The Metal-Free Approach to Restorative Treatment Planning

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Abstract

Considerable developments in the area of metal-free restorations-in response to increasing esthetic demands from patients-are offering the clinician and dental technician new therapeutic paths to follow when performing restorative treatments. Effective and reliable high-strength ceramic systems, suitable for anterior and posterior sites, may allow the achievement of predictable esthetics and function. Along with the evident indications for the treatment of anterior compromised elements, these types of restorations may be used in a wider variety of clinical cases, including complex prosthetic rehabilitations. Appropriate usage of different materials according to the specific clinical situation is mandatory for long-lasting, functional, and esthetic results. Therefore, a thorough application of metal-free restorations may be considered a "metal-free approach," which includes a specific formulation of treatment planning. In this article, the different materials, selection criteria, clinical indications, and benefits are evaluated, with a particular regard for treatment planning.

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Fig 1 **(a)** The patient requested improved esthetics of the maxillary anterior teeth, which showed inadequate composite restorations. **(b)** The teeth were prepared for all-ceramic crowns and veneers according to the clinical indications. **(c)** The final result is a natural dental appearance and good integration with soft tissues.

Today's patient demands a natural dental appearance with good esthetics in both the anterior and posterior regions. This request contributed to the considerable technological evolution of dental materials toward several types of *metal-free restorations* (Fig 1), a term routinely used in dentistry to indicate the lack of the traditionally used gold alloy. These innovations, in conjunction with the definition of new clinical procedures, largely increased the therapeutic arsenal available to the clinician.

In fact, the development of various all-ceramic systems[1–3] and computer-aided design/computer-assistant manufacture (CAD/CAM) procedures[4–9] for the fabrication of tooth-colored frameworks, the improvement of adhesion and cementation techniques,[10,11] the introduction of postendodontic metal-free reconstruction methods,[12,13] and the simplification of the implant systems associated with an enrichment of the prosthetic components brought a dramatic evolution in treatment planning.

It has been demonstrated that the use of some types of all-ceramic crowns may be effective in anterior and posterior sites.[14–16] Furthermore, the introduction of zirconia[17–19] represents a step forward in the development of restorations with a tooth-colored core for the realization of fixed partial dentures in areas under high mechanical stress.

Today, the clinician may obtain function, esthetics, and precision in various clinical situations with a more predictable and conservative approach.

The concepts and the suggestions presented in this paper are the result of 7 years of clinical experience in two private dental practices and a dental laboratory using metal-free restorations in complex prosthetic cases based on scientific evidence.

The aim of this work is to provide clinicians with the basic elements needed to use different types of metal-free restorations according to specific clinical indications.

Classification of metal-free ceramic restorations

In order to define a simple classification, the different types of metal-free ceramic restorations may be grouped into two main categories, based on whether or not they are supported by ceramic cores. Those without ceramic cores may be further divided into feldspathic porcelain restorations and heat-pressed glass-ceramic restorations. Restorations that are supported by ceramic cores may be lithium disilicate–, alumina-, or zirconia-based.

Metal-free restorations without ceramic cores

Feldspathic porcelain

Feldspathic porcelain is primarily made of common potash feldspar and potassium alumina silicate. This material presents a flexural strength of approximately 50 to 85 MPa. To compensate for its fragility, it is normally fused to a metal substrate to increase fracture resistance. As a metal-free material, feldspathic porcelain may be used for manufacturing fired ceramic veneers.[20]

Heat-pressed ceramic

In this process, pre-sintered glass ceramic ingots are heated and pressed into a refractory mold using the lost-wax technique. The crystals, incorporated through the injection molding process, counteract the tensile stress that leads to the formation of microcracks. The physical characteristics are related to the dimension and density of the crystals and their interaction with the matrix. For example, leucite crystals with 40% to 50% density bring the flexural strength of the ceramic material to about 110 to 150 Mpa. Translucency, the most relevant property of heat-pressed glass-ceramic, is comparable to that of feldspathic porcelain.[21]

Metal-free restorations with ceramic cores

Lithium disilicate

This type of heat-pressed glass ceramic presents a crystalline phase made by lithium disilicate and lithium orthophosphate, allowing an increase of resistance without negatively influencing the translucency. The flexural strength is approximately 350 to 400 Mpa. This material is used to fabricate high-strength cores for porcelain support.[22]

Alumina

Alumina-based ceramics may consist of a partially sintered porous alumina structure infiltrated by molten glass,[23] or of a highly purified alumina fabricated with a CAD/CAM technique. In this case, the original master die is read by a scanner device, which transmits this shape to a milling machine. Subsequent to CAM, the core is densely sintered and veneered with dental porcelain. The aluminum content of the coping is 99.9%, and flexural strength in-

creases up to 600 to 700 MPa. The translucency is significantly lower than for glass-ceramics.[24]

Zirconia

The authors include zirconia among the metal-free restorations, although it is classified in the periodic table of elements as a metal. In dentistry, it is used as yttrium-stabilized zirconia dioxide. The flexural strength is 900 to 1200 Mpa, and the resistance to fracture is two times higher than alumina. Fabrication of the infrastructure for crowns and fixed partial dentures may be obtained using either CAM of partially sintered zirconia blanks or direct milling of a fully sintered yttria tetragonal zirconium oxide polycrystal (Y-TZP) blank. In the first case, the size of pre-sintered structures is increased to compensate for the 20% to 25% shrinkage after final sintering. Zirconia, like alumina, is not translucent and cannot be etched.[25,26].

Indications

Feldspathic and heat-pressed glass ceramics

As a result of their translucency, feldspathic and heat-pressed glass ceramics represent the gold standard when making veneers or crowns for the anterior region in the presence of extremely conservative

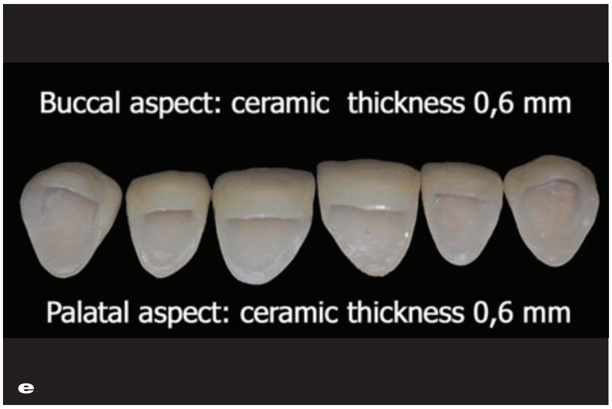

Fig 2 The compromised enamel was restored using etchable ceramic restorations cemented with an adhesive technique on very conservative preparations. Note the esthetically unacceptable resin composite restorations **(a)** and the loss of tooth structure palatally with a "cupping" aspect on the maxillary anterior elements **(b)**. Tooth reduction was very conservative, approximately 0.6 mm **(c to e)**, to guarantee full support for the ceramic restoration. This approach allowed for recreation of natural esthetics and function, protected the remaining tooth structure from further erosion, and maintained pulp vitality **(f and g)**.

tooth preparations to guarantee complete support for the material (Fig 2). These ceramics can also be used for the manufacture of inlays and onlays.

Nevertheless, the use of heat-pressed glass-ceramics in esthetic cases allows for adjustment of the shade and shape of the restoration directly in the patient's mouth, thus favoring the achievement of a predictable result. Furthermore, the patient may visualize the final appearance and help the dental technician satisfy his or her expectations. This option is not feasible with feldspathic ceramics, since the shape and color of the veneer cannot be modified after the firing process without risking a distortion.

Metal-free restorations with ceramic cores

Lithium disilicate–based ceramics are the most translucent of the core ceramics and allow the creation of highly esthetic veneers and full crowns in the presence of more invasive tooth preparation that may not support a glass-ceramic. Furthermore, they are suited to the manufacture of single posterior crowns and three-unit fixed partial dentures up to the first premolar, after a careful evaluation of the necessary space for the connectors.[27] The ability to etch the core with hydrofluoric acid allows an adhesive cementation on poorly retentive preparations in both the anterior and posterior regions (Fig 3).

Fig 3 The severe destruction of the maxillary anterior teeth **(a)** was solved using crowns reinforced by a lithium disilicate core **(b to d)**, because the deep preparations would not support a glass-ceramic. Note the extensive tooth reduction compared to that necessary for heat-pressed glass-ceramic restorations **(see Fig 2c)**. The incisors were built up to obtain natural abutments with optical characteristics comparable to a natural tooth. The adhesive cementation avoided the need for a surgical crown-lengthening procedure to obtain a good esthetic result.

Alumina was the first material routinely used to create high-strength ceramic crowns. Alumina shows intermediate optical characteristics between lithium disilicate and zirconia. This polycrystalline material cannot be etched because of the lack of glass in its content. Clinical situations where the use of alumina is indicated can now be treated with zirconia, which has superior strength.

Because of its high mechanical resistance, zirconia is suited to create single crowns and fixed partial dentures with the same indications as porcelain-fused-to-metal restorations. As a result of its masking ability, this core material is the first choice to treat nonvital discolored teeth in anterior and posterior sites. Zirconia cannot be etched because of its polycrystalline structure. Nevertheless, airborne-particle abrasion of the internal surface of a zirconia framework along with the use of a resin cement provides the best results in terms of retention (Fig 4).[28]

To further simplify the dental practitioner's choices when selecting the specific type of material, it should be noted that heat-pressed glass ceramics, lithium disilicate glass ceramics, and zirconia-based ceramics allow for treatment of the majority of clinical situations where a metal-free approach is indicated in a predictable way (Table 1).

Fig 4 In periodontal cases, the conventional gold alloy may be substituted with zirconia for the fabrication of frameworks. **(a and b)** The initial situation was a failing fixed full-arch denture. **(c and d)** The patient underwent periodontal surgery to achieve healthy tissue. Discoloration of all prepared teeth was evident. **(e to h)** Zirconia frameworks masked the dark abutments and created an esthetic soft tissue appearance. Zirconia restorations were manufactured on knife-edge preparations. The final outcome showed acceptable esthetics.

g

h

Table 1 Materials acceptable for use with different types of metal-free restorations

X = possible; - = impossible. Au: Correct?

Type of restoration	Heat-pressed glass-ceramic	Lithium disilicate	Zirconia
Inlays/onlays	X	X	-
Veneers	X	X	-
Anterior crowns	X	X	X
Posterior crowns	-	X	X
Three-unit anterior fixed partial dentures	-	X	X
≥ Three-unit anterior and posterior fixed partial dentures	-	-	X

Treatment planning

Regardless of the selected materials, defining a proper treatment plan is the key to successful dental therapy. In the metal-free approach, some phases of the treatment plan should be conceived considering the new prosthetic options. The treatment steps may be summarized as follows:

Initial hygiene phase

Patient compliance and periodontal infection must be controlled throughout treatment, whatever material is chosen. When using metal-free restorations, one complication caused by bleeding and sulcular inflammatory exudate as a consequence of gingivitis or periodontitis is limitation of the proper moisture control necessary for optimal adhesive cementation procedures.

Data collection

Study casts, photographic documentation, radiographic examination, and diagnostic waxup of the initial situation and are the first steps for correct definition of the treatment plan.

Conservative and endodontic therapies

The current adhesive techniques in conjunction with the use of metal-free intracanal posts should be used when necessary to restore both vital and nonvital teeth, in order to obtain natural abutments with chromatic and optical characteristics comparable to a natural tooth.

Provisional phase

Provisional restorations maintained for an adequate period of time allow for a proper evaluation of function and esthetics. Establishment of occlusal stability and correct guidance in eccentric movements is fundamental during this phase. Signs of abrasion or fractures of the provisional restoration, as well as parafunctional habits still detectable at the completion of the provisional stage, should be carefully considered before selecting the final prosthetic material.

Periodontal surgery

In periodontal cases, surgical procedures may be performed for pocket elimination or correction of intrabony and mucogingival defects. In healthy patients, the need to apically reposition the flaps for clinical crown lengthening may be avoided in cases where an adhesive cementation procedure may compensate for scarcely retentive prepared teeth.

Implant therapy

Implants should be inserted into edentulous areas to reduce the length of tooth-supported fixed partial dentures. Furthermore, zirconia implant abutments may be used when indicated. These two options increase the number of sites suitable for metal-free crowns and fixed partial dentures.

Final prosthetic rehabilitation

The different types of metal-free restorations should be selected based on the specific clinical indications to fully take advantage of each material.

Benefits of the metal-free approach

Taking these steps into consideration, the reconstructive treatment plan can be defined for the metal-free approach, the benefits of which may be divided into three categories: biological preservation, esthetics, and practical aspects.

Biological preservation

Preservation of structural integrity.

In both the vital and nonvital tooth, the various adhesive restorative solutions alternative to conventional complete crowns, such as ceramic onlays and partial crowns, may facilitate greater preservation of residual tooth hard tissues.[29,30]

Maintenance of pulp vitality.

The use of adhesive buildups in conjunction with the possibility to create adhesion between the ceramic restoration and the tooth preparation may decrease the need for intracanal anchorage and a consequent endodontic therapy.[31] A clinical example is the substitution of the compromised enamel, often caused by erosive processes, by using etchable ceramic restorations cemented with an adhesive technique on very conservative preparations (see Fig 2).

Dental erosive processes related to pathologies in developed countries, such as some eating disorders like bulimia and anorexia, or caused by excessive consumption of acidic beverages,[32] are diagnosed and treated with increasing frequency in dental practices. It seems appropriate, especially in advanced cases often detected in young patients, to implement a treatment plan focused on biological preservation in terms of maintenance of pulp vitality and periodontal support integrity.

Preservation of periodontal support.

The ability of some ceramic materials to bind via chemical and micromechanical mechanisms to the prepared dental elements with the interposition of resin cements[33,34] results in sufficient retention even on scarcely retentive preparations, thus limiting, in some cases, the necessity of surgical crown lengthening[35] (see Fig 3).

Maintenance of periodontal health.

Prosthetic margins of metal-free restorations may be allocated coronally or at the gingival margin level, thus obtaining strong esthetic results without resorting to invasive [Au: OK?] technical procedures such as ceramic shoulders. This option may decrease the risk of inducing a periodontal pathology in susceptible patients by invading the intrasulcular compartment.[36,37] Furthermore, oral hygiene maintenance is made easier for the patient. Treatment of periodontal cases using a metal-free approach may be considered favorable in terms of plaque control and stability of the periodontal attachment over time (Fig 5).

Esthetics

Biological preservation of intact and vital oral structures is a primary focus of the metal-free approach, but achievement of a natural and esthetic appearance is of equal importance. The use of heat-pressed glass ceramics and restorations with ceramic cores makes it easier for the clinician and technician to meet the esthetic expectations of the patients, who are increasingly asking for perfect smiles, partly as a result of media influence.

Moreover, these types of restorations make the achievement of “pink esthetics” more predictable[38–41]: the decreasing necessity to sink prosthetic margins in the intrasulcular compartment contributes to the reduction of incoming signs of gingivitis in predisposed patients, and the underlying tooth-colored framework is compatible with a good esthetic level of the adjacent

Fig 5 The maxillary fixed partial denture showed severe periodontal problems with unacceptable function and esthetics **(a and b)**. Elements at the central incisors and the left first premolar sites were extracted **(c)**. Maintained teeth were endodontically treated and restored, and periodontal surgery was performed **(c to e)**. Teeth from the right canine to the left second premolar were splinted with an eight-unit zirconia framework to compensate for the reduction of periodontal support **(f to h)**. Maintenance of the healthy periodontal condition obtained via surgery will not be compromised by the new prosthetic restoration, with the borders positioned at the level of the gingival margin **(i to k)**.

soft tissues (see Fig 5). Healthy gingiva is essential to a natural and esthetic dental appearance. An exception to the extrasulcular allocation of the prosthetic margins occurs in the treatment of discolored teeth. A bleaching procedure or a sub-opaquing technique should always be evaluated before performing the final prosthetic restoration. In the presence of adequate gingival thickness, zirconia crowns should be sunk

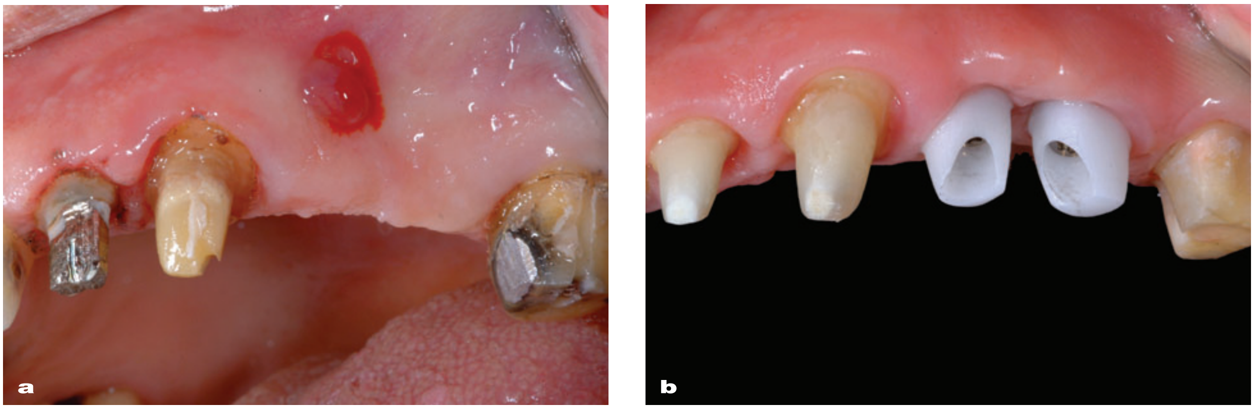

Fig 6 **(a)** The use of implants permits reduction of the length of tooth-supported fixed partial dentures when no additional elements need splinting, such as in advanced periodontal cases. **(b)** Along with natural teeth supporting a pre-existing porcelain-fused-to-metal fixed partial denture, two implants were inserted, creating all single elements. **(c)** Adhesive buildup of the right lateral incisor, canine, and first molar and the use of zirconia implant components allowed the fabrication of single metal-free restorations with ceramic cores on both natural teeth and implants.

intrasulcularly approximately 0.5 to 0.7 mm to obtain a good esthetic result (see Fig 4). Nevertheless, thin gingival tissue associated with a dark natural abutment may only allow for partial success, since the final esthetic result may be compromised by the tissue transparency even when using masking core materials such as zirconia.

Practical aspects

Another advantage of the metal-free approach is its practical and ergonomic aspects.

Prosthetic margins placed at the gingival level are easier to prepare, facilitate the detection of proper final impressions, and, consequently, offer a high degree of precision.

The use of implants allows the clinician to reduce the length of tooth-supported fixed partial dentures. The new prosthetic implant components can be made entirely from zirconia to support restorations with ceramic cores on implants (Fig 6). In cases where there is a therapeutic necessity to splint more elements, such as in advanced periodontal cases or in the full-arch implant treatment, traditional metal-alloy frameworks may be replaced with zirconia structures to simplify the achievement of the final esthetic result.

Preparation procedures

The basic preparation requirements for a metal-free restoration do not differ from those necessary for a traditional porcelain-fused-to-metal restoration, and include precision, good margin definition, and the elimination of sharp edges.

The ideal finishing line should be horizontal with a chamfer or a rounded shoulder ranging in depth from 0.5 to 1.2 mm, according to the chosen material. The occlusal and axial reduction for ceramic cores should be at least 1.5 mm.

Although a horizontal finishing line is generally recommended, in the authors' professional experience, the clinical performance of ceramic core–reinforced restorations with vertical finishing lines seems to be positive. Prospective controlled clinical studies are needed to assess the influence of horizontal and vertical finishing lines on the long-term success of metal-free restorations with ceramic cores.

Preparations for heat-pressed glass-ceramic restorations should guarantee full support of the material because of the lack of a core. The clinician should provide a uniform space of about 0.6 mm axially and 1.2 to 1.6 mm occlusally. The recommended finishing line is horizontal with moderate chamfers or rounded shoulders.

The types of preparations to be used with different restoration materials are summarized in Table 2.

Cementation procedures

The cementation procedure is related to the type of ceramic material. Feldspathic, heat-pressed glass ceramics, and lithium disilicate cores can be etched and bonded to the tooth structure, while polycrystalline core materials, ie, alumina and zirconia, cannot be etched because of the lack of glass content in their composition.

The use of an adhesive technique is strongly recommended for all types of glass ceramics, including the lithium disilicate core material, because it increases not only the retention, but also the survival rates.[42]

Feldspathic, heat-pressed glass-ceramic, and lithium disilicate restorations should be etched with hydrofluoric acid and subsequently silanized to increase covalent bond formation at the ceramic-resin interface and improve the wetting of the ceramic surface by the resin cement.[43,44] Simultaneously, the tooth surface is treated with a conventional adhesive procedure consisting of etching, priming, and application of a resin bonding agent. Finally, the resin cement is applied. Resin cements represent the ideal choice for all types of metal-free restorations, including non-etchable core materials, because of their ability to bond to different substrates, insolubility in the oral cavity, high mechanical resistance, and availability in various dentinal shades.[45–47]

Table 2 Type of preparation to be used in relation to restoration material
X = possible; XX = recommended; - = impossible. Au: Correct?

Finishing line	Heat-pressed glass-ceramic	Lithium disilicate	Zirconia
Vertical	-	X	X
Hortizontal	XX	XX	XX

Dual resin cement covers most of the clinical indications. Light-curing luting agents are appropriate for cementing veneers because of their high transparency. Self-curing cements may be used for less translucent restoration materials such as alumina and zirconia. Even in cases with low light transmission from an operative standpoint, the clinical handling of dual cements may be more practical.

Conclusions

Based on the indications, clinical implications, and procedures of the metal-free approach, the following conclusions may be drawn:

- Veneers and full crowns used for the substitution of enamel may be manufactured using either feldspathic ceramics or heat-pressed glass ceramics. The use of the heat-pressed glass ceramic may be easier and more practical.
- Single anterior crowns, where the residual tooth substance requires a supporting core for the ceramic material, may be best created using a lithium disilicate core in the presence of a nondiscolored tooth. A zirconia core ceramic should be chosen to treat nonvital discolored teeth because of its masking capacity.
- Posterior single crowns may be fabricated using either a lithium disilicate core or a zirconia core. Lithium disilicate is the first choice when an adhesive cementation procedure is required to compensate for poor retention. Zirconia is the first choice for discolored teeth or in the presence of metal posts that cannot be removed.
- Fixed partial dentures with no more than two pontic elements should be fabricated using a zirconia substructure. In cases with more than two pontic elements, implant therapy should be considered.
- Clinical situations in which the use of alumina was once indicated can today be treated using zirconia core ceramics.

The literature presents a limited amount of scientific controlled studies that analyze success rates, complications, and variables related to the clinical use of new types of high-strength ceramics.48–59 More controlled clinical studies are needed to support the clinical application of the metal-free approach.

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