDP.

Fig 6  Master model powdered for scanning before computer aided design (CAD).

Fig 7  Sintered zirconia framework for deep retainers.

Fig 8  Ceramic liner application.
CASE REPORT

inlay-retained FDP during the adhesive luting procedures:

- Less deep cavity preparations (2.5 mm): the zirconia framework lies on the cavity floor and has a reduced circumferential dimension, leaving space for etchable glass ceramic at the margins (Figs 4a, b).

- Deep cavity preparations (>3.3 mm): the zirconia framework is enclosed inside the over-pressed ceramic. In this way, all inner surfaces of the retainers are covered by the etchable glass ceramic (Fig 7).

Following the CAD stage, zirconia frameworks were milled from a pre-sintered block (IPS e.max® ZirCAD for inLab Blocks B 40 L; Ivoclar Vivadent, Schaan, Liechtenstein) with a dedicated machine (Cerec inLab® MC XL, inLab, Sirona, Austria). Refinishing with a tungsten carbide bur was necessary to remove the last zirconia excesses before sintering. The milled framework is color-infiltrated (IPS e.max® ZirCAD Colouring Liquid, Ivoclar Vivadent) and the residual connection to the base of the block was removed.

After placement in a refractory box containing zirconia-isolating spheres (Sintramat® ZrO₂ beads, Ivoclar Vivadent), the framework was sintered for 7.5 hours in the relevant sintering furnace (Sintramat®, Ivoclar Vivadent), until it reached 1,500°C, followed by approximately 30 minutes of cooling.

After sintering, different technical procedures were used for the more shallow and the deep cavity preparations:

- For the more shallow preparations, a ceramic uncolored liner (IPS e.max® Ceram ZirLiner clear, Ivoclar Vivadent) was placed in a creamy consistency all over the framework and fired. After this heat treatment, the liner thickness should be at least 0.1 mm. The ceramic veneering was then waxed up.

- For deep preparations, full ceramic contour of the FDP was obtained by performing the following procedures:
  - The occlusal portion of the liner (IPS e.max® Ceram ZirLiner clear, Ivoclar Vivadent) was layered and fired (Fig 8);
- A soft wax was placed between the pontic and the edentulous area of the master model, and the framework was moved until the occlusal clearance from the template is uniform. Then, the same wax is placed under the retentions. A new occlusal template that contacts the framework was prepared (Fig 9);
- The wax under the pontic and the retention was removed, and the liner was layered and fired in this portion;
- The FDP was locked to the new template with an adhesive wax (Fig 10) while the technician holds it in the hand, putting fluid wax under the inlays and the pontic, and obtaining the right modeling repositioning on the master model (Fig 11);
- Occlusal waxing was performed using the first template, generated from the wax up analysis.

In both cases, the wax cylinders that will drive the pressed ceramic to the framework are placed on every cusp of the pontic (Fig 12). The press-on technique follows a lost-wax technique. After this stage, the ceramic (ZirPress, Ivoclar Vivadent) was heated at 900°C for 15 minutes after an increase of 60°C/min. It was then injected by the same device (Programat EP 5000, Ivoclar Vivadent).

When ceramic cooling was complete, the ceramic channels were removed with a tungsten carbide bur and the FDP adapted to the master model (Fig 13). For the correct color matching, shade and stain can be used (1 or 2 firings). Otherwise, the FDP can be ceramic stratified (IPS e.max Ceram, Ivoclar Vivadent).

Try-in

The fit of the structure in the oral cavity was controlled using a low-viscosity silicone material (Fit Checker Black 1-1 PKG, GC, Tokyo, Japan), which showed no friction and demonstrated marginal integrity of the retainers. The occlusion was controlled with 35 μm occlusal paper, both in maximum intercuspidation position and during the eccentric movements, correct-
ing the FDP with fine diamond burs and reshaping opposing fillings, if existing. The interproximal contact areas with the adjacent teeth were also checked if they were involved in the restoration.

The FDP was then glazed (e.max® Ceram Glaze Fast, Ivoclar Vivadent) and then ready for the luting procedures (Figs 14a, b).

Placement

The temporary restoration was removed from the preparations using a manual instrument, such as a probe and excavator. A rubber dam was then placed, isolating the preparations from the oral cavity. The dam margins were placed inside the gingival sulcus using a spatula and air pressure; otherwise, the dam could cover some parts of the retentions. In some cases, the rubber dam placement should be integrated with the use of a retraction cord and/or a liquid dam. The preparations were cleaned using a pumice paste over a rotating brush at 7,000 RPM. The luting procedure then started as follows:

FDP conditioning

The cleaned and dried ceramic surfaces that are to be in contact with the cement were etched with 9.6% hydrofluoric acid for 60 seconds. The surfaces were then cleaned with suction and rinsed with a water spray for 60 seconds. The ceramic precipitates were removed from the surface by ultrasonically cleaning the FDP in 95% ethyl alcohol for 10 minutes. The surface was carefully air dried, and a silane coupling agent placed on the etched surfaces and left to react with the surface for 5 minutes at 60°C. A single layer of bonding agent from the 3-step adhesive system chosen was applied on the surfaces, and luted with a microbrush. The FDP was then placed under a dark cover, preventing polymerization of the adhesive.

Cavity conditioning

The cavities were treated with Al2O3 particles partly covered with SiO2 (CoJet Sand, 3M ESPE) with an intraoral sandblaster (CoJet Prep, 3M ESPE, Seefeld, Germany) until the surface of the preparation appeared completely treated. The surfaces were then etched for 30 seconds with 35% phosphoric acid. Etching gel was rinsed for 20 seconds with an air/water spray, and the primer of the same adhesive system used for the FPD applied for 20 seconds with a microbrush and then gently evaporated. The bonding agent already used on the FDP was then applied with a microbrush, but not polymerized.

Final placement

A 2 mm layer of restorative composite material was heated to 60°C and placed on the retentions with a spatula. The FDP was then carefully placed. Finger pressure was used first, and then more direct pressure was applied, letting the patient close the mouth with the dam in place. The patient was let bite half of a wooden bite stick that was placed between the opposing arch and the pontic. Excess composite was removed with thin instruments (Carver/Occlusal Former DD1 / DD2, Suter Dental Manufacturing, Chico, CA, USA) and floss (Oral-B Superfloss,
**Fig 13** Veneered FDP ready for clinical try-in.

**Fig 14** a) Cementation surface and b) occlusal surface of the final restoration ready for luting procedure.
Following removal of excess composite, it was polymerized from mesio-buccal, mesio-lingual, disto-buccal, disto-lingual, and occlusal directions. Additional polymerization was performed for 20 seconds at each side with glycerine gel that was placed to prevent oxygen from inhibiting the polymerization. Excess luting material was removed with a scaler.

The tooth-restoration interface was then finished using composite polishing points (Astropol, Ivoclar Vivadent, Schaan, Liechtenstein) at average RPMs and then with an occlusbrush (Occlusbrush, Kerr, Orange, CA, USA) at 6,000 RPM. Proximal areas that are difficult to reach can be finished with narrow finishing strips (Soft-Lex 1954N, 3M ESPE, St. Paul, MN, USA) (Fig 15).

Discussion

Inlay-retained FDPs could be considered when implants are not indicated or cannot be afforded by the patients. Furthermore, peri-implantitis issue or marginal bone loss around implants have not been thoroughly solved in implant dentistry. Such restorations could be considered as conservative options, compared to complete coverage FDPs. Complete coverage FDPs may present long-term survival rate due to macro-mechanical retention, but biological complications such as caries around the restorations, loss of vitality or periodontal problems are commonly reported.

When abutment teeth contain restorative fillings adjacent to the missing tooth, inlay-retained FDPs are very minimally invasive options because they require only minimum tooth structure removal beyond the filling extension. Complete coverage FDPs may present long-term survival rate due to macro-mechanical retention but biological complications such as caries around the restorations, loss of vitality or periodontal problems are commonly reported.2 When abutment teeth contain restorative fillings adjacent to the missing tooth, inlay-retained FDPs are very minimally invasive options because they require only minimum tooth structure removal beyond the filling extension. Wolfart et al reported 89% survival rate after 4 years for lithium disilicate, with failures due to debonding or a combination of debonding and fracture.11

The technique described here could reduce these phenomena due to the rigidity of the zirconia and the possibility of adhesive cementation given by the pressed ceramic.30 Ceramics materials, moreover, have some basic advantages in polishing and color matching, as well as the possibility of intraoral repair.31 On the other hand, zirconia has the potential to age due to hydrothermal degradation that could possibly occur when it is exposed to oral fluids, which is a phenomena that has not been clarified yet in dentistry.32 With the use of a full-contour veneering or at least the use of a ceramic marginal closure at the margins of the retainers, this problem could be avoided.

Conclusions

Within the limits of a preliminary clinical application, the technique described here allows for single-tooth substitution
when implant placement is not possible or not indicated. Thus excessive dental tissue removal for full-coverage FDPs could be avoided. The use of a press-on ceramic for a marginal or full contouring of the retainer, allowing the adhesive approach, could enhance the long-term stability of such restorations.

Disclosure

The authors declare that they have no financial interest in the companies whose materials are used in this article.

References

CASE REPORT


