Combining Esthetic Layering and Lithium Disilicate Sintering Technique on Zirconia Frameworks: A Veneering Option to Prevent Ceramic Chipping

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Major and minor chipping of veneering porcelain are two of the most frequent complications in all-ceramic restorations with zirconia frameworks. In cases of major chipping, replacement of the affected restoration may be necessary. High-strength lithium disilicate ceramic offers new options to serve as veneering material in a sintering technique or as repair material for chipping in combination with the adhesive technique. The purpose of three case presentations here was to describe the use of lithium disilicate ceramic on zirconia frameworks for reliable and esthetic veneering in the posterior region and to repair extended chipping in conventional veneering materials.
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Several types of ceramics are commercially available in dental practice and laboratories with a wide spectrum of indications, depending on the type of restoration.[1–6] Ceramic frameworks can be fabricated from materials such as lithium disilicate (LS_2) or zirconia (Zr).[7–11] LS_2 presents good mechanical properties including flexural strength (350 MPa machine milled to 400 MPa pressed), excellent esthetic results, and the possibility of imitating the natural tooth structure.[7] However, its main indication remains use in single-tooth restorations because the mechanical properties of LS_2 are inferior to those of Zr-based ceramics (flexural strength of 900 to 1200 MPa and fracture toughness of 9 to 10 MPa-$m^{1/2}$).[12] Zr is the predominantly used all-ceramic framework material in the posterior region because of its versatility.[9]

Zr stabilized with 3 mol% yttrium (3Y-TZP) offers superior mechanical properties and biocompatibility.[10] However, conventional Zr presents some limitations, such as long-term hydrothermal degradation and an opaque white appearance.[8,10] In general, a veneering of the Zr framework with silica-based ceramics is considered advantageous.[10] Various techniques are described to perform this layering, including the powder layer technique,[11] the overpressing technique,[11] and the sintering technique.[8,10,11] The first technique presents disadvantages of micropore formations during the lamination.[8] The literature reports frequent failure of veneering porcelain chipping in the first and second method (4% to 28%)[12–15] caused by different factors, including discrepancy in the thermal expansion coefficient between porcelain and Zr, design and connector size of < 9 mm^2 of the framework, and the lower flexural strength of the veneering porcelain (approximately 120 MPa).[10] New digital veneering methods have been developed to reduce debonding and chipping, such as the Lava Digital Veneering System (3M), the Rapid Layer Technology (VITA Zahnfabrik), and the CAD-on technique (Ivoclar Vivadent).[8] All of these systems use as a first-step computer-aided design (CAD) of a full-contour restoration, which is then divided into two files (file splitting), one responsible for the computer-assisted manufacture (CAM) fabrication of the Zr framework, and the other for the CAM-fabrication of the corresponding veneering material. The first system was designed for single-crown restorations and used a separately milled presintered silica-based veneering material. A glass-ceramic powder (fusing ceramic) was used to fuse the veneering material to the Zr framework.[8] The second technique used feldspathic porcelain (Vita Mark II, VITA Zahnfabrik), which was adhesively bonded to the Zr framework. Due to the adhesive technique, no corrections of the veneering material in shade or shape by firing cycles were possible with this method. The third technique used LS_2 ingots (IPS e.max CAD, Ivoclar Vivadent), also fabricated using CAD/CAM milling and connected with a low-fusion glass-ceramic powder.[15] Both of the latter techniques increase mechanical strength and reduce clinical chipping compared with the conventional veneering technique.[11] They enable a highly efficient and standardized processing chain, which results in reliable all-ceramic fixed dental prostheses (FDPs).[16] However, the digital veneering technique is still limited in its capacity to reproduce the detailed occlusal surface contour and shade of natural teeth.[11]

This article presents an innovative approach to reducing chipping failures without compromising esthetics. This method consists of fabricating a CAD/CAM Zr framework and performing a direct wax-up to obtain an equivalent veneering structure of the crown. After fabrication of the Zr framework and LS_2 veneering, a glass-ceramic powder is used to fuse these two materials permanently. Three different case reports are presented, including two clinical cases of all-ceramic restorations treated with a modification of the sintering technique to perform the restoration of natural teeth and dental implants, and one additional clinical case that shows an alternative technique to repair a Zr restoration, which was veneered with a traditional powder layer technique.

Clinical Report

All patients reported in this manuscript presented to the Department of Prosthodontics at the Ludwig-Maximilians University, Munich, between 2013 and 2014 with teeth and dental implants in need of restoration. The restorative dental team concentrated on the mutual principle of occlusion in fixed prosthodontics: the posterior teeth should protect the anterior teeth in static occlusion, and the anterior teeth should protect the posterior teeth in dynamic occlusion. The occlusal concept included freedom in centric concept in dynamic occlusion for the fabricated FDPs in all presented cases.

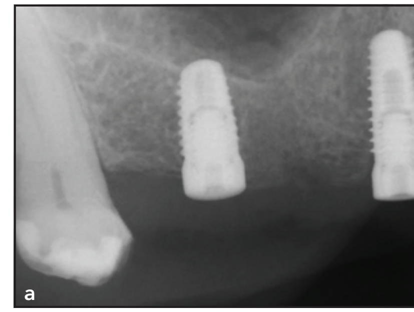
Clinical Case 1: Ceramic Restorations of Implants and Natural Teeth

Two implants (CAMLOG Implant System) were placed in the first premolar and first molar position for a three-unit FDP to replace the second premolar (Fig 1a). Because the patient had high esthetic demands, the treatment plan also included a veneer restoration of the maxillary canine as well as an additional all-ceramic crown for the second molar. The palatal canine veneer (IPS e.max Press, Ivoclar Vivadent) was fabricated to correct canine guidance. For the three-unit FDP and crown frameworks, presintered Zr frameworks were manufactured and veneered with LS_2.

Step 1

A full-arch impression was taken using polyether material (Impregum Penta, 3M), and master casts were fabricated. A wax-up of all prosthe-

Fig 1 *Case 1.* (a) *Preoperative radiograph.* (b) *Occlusal view of canine, try-in of Zr FDP framework and coping of second molar for posterior wax-up, and fabrication of* LS_2 *veneering caps.* (c) LS_2 *palatal veneer of canine, all-ceramic crown of second molar, and FDP over implants, veneered by modified sintering technique, ready to be placed.* (d) *Occlusal view of FDP, palatal veneer and all-ceramic crown after insertion.* (e) *Vestibular view of FDP and all-ceramic crown placed.*



ses was performed and replicated using a silicon matrix (Matrix Form 60 A+B, anaxdent) to register the structural form of the future crowns. Afterward, reduction of the portion referent to the enamel of the natural tooth of the wax-up[16] that corresponded to the veneering space, leaving only the wax corresponding to Zr frameworks, was necessary.

Step 2

The upper cast with the performed wax-up was sent to the milling center (Corona Lava Fräszentrum, Starnberg, Germany) for a digital scan of the wax-up and the master cast. CAD/CAM blocks of presintered Zr (Lava Classic, 3M) were milled (Lava CNC 500 Milling System, 3M), and frameworks were obtained. To achieve a more dentin-like color for an esthetically superior outcome, they were colored with a liquid color pigment (Lava Frame Shading Liquid, 3M) and returned to the dental laboratory. Individual color modifications according to the natural dentin shade were done and fluorescence ceramic powder (In Nova Neo, Creation Willi Geller International) was applied.[17] Afterward, a fit check (Fit Test C&B, Voco)and bite registration of the temporarily cemented framework on the implant abutments and the crown of the

Figs 2a to 2c *Case 2.* (a) *Preoperative radiographic exam.* (b) *Occlusal view of the final preparations.* (c) *Five-unit FDP from canine to second molar veneered by conventional veneering technique and wax-up of first and second molars for* LS_2 *posterior fabrication of veneering.*

second molar were performed in the dental office (Temp Bond, Kerr) (Fig 1b).

Step 3

LS_2 veneering caps were generated, fitting on the Zr framework and corresponding to the esthetic and functional characteristics of natural posterior teeth. The silicon matrix fabricated over the first wax-up was used as a reference for a direct wax-up on the framework. After idealizing the static and dynamic occlusion, the wax was embedded on a muffle (AnaxVEST PM, anaxdent), and glass-ceramic (IPS e.max Press, HT color A2, Ivoclar Vivadent) was pressed for the resulting veneers.

Step 4

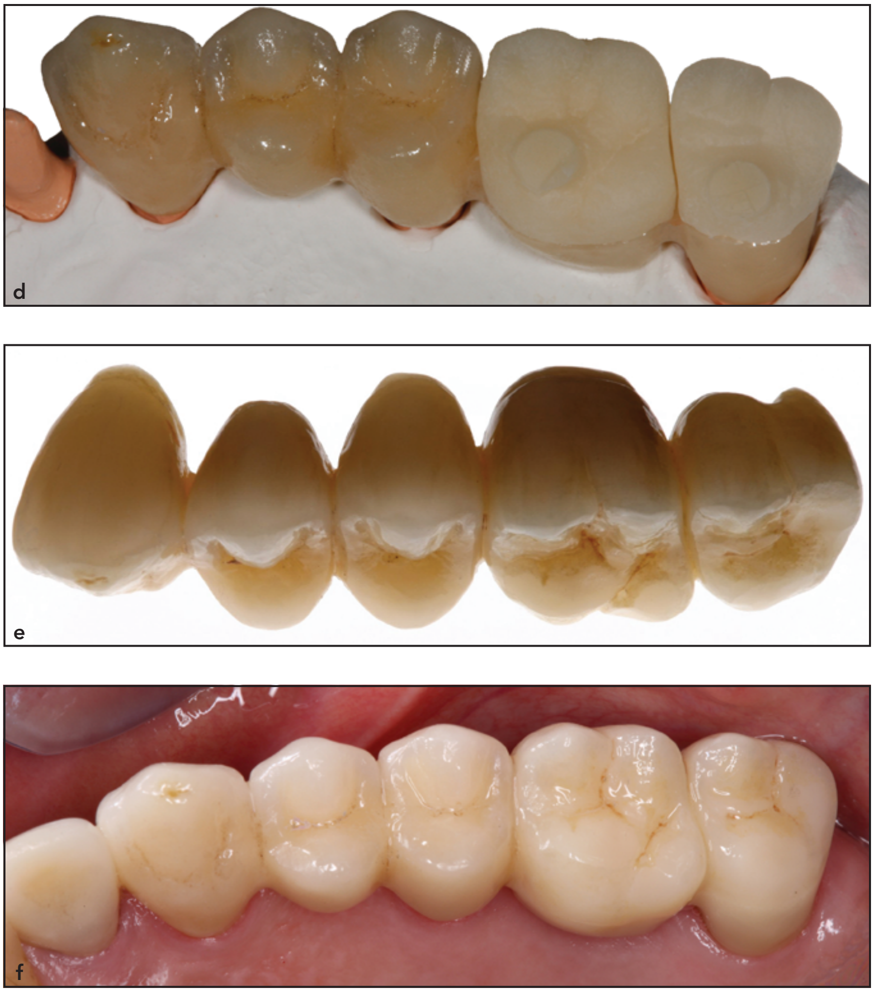
The LS_2 veneering caps were idealized over the Zr frameworks for the adequate adaptation of both components (CAD/CAM framework and LS_2 veneer caps). They were connected using a glass-ceramic powder (DCM hotbond fusion system, Dental Creative Management) and sintered at 770°C with a heating rate of 30°C for 3 minutes in a ceramic furnace (Dekema Austromat, DEKEMA Dental-Keramiköfen). The surfaces of the restorations were characterized using special shades (IPS Shades, Ivoclar Vivadent). Definitive cementation of Zr frameworks on a titanium base was done using resin cement (Multilink HybridAbutment, Ivoclar Vivadent) according to the manufacturer's recommendations (Fig 1c).

Step 5

The implant FDP was inserted with a final torque of 20 Ncm according to the manufacturer's guidelines, and the orifices were sealed using Gutta-Percha (VDW) and Tetric EvoFlow (Ivoclar Vivadent) (Figs 1d and 1e). The single crown of the second molar was bonded after air abrasion (Al_2O_3, 50 µm, 1 bar) of the internal crown surface and application of a coupling agent (Monobond Plus, Ivoclar Vivadent) with Multilink Automix self-curing resin cement (Ivoclar Vivadent). For the reconstruction of canine guidance, the palatal veneer was inserted using resin cement (Variolink II, Ivoclar Vivadent).

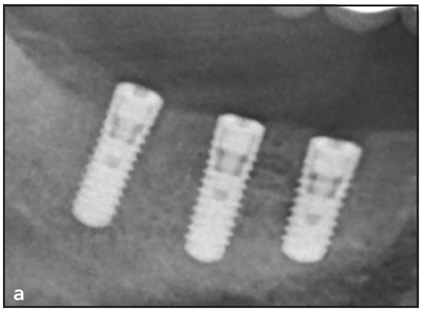
Clinical Case 2: Ceramic Restorations on Natural Teeth

This case combined two different types of Zr veneering within one five-unit-FDP according to the different esthetic and functional requirements of each region, canine/premolar area, and molar area (Fig 2a). A CAD/CAM system was used to fabricate Zr frameworks (Lava Classic, 3M), and two diverse veneer-

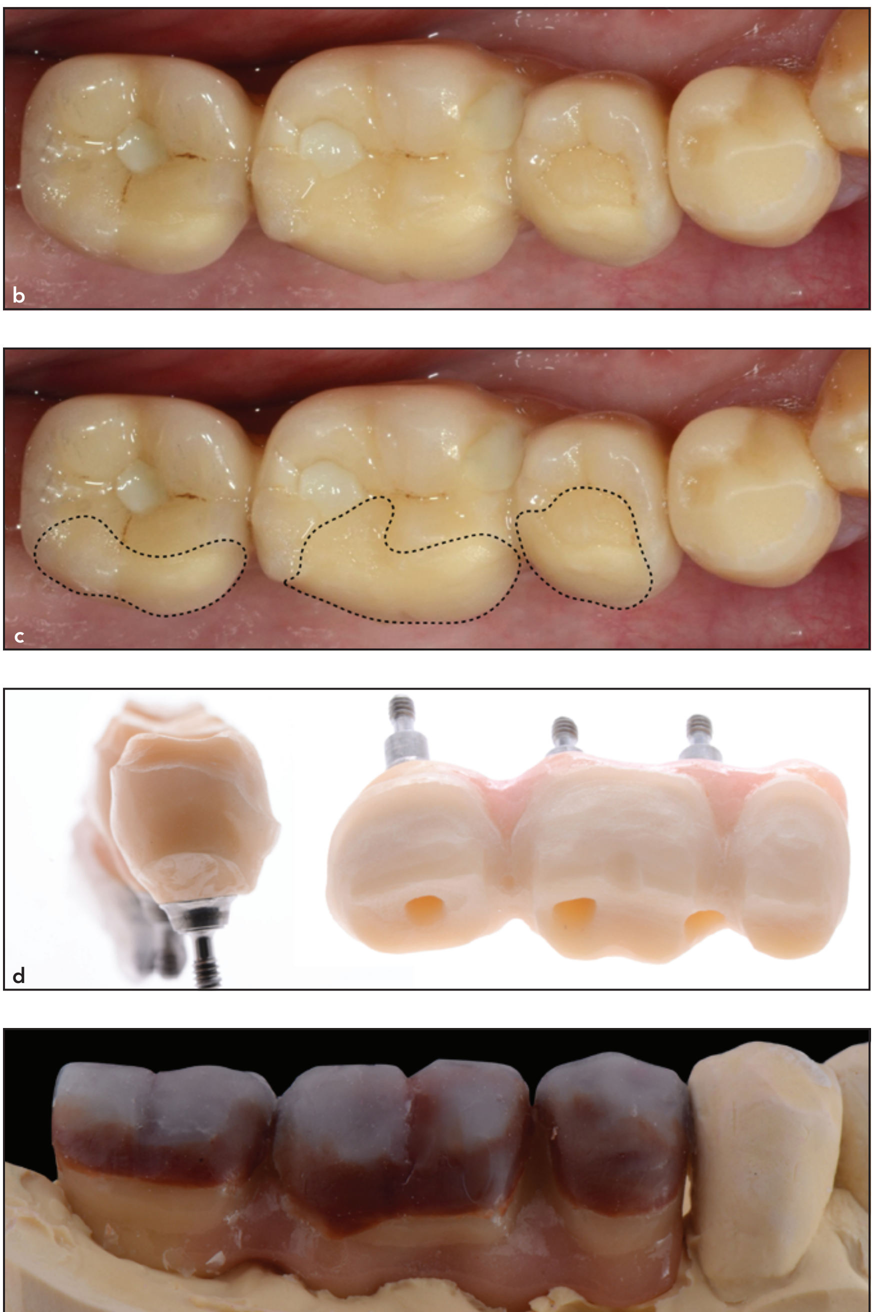


Figs 2d to 2f *Case 2.* (d) *FDP from canine to second molar veneered by conventional veneering technique and veneers of first and second molar before polishing, fabricated by modified sintering technique.* (e) *Final all-ceramic FDP.* (f) *FDP inserted intraorally.*

ing methods were employed. The patient was provided with a three-unit FDP (metal-ceramic) and two splinted crowns, and adequate oral hygiene could be performed due to optimal compliance of the patient. The first molar had to be extracted for endodontic and periodontal reasons. The dental team decided to replace the first premolar and first molar with a five-unit FDP. Segmentation of the FDP was not possible. The patient was trained in hygiene measures (Super Floss, Oral B). Figure 2b shows the final preparation. On the canine and premolars, the conventional powder layering technique was used with high-fusing porcelain (ZI-CT, Creation Willi Geller) to fulfill the highest esthetic demands. Firing was conducted in a calibrated ceramic furnace (Dekema Austromat, DEKEMA Dental-Keramiköfen) at 910°C (Fig 2c). Due to the higher masticatory forces in the posterior region, the restorative team decided to use LS_2 veneering onlays for the molar area. Veneering was performed as described for the previous clinical case with modifications to the sintering technique. A prior fit check before recontouring the LS_2 was necessary (Fig 2d). The glass-ceramic powder (DCM hot-bond fusion system, Dental Creative Management) was used for fusion at 770°C, as presented in Case 1 (Fig 2e). The restorations, including a single Zr crown on the lateral incisor veneered using the powder layering technique, were adhesively cemented using the same procedure and self-curing resin cement (Multilink Automix, Ivoclar Vivadent), as described in Case 1 (Fig 2f).



Figs 3a to 3e *Case 3.* (a) *Preprosthetic radiograph of the implants.* (b) *Chipping of the vestibular veneering material.* (c) *Areas of chipping demarcated on previous all-ceramic FDP.* (d) *1-mm preparation of the Zr framework.* (e) *Wax-up on Zr framework.* (f) *The pressed ceramic IPS e.max veneering caps were fabricated for veneering the Zr framework.*

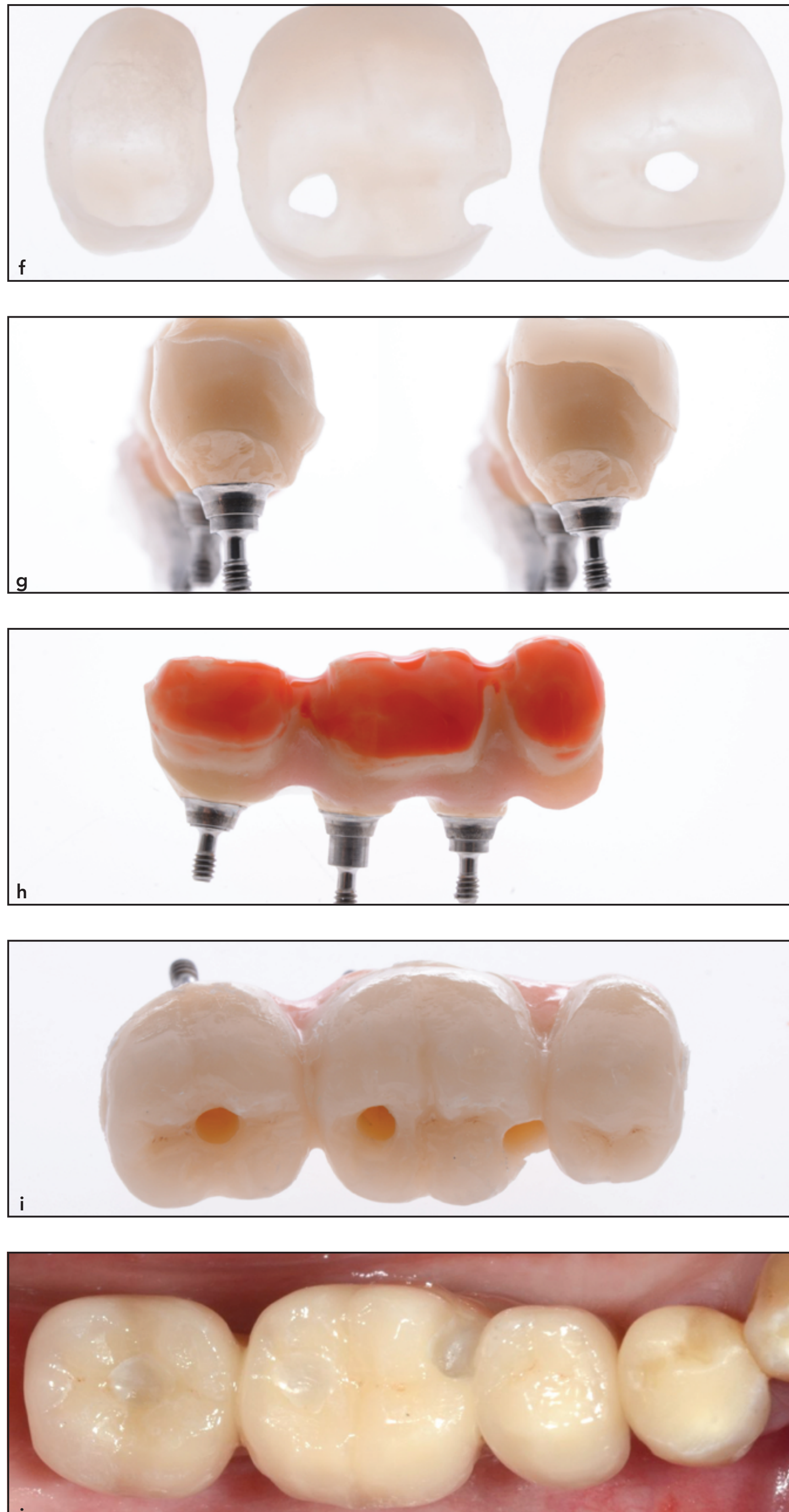


Clinical Case 3: Chipping of All-Ceramic Restorations

This clinical case demonstrates a further application of LS_2 as material for the repair of major chippings in conventional veneering ceramics. Figure 12 shows the three implants (Straumann) placed before the prosthetic rehabilitation. A three-unit implant-supported all-ceramic crown restoration veneered using the conventional powder layer technique presented with major chippings in the veneering ceramic after 2 years of clinical service (Figs 3a and 3b). The option most often used to solve this problem is a total replacement of all affected restorations. The restorative team and the patient decided to solve the extended chipping with reduced time and costs.

Step 1

A pick-up impression of the mandible was taken using polyether impression material (Impregum Penta, 3M) to transfer the restoration onto the master cast. Additionally, an arbitrary facebow record (Axioquick, SAM Präzisionstechnik), a bite registration (GC Bite Compound, GC Europe), and a maxilla impression (Cavex Cream Alginate) were performed. During the laboratory



Figs 3f to 3j *Case 3. (f) The pressed ceramic IPS e.max veneering caps were fabricated for veneering the Zr framework. (g) The try-in of the IPS e.max press veneering caps on the Zr framework. (h) Etching process of the prepared surface of the framework for bonding of the IPS e.max press veneering caps. (i) Final restoration after milling and polishing. (j) Final restoration inserted.*

period, the patient used healing abutments to maintain gingival architecture.

Step 2

The casts were articulated and an analytic-functional idealized wax-up of the chipping areas was created (Fig 3c) and captured with a silicon matrix. A veneer layer of 1-mm depth was prepared to create adequate space and margins for the lost-wax technique (Fig 3d). The wax-up was made again using the previous reference of the silicon matrix (Fig 3e). The following steps were identical to those already described in Case 1.

Step 3

The LS_2 veneer caps were fabricated as described above for all framework parts (Fig 3f). Thermal fusion of the LS_2 veneers on the Zr framework was not possible due to the risk of damage to the remaining implant FDP as well as to the pre-existing hybrid abutments (Zr bonded to titanium base) by the heating process during sintering. Therefore, an adhesive cementation was performed.

Step 4

The LS_2 veneering caps were treated with hydrofluoric acid (IPS Ceramic Etching Gel, < 5%, Ivoclar Vivadent)

(Fig 3g) for 20 seconds and cleaned in an ultrasonic bath with a 96% ethanol solution for 5 minutes. The Zr framework was air-abraded with alumina particles (50 µm, 1 bar) and etched with hydrofluoric acid (90 seconds; IPS Ceramic Etching Gel, < 5%, Ivoclar Vivadent) (Fig 3h) to activate the surfaces of the remaining feldspathic porcelain-veneered areas. Resin cement (Panavia F-2.0, Kuraray) was used in combination with ceramic primer (Kuraray) for adhesive placement. Finally, the restoration margins were polished for an esthetically satisfying final result (Fig 3i). The restorations were fixed onto the implants with a final torque of 35 Ncm (Fig 3j). All screw accesses were closed using Gutta-Percha and flowable resin composite (Tetric Flow, Ivoclar Vivadent) (Fig 3j).

Discussion

The use of Zr stabilized with 3 mol% yttrium (3Y-TZP) for CAD/CAM fabrication is widely indicated in the literature[8,10,11,13,17] for its favorable mechanical properties, adequate clinical function, longevity, and favorable optical properties in comparison with metal restorations.[13] However, there are some limitations to using this material, such as the bond strength between Zr and the veneering porcelain and the possible hydrothermal degradation of Zr, known as aging, when it is exposed to the humid oral cavity.[13] This might lead to discussion of the long-term durability of their mechanical properties.[12] As a result of these limitations, catastrophic failures or chipping of the veneering material seems possible.[13,18] Although failures can occur, the rate of complete failure of frameworks is approximately 10%. Failures are usually related to under-reduced tooth structure and insufficient connector size of the 9-mm^2 framework.[19] Chipping of the porcelain veneers is widely mentioned in studies and is related to the different coefficients of thermal expansion of veneering materials and the extremely low thermal conductivity of the zirconia framework material.[10–13,19] The chipping phenomenon primarily occurs when the conventional veneering technique has been used, justifying the necessity of improving the veneering technique of Zr frameworks.

Studies have already described new methods to improve the mechanical properties of Zr frameworks, such as the digital sintering technique.[11] It has been reported that the use of these techniques may reduce the phenomenon of chipping and enhance mechanical properties.[13] The dental team that was involved in the present case series opted to use the innovative technique of digital sintering. To achieve a favorable reproducibility with ideal shade characterization of the occlusal surface, a modification of the already described[11] sintering technique was used to allow characterization of veneers by a specialized technician. Replacing the CAD/CAM veneer with LS_2 by the traditional hot-pressing technique with the same material resulted in enhanced mechanical properties in comparison with the veneering and overpressing technique. Major complications occurred in the posterior region with high masticatory forces, mainly on the first and second molars,[12] explaining the choice to veneer the canine and premolar using the conventional veneering technique and the first and second molars using the modified sintering technique. A further considerable advantage of this modified technique was that it allowed a possible solution for previous chipping as described in Case 3, leading to a treatment with reduced time and costs.

Other techniques and materials have already been described to produce Zr FDPs without veneering, such as monolithic Zr reconstructions, to avoid the chipping problem. However, this type of Zr presents inferior mechanical properties and is thus not indicated for the posterior region. Moreover, this material commonly develops cracks in the antagonist enamel, mainly in bruxism patients.[20]

Conclusions

For patients with high esthetic demands, this innovative sintering technique combines favorable esthetic results with mechanical strength for use in the posterior region. Nevertheless, clinicians need to be aware of the ideal computerized design and connector size of Zr frameworks, the sensitive technique of fabrication, and adequate marginal adaptation. Special attention is needed during the cementing of these restorations. The present literature considers the use of resin cements to avoid decementation and secondary caries.[15]

Acknowledgments

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