Additive Contour of Porcelain Veneers: A Key Element in Enamel Preservation, Adhesion, and Esthetics for Aging Dentition

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Esthetics and function are equal concerns when restoring the anterior dentition. Modern concepts in restorative dentistry have brought new solutions through bonded porcelain veneers that are stress distributors and involve the crown of the tooth as a whole in supporting occlusal force and masticatory function. This recovery of the original biomechanics of the intact tooth, the biomimetic principle, is particularly valuable when considering the restoration of an aging dentition. Both function and appearance are affected by the senescent changes of the aging teeth. Erosion and surface wear lead to a progressive thinning of enamel, ultimately leading to increased crown flexibility and higher surface strains. It appears therefore that the restoration of tooth volume will not only re-establish the original and youthful appearance of the smile but will also allow the biomimetic recovery of the crown. The final treatment outcome strongly depends on the therapeutic approach chosen, the driving force of which should be the preservation of the thin remaining enamel. While a number of preparation techniques will expose dentin to a great extent, the principle of enamel preservation can still be fulfilled by the use of a specific approach. This article describes a treatment method which includes the use of a diagnostic template. This type of work strategy, documented with clinical cases, integrates additive wax-ups and acrylic mock-ups. The latter will provide a significant amount of diagnostic information and economy of tooth substrate, the importance of which cannot be overestimated in the completion, functionality, and longevity of the final restoration.

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Numerous clinical studies[7,8,10,12,13,23,26,28,29,33,34] have revealed the good clinical performance of porcelain laminate veneers (PVs). Based on these promising evaluations and motivated by the principle of tooth preservation, a new range of indications for PVs has been defined,[4,19] including cases of crown-fractured incisors[1,2] and worn down anterior dentitions.[36,37] PVs permit, above all, avoidance of the use of a conventional type of fixed prosthetic restoration and maintenance of tooth vitality in spite of a severe breakdown of tooth structure. Such enhanced applications of PVs have marked a turning point in restorative dentistry, generating considerable improvements involving both the biological aspect (ie, economy of sound tissues) and the socio-economical requirements (ie, decrease of costs when compared to traditional and more invasive prosthetic treatments). At the other end of this spectrum, more cosmetic indications for PVs have emerged as a result of patients' growing esthetic expectations (Figs 1a and 1b). Even though it does not constitute a primary objective in dental medicine, oral esthetics requires special consideration. Modification of form, position, and color of anterior teeth generate significant effects on the smile,

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Figs 1a and 1b Typical case of prematurely aged dentition. Tooth volume is lost mainly on teeth 11 and 21; the main request of the patient is for restoration of the prominence of these two teeth (1a). The left central incisor is nonvital and discolored. Internal bleaching of the latter was followed by a customized diagnostic approach (acrylic mock-up) and the completion of two porcelain veneers aiming to recover the original volume of the teeth (1b). A rational procedure allowed the preservation of the initial thin enamel (see Figs 7a to 7f, same patient).

Fig 2 Naturally aged dentition. The reduced thickness of enamel is first revealed by the abnormally saturated shade (thin enamel being more translucent, and the dentin underneath more perceptible). Numerous crack lines stand as a possible consequence of the cyclic strains experienced by the thinned enamel over the years.

which in turn contributes to the personality and the functional social life of the patient. Balanced anterior tooth prominence is a strategic element of the smile, which can be lost during aging, thus generating new challenges for the restorative dentist.[24] Both enamel surface wear and color changes can be responsible for this degenerative phenomenon. The great interest in vital bleaching is just one example of the driving force to rejuvenate tooth appearance, which has given esthetic dentistry an important place in the range of dental services offered to the public.

BIOMIMETIC INTEGRATION OF PORCELAIN VENEERS

The color and cosmetic problems related to tooth aging, however, should not be the only concerns of the restorative dentist.[9] It may be argued that the recovery of the original biomechanics of the intact crown, the biomimetic principle, is an important criterion of successful restorative dentistry. The increased crown flexibility following loss of palatolabial dimension in worn teeth can be associated with functional and mechanical problems. It was demonstrated that a sufficient and uniform thickness of enamel is essential to the balance of functional stresses in the anterior dentition.[22] Thin, aged enamel can generate high strain concentrations during function. Surface cracks typically found on aged teeth are the consequence of this problem (Fig 2). Enamel thickness recovery therefore can be regarded as a combined esthetic and biomechanical endeavor. Composite resins have not proven able to replace enamel and restore the original tooth stiffness.[30] In a recent in vitro investigation, PVs were shown to effect a "biomimetic" recovery of the tooth mechanics, even when bonded to extensive dentin surfaces.[16] On the other hand, composite resin veneers often present signs of early fatigue[35] (chipping-type fractures), marginal microleakage,[14] and poor acceptance by the patients in comparison to PVs.[23] Freehand application of composite resins, however, remains particularly useful in the young patient as interim restorations prior to the final PVs. In specific cases where the entire smile line of the patient is involved, the difficulty of simultaneously mastering general form and length of the teeth involved must be added to the shortcomings of direct composites mentioned above. Consequently, PVs may be proposed as yielding a more predictable result, providing that the moderate sacrifice of sound tooth structure and the costs involved in the technique are explained to and accepted by the patient.

DEVELOPMENT OF RATIONAL DIAGNOSTIC TOOLS AND PROCEDURES FOR PORCELAIN VENEERS

In most cases of esthetic rehabilitation, the treatment objective must be reached with the help of a diagnostic tool.[20] The latter can consist of a two-step approach: first, the development of a diagnostic wax-up and, second, the fabrication of a corresponding template to be evaluated in vivo by the patient. In the case of PVs, a customized approach had to be developed. The aim of the present article is to present simple but essential tools: the additive diagnostic wax-up and the acrylic mock-up, the use of which is indicated during diagnostic steps and tooth preparation procedures for the optimal restoration of the aging dentition using PVs. Two elements must be emphasized: *(1)* the objectivity and the simplicity of the approach and *(2)* the significant amount of diagnostic information and preservation of tooth substrate invaluable to the completion, function, and longevity of the final restoration.

ADDITIVE DIAGNOSTIC WAX-UP: INSTRUMENT FOR ENAMEL PRESERVATION

General Considerations

Enamel constitutes perhaps the most highly specialized tissue in the body. It has been extremely valuable to the clinician since 1955, when Buonocore showed it to be an essential substrate for bonding.[6] Today, the value of enamel bonding is witnessed by the predictable long-term clinical success of PVs.[10,28,34] Enamel is a brittle structure, the integrity of which is dependent on the crack-arresting effect of the thick, longitudinally oriented collagen fibers of the dentin-enamel junction[15] (DEJ). Therefore, the optimal preservation of both enamel and the DEJ must be consciously promoted by the appropriate tooth preparation technique.

When the initial enamel is thin, as is the case with aged or worn incisors, preparation methods using the preexisting tooth surface as a reference

for enamel reduction are absolutely contraindicated. So is the "simplified laminate preparation" associated with specific cutting tools to avoid freehand preparation.[11] In the proposed procedure, a uniform tooth reduction of at least 0.5 mm is realized using diamond burs with calibrated rings. Another classical preparation method, using the preexisting tooth surface as a guide, consists in taking silicon indices of the labial surface of the unprepared tooth. Significant dentin exposures are expected using such a freehand procedure on intact central incisors as demonstrated by Nattress et al.[25] The situation is most critical when treating aging dentitions with thin initial enamel; it can be anticipated that the use of the above-mentioned tooth reduction methods may lead to extensive exposure of dentin.

Accordingly, a first and key element for enamel preservation during tooth preparation is the definition of the final tooth volume. Specifically, when a significant thickness of enamel is initially missing because of a history of wear or erosion, the future restoration should aim to recover the original volume of the tooth. This, as noted above, will then restore an adequate tooth prominence and biomimetic behavior of the crown.[16] Above all, it will allow significant preservation of enamel substrate and the supporting DEJ during tooth preparation. Therefore, a silicon index of an additive wax-up constitutes the essential tool used as a reference for tooth reduction (see details in section on "Predictable tooth preparation").

Essentials for the Additive Wax-up

In this first stage of the diagnostic approach, intuition, sensitivity, and a good perception of the patient's individual character should allow the dental technician to define a preliminary prosthetic goal. As previously described, for the aging dentition, this is mostly obtained by the application of wax to the preliminary model. This procedure requires precise knowledge of the critical elements of tooth anatomy. An essential learning step results from the systematic observation of natural teeth. The use of stone replicas covered by metallic contrast powder is very useful in comprehending the anatomy of the intact facial tooth surface (Fig 3). The landmarks of different basic shapes are defined by the vertical proximal crests. They represent fundamental transition lines between the facial and proximal surfaces. Because of their prominence, these ridges are the first element to wear off and therefore are the first element that should be recovered by the addition of wax to the preliminary model (Figs 4c and 4d). The position and arrangement of these lobes will be a determinant for the definition of tooth form. A secondary step of the wax-up procedure consists in recreating the superficial vertical lobes and horizontal developmental lines that define the secondary and tertiary enamel surface topography.

ACRYLIC MOCK-UP: INSTRUMENT FOR DIAGNOSIS AND PREDICTABILITY

A predictable outcome of the treatment is essential when planning an important esthetic rehabilitation.[20] The basis of the prescribed treatment is determined by the diagnostic analysis. Nevertheless, the latter should remain a simple and rational procedure. If subtle changes are being considered, it is advisable to communicate these to the patient using mostly visual devices in order to avoid even the slightest misunderstanding.

At this stage of the diagnostic approach, the additive tooth volume must be approved by the patient, resulting in total agreement on the definition of tooth shape, size, and length. In traditional prosthodontics (full crown coverage), preliminary tooth preparation usually precedes the completion of the diagnostic template which is represented by the temporary restoration itself.[18,20,31,32] Such treatment planning is not possible with PVs. Because of the reduced thickness of the laminate and the intrinsically conservative approach, the final volume of the restoration plays a decisive role in the determination of the tooth preparation itself. The in vivo evaluation and full approval of the template by the patient should, therefore, precede tooth preparation procedures.

The simplest method consists of fabricating an acrylic template directly in the patient's mouth or onto an intact study cast using self-curing resin molded on the unprepared tooth surfaces with a silicon matrix of the wax-up (Figs 4a to 4k). Subsequently, the patient him- or herself can easily examine this removable mask. A common situation must be pointed out: when looking at the template for the first time, the patient will usually complain about the excessive tooth volume. This reaction is normal and understandable, since the process of wear and erosion is slow and extends over years

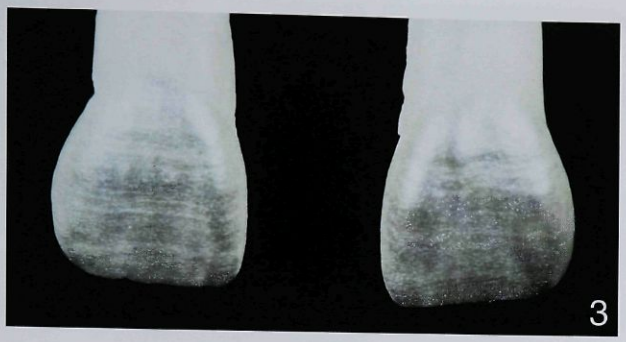


Fig 3 Intact teeth, details of the facial morphology. These stone replicas were coated with a metallic contrast powder to highlight anatomic and surface texture characteristics. The proximal crests are very prominent, specifically on the mesial aspect.

Figs 4a to 4k Diagnostic procedures. This South American patient presents an open gold crown on the right lateral incisor and an old resin crown on the left central incisor (4a). After removal of the latter, a preliminary impression was taken (4b), followed by the realization of a direct temporary acrylic on tooth 21 (removal of the open crown did not require temporization). Two porcelain veneers were planned for teeth 11 and 12, and a porcelain-fused-to-metal for tooth 21. The detail of the initial situation reveals the loss of enamel on the right central incisor (4c). The new volume of the tooth was carefully designed by the wax-up including superficial lobes and proximal ridges (4d). The final treatment objective is first defined on the model (4e), then tested in vivo by the fabrication of a mock-up: a silicon index of the wax-up is filled with liquid resin (4f) and pressed on unprepared teeth. A thick layer of Vaseline must be previously applied to the teeth to avoid adhesion between the acrylic mock-up and eventual preexisting resin restorations (4g). The silicon matrix is maintained in position until complete curing of the resin (the mock-up is usually thin and would be deformed by premature removal), the operatory field being cooled with abundant rinsing (4h). The resin template can be easily unlocked and removed by inserting a scaler at the proximal surface (4i). The final acrylic mock-up is left to the patient for prolonged trial of several days (4j) and eventually bonded by enamel spot etching. Based on the patient's accurate input at the end of the trial, minor modifications can be integrated to the final restorations (4k). Details of tooth preparation procedures are presented in Figs 8a to 8f.

Figs 4a to 4k continued.

Small changes in tooth length and shape take place progressively, without generating sudden modification in the patient's smile. This long degenerative process, however, is now counteracted by an instant restorative procedure (the mock-up itself) involving major changes in the smile design. The patient must therefore be prepared and informed; an objective esthetic evaluation requires a prolonged clinical trial of several days. Accordingly, the unchanged mock-up is left to the patient for assess-

Figs 5a to 5c Typical evaluation of a mock-up. Note the large preexisting Class IV composite restorations on the central incisors of this young female. Despite the harmonious relationship between the lower lip and the incisal line, the patient, who did not request longer teeth, did not initially approve the acrylic mock-up (5b). After several days of trial, the patient felt comfortable and gave total consent for the fabrication of the corresponding final veneers (5c).

ment for one week. The template can be temporarily bonded by enamel spot etching if necessary. At the next appointment, the patient often feels more comfortable and discusses eventual changes with more objectivity (Figs 5a to 5c). Since the method is not time consuming, modifications of the initial diagnostic study can be carried out and integrated into a new template. The actual tooth preparations will only be performed after the patient's formal approval.

In certain circumstances where the original tooth volume must be reduced or transposed (eg, correction of tooth position), the previously described approach is clearly not applicable. Such exceptional situations will require preliminary tooth preparations which create minimum space for the completion of the mock-up that will also act as a temporary restoration. After the patient approves the configuration of the latter, tooth preparations are finalized. A similar sequence can be applied with extremely demanding patients. These individuals often demonstrate a great deficit of self-confidence and seem immediately confused by the insufficient esthetic quality of the traditional mock-up. They are unable to objectively evaluate the template unless more esthetic stratified acrylics are used. Here, preliminary tooth preparations and impressions are best indicated for the laboratory fabrication of an elaborate template using, for instance, a sandwich technique.[20]

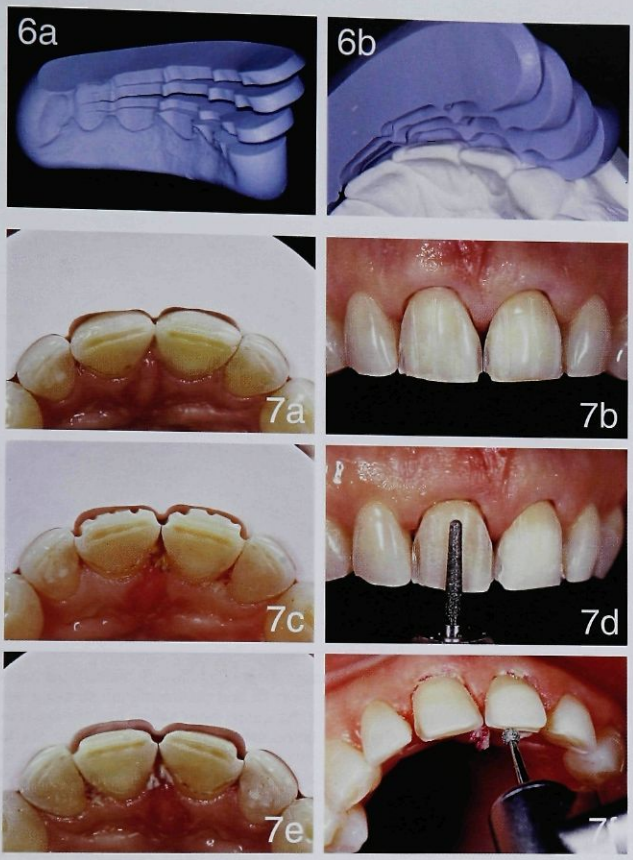
Such diagnostic commitment may seem exaggerated. It proves, however, to provide the treatment outcome with maximum predictability, resulting in a high probability of recovering the patients' confidence. This aspect of the relationship is invaluable when compared to the possible consequences of inadequate treatment objectives.

PREDICTABLE TOOTH PREPARATION: TECHNIQUE AND BONDING

When the approach described above is strictly applied, practical restorative procedures can be considered to possess maximum safety and predictability. This is particularly important when the operator is confronted with the rehabilitation of the aged dentition. The final objective being well defined, the active therapeutic effort can now focus on the technical procedures for tooth preparation.

The simplest and most important tools for enamel reduction are represented by sectioned silicon indices from the wax-up. In order to obtain a stiff and accurate matrix, the model can be subjected to a pressure of 4 atmospheres (using a pressure pot) during the setting of the silicon material. The index can be cut in two, and the facial half prepared according to a "notebook method" (Figs 6a and 6b). The latter is like a bound multi-layer index that will allow efficient checking of the hard tissue reduction at different horizontal levels of the preparation. Before starting to reduce enamel, the placement of the facial index reveals that some areas of the tooth surface (typically the proximal crests and transition lines) will require minimum preparation (Fig 7a). The axial reduction does not require the use of specialized rotary tools but only tapered round-ended burs classically designed for traditional fixed prosthodontics. Three different diameters of burs are recommended (eg, 856L-014, 856L-016 and 856L-020, Brasseler, Savannah, GA or D6, 235 and 237, Intensiv, Viganello, Switzerland), the thinnest bur being used first for cutting proximal reduction grooves, then the medium bur for facial reduction grooves. The depth of each groove is individually controlled using the silicon guide (Figs 7b and 7c). The preexisting surface of the tooth must be ignored, using only the surface of the silicon index to check the depth of the cuts. The gross axial reduction is preferably carried out with a larger bur to prevent re-penetration into the grooves (Fig 7d). In this simple way, wavy surfaces can be avoided. A uniform space of 0.5 to 0.7 mm should be generated by this method (Fig 7e), ultimately producing the same thickness of ceramic at the proximal and axial levels. The palatal half of the silicon index is finally used to check the incisal clearance (1.5 mm is required), followed by the completion of the palatal finish line, which usually constitutes the last step of the tooth preparation (Fig 7f). It is essential to produce preparations without sharp angles, considering that the improved quality of both the preparations (sufficient clearance for the ceramic, smooth contours, absence of undercut) and the final impressions will significantly facilitate the work of the dental ceramist, leading to a minimal use of die spacer, thus reducing the risk of post-bonding cracks.[3,17,21]

Despite a major effort to confine the preparation within the enamel shell, old preexisting Class III and IV restorations may lead to more extensive coverage and involve deeper preparations into the dentin (Figs 8a to 8f). Accordingly, local application of a dentin bonding agent (DBA) is recommended. The application of the DBA is usually delayed until the last treatment stage, just before luting the veneer. A new approach has been recently proposed to optimize the DBA application.[5,16,27] Because freshly prepared dentin appears to have a much superior potential for adhesion when compared to contaminated dentin, the DBA is best applied immediately after the completion of tooth preparation and before the final impression (Figs 8d and 8e). Additionally, this immediate application of the DBA and



Figs 6a and 6b The "notebook method" for the preparation of the silicon index. The traditional silicon index was cured under 4 atm in a pressure pot, then sectioned horizontally. The different layers are still bound on one side the index (6a). The matrix can be opened like a book to visualize the entire aspect of the reduction, from incisal to the most cervical part (6b).

Figs 7a to 7f Rational tooth preparation procedure (same patient presented in Figs 1a and 1b). The initial control with the silicon index shows already available space for the future restoration (7a). Depth cuts are barely visible because of the minimum sacrifice of sound tissues (7b). Each groove is individually controlled with the silicon matrix. Some aspects of the preexisting surface will be almost untouched, eg, the facial-proximal transition line angles at the distal surface of tooth 11 (7c). A retraction cord is placed, followed by axial reduction; a larger bur is used (ie, 856L-020, Brasseler) to prevent the formation of wavy surfaces resulting from re-penetration into the depth cuts (7d). The control of axial reduction reveals that minimum reduction was made at the level of proximal crests, leading to a maximum preservation of enamel (7e). The incisal edge reduction is followed by the definition of the palatal finish line (ie, a slightly concave, butt margin) using a large round diamond bur (ie, 801-016 or 801-023, Brasseler)(7f).

Figs 8a to 8f Tooth preparation procedures in the presence of large preexisting Class III restorations (same patient presented in Figs 4a to 4k). An open gold crown was originally removed from tooth 12 and the interdental surfaces were separated up to the palatal margin of the class III restorations (8a). The placement of the silicon index shows that the facial wear was limited by the presence of the gold crown on tooth 12 while no depth cut will be necessary on the central incisor due to the significant space generated by the additive wax-up (8b, see also corresponding situation in Figs 4c and 4d). As a result, a maximum amount of enamel could be saved on the facial aspect of the central incisor (Fig 8c). Significant dentin exposures, however, are generated proximally and necessitate immediate lining with a dentin bonding agent, including dentin etching (8d). The use of a filled resin (Optibond FL, Kerr, Orange, CA) allows an accurate placement of the adhesive prior to impression taking (8e). To promote adhesion of the luting composite to the preexisting adhesive resin, surface roughening of the latter (ie, using a coarse diamond bur at low speed) and alcohol drying were performed just before luting the final veneer (8f).

sealing of dentin will prevent bacterial leakage and sensitivity during provisionalization and provide the pulpo-dentinal organ with maximum protection. With this technique, further adhesion of the luting agent to the preexisting dentin adhesive must be promoted by surface roughening and drying with alcohol just before luting procedures.[16]

CONCLUSION

A well-defined work strategy for the porcelain veneer reconstruction is presented, documented by clinical cases. In most cases of esthetic rehabilitation, the treatment objective must be reached by means of a significant diagnostic effort. The present article has shown that this can be achieved by simple but essential tools: the additive diagnostic wax-up and the acrylic mock-up, which achieve optimal contours and patient accommodation and ap-

proval. The transfer of vital biological information to the tooth preparation stage can be carried out by a leafed silicon index, the so-called "notebook" technique. Each stage of the procedure is characterized by objectivity and clinical control. This assures the retention of a maximum amount of enamel which lies at the heart of the porcelain veneer approach. It is strongly suggested that the advantages of PVs go beyond esthetics to proffer complete biomechanical recovery of anterior function, the so-called biomimetic principle. This is expressed in the labiopalatal resistance of PVs to anteroposterior movement as in food incision and anterior guidance. It is probably safe to say that with the continual improvement of materials and diagnostic techniques, there is potential for enhanced application of PVs to cases where greater loss of hard tissue has occurred.

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