

Porcelain veneers – preparation design: A retrospective review

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Abstract

This paper discusses the preparation of tooth design for porcelain veneers. It follows the literature more than three past decades. From the very beginning, the porcelain veneers were placed to no/minimally prepared tooth substance, showing different problems in clinical use. Later, the technique of etching the porcelain and controlling the reduction of tooth structure presented the great steps forward in porcelain veneers accepting. The special accent concerning the preparative design was placed on variations of incisal edge preparation - the problem, which is still present in current practice. Additionally, the paper emphasizes the extremely demanding protocols in making the porcelain veneers, as well as their expanded clinical indications.

Keywords: literature review, porcelain veneers, preparation design.

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In the aesthetic dentistry, the porcelain veneers present the first class clinical conservative modalities. The current literature recognizes them as the state of the art of each auspicious dental practice. As being less invasive, for both hard and soft tissues and granting satisfactory aesthetic outcome, the rehabilitation procedure with porcelain veneers has been widely welcomed by the patients. In addition, the modern improvement of composite cements, adhesive systems and simplified cementation procedures also enable the promotion of this effective treatment approach among the dentists.

But, different literature data bring to the practitioners various dilemmas concerning tooth preparation design, as well as the clinical recommendation with expanded indications, opening the controversial suggestions.

The following literature review with retrospective glance will thoroughly highlight this topic.

HOW DID IT ALL BEGIN?

The use of porcelain veneers goes back in the late 1930s. The wish of a famous Hollywood actress to „urgently“ alters the looks of her several teeth represents the true beginning of these restorations; at least that is how the idea that some aesthetic problems could be solved in this non-aggressive way was born. The procedure was performed by Charles Pincus, one

of the pioneers in aesthetic dentistry, who applied thin veneers and provisionally fixed them by means of using prosthesis adhesive powder. Created as an emergency solution, porcelain veneers of Pincus's time were labelled as false front or Hollywood veneers. The most commonly created as thin porcelain veneers, they covered the irregularities of existing teeth: diastemas, rotations and malpositions, and established the desired shapes of the dental arch. Sometimes they were also placed on the teeth in the lateral regions in order to fill in too narrow or sunken cheeks of the actors. Due to the unresolved problem of their fixing and huge functional stresses to which they were exposed, these veneers had a short life span in the mouth [1].

The innovation of acrylic resin and their fast development marked a second step in the application of aesthetic materials for the acrylic veneers fabrication. A number of physical performances of resins limit their clinical longevity in the mouth: high degree of polymerization shrinkage, poor edge adaptation, high coefficient of thermal expansion, risk of restoration edges recolouring, insufficient abrasion hardness, increased water absorption, resin softening and change of the basic colour. Nowadays, viewed from this time distance, it can be said that the application of acrylics as aesthetic materials meant for dental science and practice is a true driving force for the innovation of new and better materials [1-5]. Lately, indirect acrylic veneers were recommended as an alternative to direct composite veneers. Unfortunately, instead of the improved characteristic of these modality, two unsettled problems remained to discredit them as high quality restorations: low resistance to abrasion and separation from composite resin due to poor chemical bonding to cement [1,3,6,7].

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Through the next decades the great emphasis in dentistry has been placed on development of the microfine composite cements and reliable etching to dental enamel [8,9]. The resulting effects led to the introduction of composite veneers for masking different tooth discolorations. These restorations showed a short clinical lifetime of four years or less and various problems such as polymerisation shrinkage, staining, poor wear resistance and thermal dimensional changes [10].

The impossibility of achieving long term aesthetic results with use of composite veneers reactivated the interest of the profession, once again directed it towards porcelain as a chosen material for veneer fabrication. The idea of special preparation of porcelain veneers and their bonding to tooth enamel was first mentioned in prophy text in 1975 [11], but the technique of etching the inner porcelain veneer surface with hydrofluoric acid was developed later, in 1981 [12]. By measuring the tensile bond strength of etched porcelain to composite cement, NYUCD researches concluded that sufficient retention was obtained [13,14].

The first indications for porcelain veneers were amelogenesis imperfecta, intrinsic staining and anatomically malformed teeth, while teeth in an edge-to-edge or cross-bite relationship were contraindicated. If the teeth being restored have old restorations class III, IV or V, these must be retreated; or if the teeth are incorrectly positioned, they need minor cosmetic contouring first. Early cases of porcelain veneers in 1982 were placed without removing tooth substance and the lingually inclined teeth were selected for that purpose. The literature of that time criticized the possible consequences of increasing the tooth emergence profile and undesirable material bulk in such cases (periodontal problems and unnatural aesthetic appearance of the restorations). Therefore, the professional standpoint was planning the optimal tooth reduction, which simplifies the fabrication and placement of porcelain veneers [14,15].

The first step in preparation procedure was to make a lingual plaster index suggested to be obtained in a wax tray. The labial extension of the plaster was trimmed, and the incisal edge of tooth was reduced 1 mm, using the lingual plaster as a guide. If the incisal length of the anterior teeth needs a modification, the aesthetic planning is done on the stone models (study cast) with tin foil painted on the stone teeth and a lingual plaster index [15]. The controlled reduction of tooth labial surface is critical. It was recommended to be done into two planes, gingival and incisal, using cut horizontal grooves 0.5 mm depth marked with a lead pencil (to protect against over reduction). The two planes should merge smoothly into each other forming a gentle labial curve. The gingival portion was prepared

with a diamond bur to create chamfer and was extended up to the free gingival margin. The same bur was used to prepare the rest of the labial surface. When the teeth possessed proximal contacts, enamel reduction was followed toward in the proximal embrasure without eliminating the contact points. To avoid the unsightly appearance of the junction of the proximal porcelain/tooth substance and gingival-proximal bulk, it was suggested to extend the preparation proximally into gingival area. The enamel reduction was 0.5 mm at incisal edge, and the edge was rounded. In addition, it was mentioned as modality, the incisal overlap with finishing line on inciso-lingual portion. It hides the incisal margin, makes the new one in porcelain more esthetic, provides the incisal edge reinforced and allows a positive seat for veneer. In those cases, the incisal edge should be reduced approximately 0.5 mm with 0.75 mm at mesio/disto incisal angles [14]. Also, some authors preferred local anesthesia during preparation procedure [15].

The article printed in the late eighties, stresses the main contraindications in use of porcelain veneers: teeth with poor quality enamel, rotated or overlapped teeth and broken down teeth which may not offer enough support for veneer. Also, there is opinion that if teeth are in linguoversion, retroinclined or are peg-shaped, reduction of enamel can usually be avoided, especially in the young patients. But, if there is need to mask out strong discoloration or prevent an overbulked restoration, better aesthetic appearance would be achieved by reduction of enamel tissue at least for 0.5 mm. In addition, there are recommendations for preparation protocols. The first step is the establishment of a confluent finish line proximally and gingivally with round diamond bur which creates a positive chamfer. Cervically, the finish outline is in level with the contour of the free gingival margin in the most cases. Rarely, it could be positioned 0.5–1 mm subgingivally. The proximal finish line is extended into the embrasures, but usually short of the contact point. The second phase is the reduction of labial enamel by applying a series of 0.5 mm deep vertical tracer cuts close together, which in final provide tooth reduction of 0.5 mm labially. The most critical step is preparation of the incisal surface, which may considerably vary. The preferred way is the reduction of incisal edge by applying a bevel at the expanse of a labial surface and incisal edge to a depth of 0.5–1 mm. The other possible designs are: feathered incisal edge or window preparation. Also, the overlapped incisal edge preparation is useful in circumstances where it is necessary to change the tooth dimensions or to protect part of the palatal surface. The final step in the preparation procedure is achieving the smooth enamel surface and round off sharp angles with fine diamonds and flexible discs [10].

At the beginning of nineties, over 68% of general dentists have placed at least one porcelain veneer in their practice. Instead of the fact, that laminates are believed to be the simplest aesthetic modality, they are very sophisticated and need special skill and accuracy by all dental team [16]. The clinical problems associated with veneers are poor marginal integrity [17], unaesthetic monochromatic color, unpredictability of cementation [18–20], extensive placement time and unrealistic long term expectations by patients [19]. The dental profession stated that the definite tooth preparation must be done in enamel (ideally) with a chamfer finish line; only in some instances, the preparation includes a rounded incisal edge and terminates lingually with a heavy chamfer demarcation [10,21–23]. At that time the first special diamond set of instruments for depth cutting (LVS-1 or LVS-2) (Brasseler laminate veneer system set 4151, Brasseler, USA) were born. The remaining excess enamel was removed with two-grit diamond stone (LVS-3 or LVS-4), and the margins were polished with a 12-fluted finishing bur (brasseler H283K016). All other internal surfaces of preparation are left non polished intentionally to create the optimal bond to composite cement. The cervical margins are placed slightly above the gingival level, and the application of the retraction cord is not always necessary. Additionally, it was highly recommended the use of magnification for checking and visualization of all the phases of the preparation procedure [23].

WHAT IS NEXT? (1990–2000)

During the last decade of the old millennium, literature's data announced the statistic details about the quantity of prepared tooth structure in porcelain veneers making: only 25% of the practitioners remove 0.75 mm of tooth tissue, while 65% of the therapists remove less, around 0.5 mm. Also, 84% of the practitioners create the cervical chamfer as demarcation, 22% provide complete coverage of the incisal edge while 78% of the clinicians offering complete coverage occasionally [24].

Still, there are controversy as to whether or not tooth preparation is required on labial surface. Among the results of 26 literature reports which have been published since 1991, majority of them, 22 studies favored some of the preparation modality [25]. Those days, the scientific community discussed the problem of three different incisal edge design variations: the „window“ or intra-oral preparation, the „overlapped“ and the „feathered“ incisal edge preparation. The window style of preparation was recommended as it can withstand the highest load until failure (dynamic stress analysis) and transmitted the least forces through the veneer (photo-elastic stress analysis) compared to the other two designs. It was stated that the porcelain

is the weakest point in tooth-cement – veneer system, and if the selection of preparation is based on mechanical criteria, the window type of edge preparation can be one of the most optimal conservative choices [25,26].

Studies evaluating the marginal integrity of porcelain veneers depicted different, but considerable discrepancies which range from 60–292 μm . It would be ideally, to create the porcelain margin in enamel enabling the excellent veneers sealing. But, clinical situations such as root recession, caries, abrasion cavities, aesthetic demands, very often impose to the practitioners to finish the porcelain margins on dentin or cementum, significantly increased the potential for microleakage. Also, there were professional attempts of using the denting bonding agents to pretreat the dentin surface and to promote wetting of the composite cement. Glass-ionomers as pretreatment modality did provide no resistance to microleakage; therefore it seems that acceptable solution to reduce the microleakage is to seal all finished veneer margins with unfilled resin [27–33].

It was discussed the possibility how to restore worn mandibular anterior teeth. As complete crowns are the last option (weaken the teeth), the porcelain veneers could be used in cases, when the vertical dimension need to be increased. But, such a choice of restoration must be carefully checked, because the mandibular teeth have the important role in anterior guidance and they will be subjected to significant occlusal force in function. It was considered that patients with excessive vertical overlap and little horizontal overlap are not good candidates to carry the porcelain veneers. In addition, when restoring all anterior mandibular teeth, maxillary palatal surfaces could be restored with porcelain to minimize the possible wear effects (similar materials) [34].

Still, there is a promotion of incisal edge design without overlapping, instead of an existing opinion, which supports the overlapping way as standard procedure. There are results about the efficiency of different preparation style of incisal edge: feathered edge, window preparation, incisal bevel and overlapped incisal edge in the 3-years follow up study. It was illustrated that wrap-over method is not optimally conservative and must be avoided in young patients. It appears, that the veneer should not be brought into contact with the opposite tooth, as porcelain is known to be very brittle material (etched porcelain with silane produced bond strength which surpasses the cohesive strength of porcelain). Under normal overbite a preparation modality without incisal overlapping will be preferable [35]. At the same time, the critics of the incisal edge window preparation design have started. It is „accused“ of leaving a weak enamel margins of

poorly supported enamel prisms, which may result in chipping during protrusion movement in future. Moreover, with window preparation, resin cement will be bonded to the longitudinal oriented enamel prisms. Such a situation produces a weaker bond between the enamel and porcelain veneers, and leads to the veneers' debonding (polymerization shrinkage of composite cement) [10,36,37].

During mid-nineties, the porcelain veneers are recognized as accepted method to restore malformed, malaligned, discolored and fractured teeth. They presented a good alternative to complete ceramic crowns, when combine with correct technique and careful application [38,39]. Literature data emphasized the necessity of the tooth preparation procedure for several reasons: shear bond strength of composite cement to etched enamel is increased, particularly if a coarse diamond bur is used, it is possible to provide the sufficient place to prevent overcontouring at the gingival margin and also is easier to control stress distribution in the veneer [15,40]. It was advocated to use the specially designed depth gauge burs for rational removing of the tooth substance to avoid the improvization. The „handfree“ technique, which is very often employed by the practitioners, illustrated different drawbacks. The studies showed the significant reduce of tooth structure in cervical and proximal regions, in excess of 0.5 mm (till 1.2 mm), while the least reduction occurred in the incisal third (0.2–0.4 mm). The consequence of such preparation technique is overcountered veneer in mid-incisal level and exposed dentin in cervical zone [41]. The other studies confirmed that the incisors enamel thickness in gingival third is 0.3–0.4 mm, so it seems that 0.5 mm reduction at this level would result in dentin exposure or possibly complete elamination of enamel (laterals) [42]. The use of hydrophilic dentin bonding system has demonstrated penetration of resin into dentinal tubules, therefore that procedure could be beneficial in decreasing the sensitivity and microleakage [43].

The interesting longitudinal studies which followed the efficiency and the other parameters relevant for the clinical performance of porcelain veneers were published during the late nineties. The results of 6.5 years long study, which evaluated the survival rate of 372 porcelain veneers fixed mostly (90%) on not prepared teeth, showed the high failure rates, 22–39%, with overall probability of a veneer surviving with no problems only in 50%. The main technical reasons contributed to the failures were the two clinical protocols: veneers were bonded to unprepared enamel and the veneers were sandblasted and silanated only, they were not etched with HF acid [44]. On the other hand, the retrospective report of 3500 placed porcelain veneers observed during the 15th period, showed

approximately 7% of failure rate manifested as fracture, debonding or leakage. The fractures are described as static, cohesive or adhesive, leaving the leakage almost between the tooth and resin. The author promotes an enamel substrate as a critical element to a successful clinical outcome, as well as tooth preparation including an intraenamel preparation (whenever is possible). Also, the porcelain veneers were referred as an enamel ceramic restorations. In the commentary, it was discussed the new trends in tooth preparation for veneers which are more aggressive than initially described, concluded that veneers were very often primarily adhered to a dentin substrate in clinical reality [45,46]. Another ten-year longitudinal study of 191 porcelain veneers presented the excellent results with survival probability of the veneers of 97% in five years and 91% in 10.5 years. Over the observation period only 4% of examined restorations failed. Veneers' failures like gingival recession, marginal discoloration debonding or porcelain fracture, were more likely when the restorations were bonded to dentin or when the patient suffered of CMD (clenching, grinding) [47]. Also, in a 2.5 year interim evaluation of veneers durability, it was shown no difference between the techniques of preparation (without the reduction of incisal edge or incisal reduction with palatal bevel). The study recommended that incisal edge should be left unprepared if possible (aesthetic reasons). Additionally, preparation of incisal edge was considered to be unnecessary to assure or improve the veneers strength, therefore it would be avoided [48].

During this period, the profession states a problem concerning the long clinical duration of porcelain veneers, turning the interest toward to the other structures essential for their functional quality. A 2-dimensional finite element analysis (FEA), known in mathematics, is used to show the stress distribution in the veneers and the fracture mode at maximum load. It was noticed that the different designs of cervical demarcation (feather edge, chamfer and shoulder) were of less importance than the masticatory loading condition. For the first time, it was mentioned, that the most significant factor for stress variation in porcelain veneers was the cement layer. In that sense, it was recommended to pay attention to moisture control and proper handling of composite luting, as procedures relevant for the veneers' success [49].

The research on crack propensity of porcelain veneers frequently occupied the scientists at the end of the 20th century. Incisal chipping and development of cracks that occur before and during the cementation, appear to be primarily, a consequence of therapeutic skills in handling and positioning of the veneers. However, considering the polymerization cement shrinkage, as well as temperature variations (consuming of

food and beverages), there is considerable disagreement in the CTE of the teeth and porcelain, which in turn produces significant stress in the porcelain. Then, they began seriously thinking about a new design that includes a proximal surface of the teeth, “wrap around”, the importance of location and configuration of the cervical demarcation and the relative thickness ratio of porcelain/cement layer. It was pointed out the importance of: 1) uniform tooth reduction (special attention is focused at facial axial level of the preparation which thickness is critical), 2) improved quality of tooth preparation (smooth contours, absence of undercuts), 3) the optimal CER/CPR relationship (above 3) and 4) the application of die spacers during laboratory procedures (to define the uniform cement layer); all of them presented the key elements of good clinical practice [50].

The most of the available literature data from the beginning of XXI century brought the recommendations regarding the preparation of teeth for porcelain veneers. Those studies supported removal of varying amounts of tooth structure, contrary to early concepts of no tooth preparation [15,51–53]. In particular, the literature data highlight the removal of aprismatic top surface of mature unprepared enamel, which offers a minor retention capacity and can jeopardize the bond strength of the composite cement to tooth structure

[54]. On the other side, the preparation must be maintained completely in enamel to achieve the optimal bond of different substrates [55]. If dentin is exposed, it must be protected for the period between preparation and cementation. It could be done by means of primers, hydrophilic reactive monomers in organic solvents, which seems not to decrease adhesion of veneers system, also making possible the further cementation [56,57]. The proposed alternative, is the application of denting bonding agent immediately after the preparation. This procedure may prevent the development of bacterial leakage and dentin sensitivity [58]. If temporary resin veneers must be created (aesthetic, phonetic reasons), it is indicated to use eugenol free provisional cement or to fix it by a small area of etched enamel (Table 1) [53,59].

Again, there are polemics concerning the differences in the amount of tooth substance which must be removed during the preparation procedure. Free-hand technique tends to leave underprepared labial surface, with possible overcontouring of the finally restored tooth. The excessive bulk in the gingival portion of the restoration changes the emergence profile and could initiate gingival inflammation. Overcontouring in the incisal part of the restoration alters the protrusive relationship, promotes atypical incisal loading of the veneer, creates subsequent fracture and pro-

Table 1. Descriptive statistics of porcelain veneers clinical trials with reference to material brand and type of tooth design

Author	Number of veneers	Number of patients	Porcelain/adhesive system	Preparation design
Clyde and Gilmoure	200	Not specified	Chameleon (Terec)/duo-cure (Terec)	Feathered incisal edge In. Bevel Palatal overlap
Calamia	115	17	Chameleon/Comspan?+Ultradond (Den-Mat)	No preparation Slight incisal overlap
Jordan <i>et al.</i>	80	12	Not specified/dual cure (not spec.)	Conventional (no incisal overlap)
Rucker <i>et al.</i>	44	16	Vitadur –N /Vita)/Heliolink + dual cement (Vivadent)	Incisal bevel Feathered incisal edge
Christensen and Christensen	163	45	Cerinate (Den-Mat) ultrabond (Den Mat)	Feathered incisal edge
Nordbq	135	41	Ceramco (Ceramco Inc)/Porcelite LC (Kerr)	Conventional (no incisal overlap)
Jäger <i>et al.</i>	80	25	Mirage/Mirage FLC +Mirage Bond (FA Mirage)	Palatal overlap
Strassler and Weiner	291	60	Cerinate (Den Mat)/Ultradond (Den-Mat)	No preparation Conventional (no incisal overlap)
Walls	54	12	Fiber reinforced porcelain/Heliolink (Vivadent) + Gluma (Bayer)	Special preparation for worn teeth
Meijering	56	Not specified	Flexo-ceram (Elephant Ceramics)/not specified	Conventional (no incisal overlap) Palatal overlap
Peumans <i>et al.</i>	87	25	GC Cosmotech Porcelain/CG Cosmotech Bonding set (CG) + Scutabond 2 (3M)	Palatal overlap
Kihn <i>et al.</i>	59	12	Ceramco Colorlogic/Ceramco Colorlogic Bonding System	Conventional (no incisal overlap) Palatal overlap

duces poor aesthetic outcome. Teeth prepared with a silicone key or depth gauge bur can be overprepared with exposed dentin, particularly in the cervical third of the preparation (enamel is very thin). Therefore, it was recommended to use 0.4 mm depth gauge bur for limited removal of tooth structure. In fact, the orientation grooves involve additional smoothing out of the grooves done by depth bur, so the tooth removal would be higher than 0.4 mm, approximately 0.5 mm. Also, there are situations where free-hand technique is the proper choice: severely discoloured teeth and non-carious tooth surface loss. In addition, the silicone index is more helpful than a depth bur when reducing the incisal edge and bevelling or overlapping the incisal/palatal surface [60].

The study of stresses within the porcelain veneers with different preparation design, using 2D finite element analysis, has shown unexpected interesting results. Incisal overlap preparation model was associated with less compressive stress within porcelain and composite, than the window preparation design. Also, the tensile stresses with labial and palatal loading were significantly greater for the chamfer and shoulder design (25 times) compared with knife-edge preparation design. The authors confirmed that porcelain physical properties, and the bond strength at the composite-tooth interface, as well as composite-porcelain interface, presented critical points for veneer restorations clinical success. Additionally, using the incisal overlap design, the porcelain veneers with knife-edge labial margins could better introduce occlusal stresses without fracture [61]. The other similar study stated that the lowest values for the loadability for the overlapped preparation is more than three times higher, if compared with the biting force for incisor (axial direction), therefore this design may be used in different clinical indications safely (to re-establish the proper anterior guidance) [62].

The actual scientific literature criticizes the professional attitude which does not offer a relevant information of the preparation design responsible for veneers longevity. Still, it remains controversial whether various tooth preparation design could influence the fracture strength of veneers or whether one tooth preparation modality is superior to another. Currently, a new design in veneers preparation technique, named „butt joint“ configuration is introduced. It is created by cutting the incisal surface (edge) 2 mm flat, without forming the palatal chamfer. The substitution of a palatal chamfer with a new design offers a several advantages: 1) provides an optimal ceramic/composite ratio at the palatal surface, 2) decreases the risk of postinsertion palatal cracks caused by shrinkage of composite cement (polymerization contraction, natural thermal changes in the mouth), 3) permits the pre-

servation of a peripheral enamel layer around all margins, which is essential for eliminating microleakage at the palatal/restoration contact and counteracting shear stresses, 4) allows for optimal characterization of incisal third of veneers, 5) butt joint preparation is easier, less time-consuming, easily reproduced on the model, 6) provides a significant support for ceramic layers, 7) the path of insertion could be buccal-palatal or incisal-cervical and 8) the risk of fracture for thin palatal edges of ceramic is controlled with butt-joint design.

The treatment with bonded all-ceramic restorations, including the porcelain veneers, is based on adhesive properties of different materials and not classical micromechanical retention and resistance. If it so, the palatal chamfer is not only essential for providing retention to tooth structure for the ceramic veneers. Ceramic as a brittle material fails at a critical strain of 0.1%, and if the bond to tooth fails, the ceramic would be broken easily [63–66].

„BACK TO THE FUTURE“ (2000–2012)

The first decade of the new millennium has brought the studies concerning tooth preparation design for porcelain veneers, mainly in terms of possible clinical failures over the longer lifetime. Interesting, but somewhat confusing, were the results of the study which emphasize the importance of the knife-edge cervical finish line combine with the “overlap” incisal edge design that produced the smallest tensile stresses in the porcelain and composite cement compared to the other recommended designs [61].

During this period the profession asked a real question that demanded an answer. In fact, it appears, that this question has always been controversial in some way. How thin veneers made of brittle ceramic materials survive in the conditions of the oral environment for a long time?

What is surely known is the information that porcelain veneers can clinically fail due to the development of flaws on the restorations surface [50]. The surface imperfections act as a potential source of deeper cracks initiation. The microcracks and the place of stress concentrations may be inherent to the porcelain or may occur during laboratorial and clinical procedures (PV manufacturing, pre-cementation treatment, cementation). The slow crack growth at the tips of surface flaws is obvious in the moist environment due to the hydrolysis of silicate bonds [67]. But, equally, the surface flaws may become expanded as the result of stresses induced by thermal variations of every day ingested food and drinks (10 extreme thermocycles would occur per day). A large flaw on the porcelain surface may turn into premature fracture, if the temperature differences are greater as well as the imposed tensile stresses [68].

According to some professional opinions there are generally two techniques for localization of the incisal finish line during the veneers preparation procedure [69]. The first way leaves the lingual surface unprepared, that is window or intraenamel preparation, obtained when the facial surface is finished at the incisal edge. The second technique terminates on the lingual tooth surface, while the incisal edge is reduced. Literature data showed the interesting connection between microleakage and different incisal edge preparation. The marginal fit and integrity, as well as resistance to microleakage, are important elements for clinical success of porcelain veneers. Marginal leakage involves percolation of fluids and invasion of different enzymes, acids and bacteria. The percolation is the result of the mismatch of CTE between tooth structure and restorative materials and curing shrinkage of luting cements [70]. The porcelain-composite bond could be compromised by hygroscopic expansion of the resin cement or by hydrolysis of the silane [71,72]. Studies, using radioactive isotopes (CaCl_2 , pH 7), indicate that the incisal edge preparation type affects the microleakage features at the incisal finish line. The window veneers preparation has the greater preventive potential in decreasing the microleakage at the incisal margin than the overlapped modality. However, the cervical microleakages were of the similar degree in the two different tested incisal margins [69].

Two impressive publications, which came out in 2002/2003, dealt with the problems of minimal invasive modalities in aesthetic dentistry, with especially emphasis on porcelain veneers. Biomimetic approach in aesthetic reconstruction of the anterior teeth with bonded porcelain veneers is an extraordinary issue, which offers a new restorative solution that balanced the expanded indications for porcelain veneers and various clinical references. The great topic of this publication underlines the porcelain stiffness and the biomechanical strength achieved through tooth/composite/porcelain bonding, as new powerful structure enabled as a whole entity to support different masticatory activities.

Generally speaking, the tactics of tooth preparation for the porcelain veneers depend on appropriate selection of the patient and a correct diagnostic stages. The first task during tooth preparation is the maximum preservation of remaining sound tooth structure, bearing in mind that porcelain veneers significantly differentiated from traditional cemented restorations. The preparation of sequential procedure starts with detailed case analysis and making the silicone index (template) over diagnostic wax-up. It is pointed out that horizontally sectioned silicon key is the most useful tool for enamel reduction. The next step is the preparation of the axial surface where tooth reduction is done through

three phases using the tapered, rounded-end diamond burs of different diameter. The smallest diameter bur is used first to cut the proximal reduction grooves. Afterwards it is suggested to place the deflection cord to improve visibility of the paragingival margin, while in second phase the medium-diameter bur is used to create vertical facial grooves. The depth of each groove is individually controlled by silicon template. The third phase is gross preparation or axial reduction III, which is created with a larger bur to prevent the penetration into the grooves. The final effect of those phases is removing of 0.5–0.7 mm tooth tissue uniformly and producing enough space to ceramic at the proximal and axial levels. Going further, the incisal edge is reduced at least 1.5 mm and established the palatal finish line as the last step of tooth preparation. At the end, it is essential to realize the preparation without sharp angles and undercuts during the finishing procedure. In the cervical and proximal areas it is necessary to make a light, clinically accepted chamfer. The intra-sulcular margins are recommended only when closing interdental black triangle (loss of papillae) or diastema to enable the ceramist to produce a progressive emergence profile [73,74]. Additionally, the excessive interdental penetration must be avoided, except for the two particular cases such as wrapping of old class III restorations and reduction of diastema/“black triangles”. The introduction of sonic oscillating technique and instruments seem promising when used on large interdental contact surfaces, overlapping teeth (a more conservative proximal preparation as compared to burs) and also for cases of subgingival margins, when is possible to finish the margins without damaging the soft tissues.

Talking about the palatal extension of porcelain veneers, which is always critical, the authors stated that the extent of tooth substance loss have to be considered. The main rule to respect is to avoid the palatal extension of the preparation in the zone of palatal concavity. That part of the palatal surface is the place of the maximum tensile stresses generated during loading. Therefore, the use of a butt margin instead of a mini chamfer (finish line) could provide the restoration margin with a bulk of porcelain.

If it is case of maximum remaining tooth substance, it would be possible to create incisal overlaps with butt margin or mini chamfer, but is imperative to avoid a long chamfer extended into palatal concavity. For moderate crown fracture that involved incisal one third, or severe wear, it is recommended to make butt margin which limits the extension of the ceramic and reduce the amount of stress at tooth/veneer interface [75]. In addition, a horizontal butt margin is correct choice for fractured teeth, especially from the aspect of future adhesive bonding, which would be obtained with ena-

mel prisms obliquely sectioned at angle greater than 50° . One of the interesting solution which could be useful in fractured teeth to avoid the palatal fossa, is to make a composite builtup „stress breaker,” when is expected a stress redistribution into the more flexible material [76]. The clinical situations with severe crown fracture that involved incisal two thirds are less complex than moderate tooth fracture, because the palatal margins (butt margins or mini-chamfer) could be situated in the low tensile stress area of smooth cingulum. It must be noticed that evaluation of indication spectrum for porcelain veneers toward replacement of great quantity of tooth substance complicated their original preparation design, making it closer to partial crowns design.

Another fascinating book about porcelain laminate veneers presents a comprehensive theoretical and clinical issues, essential for understanding the procedures, practical guidelines and the doctrinal rules, important in veneers production. Also, the publication illustrates the differences in the veneers preparation design compared to protocols mentioned earlier [73–76], showing the authors distinct individual approach to this topic.

The fact, that enamel has different thickness at the gingival (0.3–0.5 mm), middle (0.6–1 mm) and incisal (1.0–2.1 mm) $1/3^{\text{rd}}$ s of the tooth labial surface, requires a special diamond instrument to facilitate the labial preparation. Diamond depth cutters have different cutting depths within themselves and the wheels can cut through the enamel until the shift is flush with the surface, creating the horizontal grooves. The technique will be successful only if the depth cutter bur is held at three different angles, thus enabling the preparation of the labial surface into different planes. But, the clinical practice confirms that is impossible to cut the three grooves simultaneously (natural curve of the facial surface) especially in lower premolars or canines. It is therefore recommended to begin with the cervical and medial striations, afterwards adjusting the angle of the instrument and tracing the occlusal (incisal) groove, with the medial one as a guide [42]. The remaining tooth structure between the orientation grooves, is removed using the tapered round-end fissure diamond bur. The labial surface design has to reproduce its natural convexity, respecting, first of all, the biological principles. A minimum reduction thickness of 0.7 mm in junction of the middle and incisal thirds of the tooth is necessary to achieve the optimal thickness and promising optical properties of the future porcelain veneers. Cutting the silicone index, that had been made before, into horizontal slides, it is possible to control the vertical levels of labial surface preparation.

A mini-chamfer 0.3 mm is preferred as finish line for all the gingival margins, practically done with the round

end fissure diamond bur. The bur must be held parallel to the inclination of the cervical $1/3^{\text{rd}}$ of the labial preparation, moving from the distal towards mesial interproximal surface. Additionally, it is important to remove serrated, overhanging enamel prisms, to achieve a distinct finish line. The gingival extension should be placed in the enamel whenever is possible, supragingivally, providing the great benefits. Very often, if the cervical finish line is located subgingivally (tetracycline staining, „gummy smile”, case of caries, old fillings), it will be created in dentin, with all the risk for adhesive bonding [77]. If deeper chamfer preparations need to be placed at the gingival margin, it should be recommended to use fine-grit round ended fissure diamond burs of a larger diameter.

The preparation design of the tooth proximal surfaces is planned in details, before the preparation of labial surface and positioning the gingival finish line. The basic principles are: to preserve the contact area (problems: the cases of natural diastema, fractured tooth angle, encompass a proximal composite fillings; margin should be extended further in a lingual direction) and to place the margins beyond the visible area (important for aesthetic appearance, especially if there are major differences in tooth and veneers shade) [78].

It is very interesting to pay attention on authors' instructions concerning the proximal tooth preparation. There is suggestion to follow the preparation procedure in two regions: the gingivoproximal area and direct proximal contact area, both necessary to be prepared differently. The simplest way to prepare the gingivoproximal margin (extends gingivally from the interdental contact zone or point) is to start preparation after the gingival prep is finished (labial finish line). The same, round end tapered fissure diamond bur is used, held at 60° following the gingival margin towards the palatal, from mesial and distal. Looking from mesiolabial aspect, the curve that looks like interproximal elbow, frequently positioned supragingival [79]. Direct proximal reduction (area which is located in the incisal $2/3^{\text{rd}}$ of the proximal surface) is natural extension of the labial tooth reduction. Using the same bur, as used before, the gingivoproximal reduction is continued by uprighting the angle of the bur vertically into the proximal area, parallel to the long tooth axis and to the mid-line. Mostly, the proximal wall should end 0.25 mm labial to the contact area, following buccolingual tooth inclination. It is considered as some kind of interlock which can improve the mechanical stability and resistance of the cemented porcelain veneers. In some particular cases, the metal matrix band or oscillating instruments (one side is noncutting flat area) could be useful to protect the proximal surfaces of adjacent non prepared teeth during this phase.

The author underlines the two basic techniques for the placement of the incisal finish line. The first ends at the incisal edge and can be in a form of window (intraenamel preparation, without incisal reduction) or feathered incisal preparation (there is no prep of the lingual surface). The second technique looks for the incisal edge reduction, overlapping the incisal edge with porcelain, and finishing the preparation on the lingual/palatal surface.

However, it is still a great dilemma whether the incisal edge of the tooth should be included in the preparation design for porcelain veneers, or not.

The contemporary dental practice frequently favors the overlapped preparation modality as well as finishing the porcelain veneer on the palatal surface. In that case the incisal edge must be shortened 1 mm or 1.5–2 mm for canines and lower incisors with light palatal chamfer 0.5 mm wide, terminated 1 mm far away from the central contact points, not involving the palatal concavity. The same effect can be obtained with the flat shoulder finish line, butt joint, design.

Also, localization of opposing tooth should prevent any centric contacts at the border of the porcelain veneer and tooth structure. All sharp internal angles and corners of the preparation need to be rounded off, to reduce the restoration stresses during luting procedures and function, decreasing the number of weak points in the porcelain.

The most of the complex indications for porcelain veneers (diastema, atypical teeth, lower incisors, porcelain palatal laminates on canines, tooth discoloration) demand for the specificities in the preparation design, related to different amounts of tooth structure to be removed, the position of orientation grooves and the protection of exposed dentin [80].

The results of 7-year long-term survival of 110 porcelain veneers with [51] and without [71] incisal porcelain coverage, published in 2004, did not indicate the statistically significant differences between the different approach in preparation design [81].

Later on, in 2005, the retrospective evaluation result of the clinical performance of porcelain veneers placed in the anterior region over a 12-year period was published. Various features, like color match, porcelain surface, marginal discoloration, and marginal integrity of the porcelain veneers were clinically tested using modified CDA/Ryge criteria [82]. The obtained probability of survival rate of 182 veneers was 94.4%, while the clinical failure rate shows only 5.6%. The study stated that the porcelain veneers are associated with nearly the same risk of loss by fracture as metal-ceramic crowns and all anterior ceramic crowns [83–85]. In addition, it is important for successful clinical longevity of porcelain veneers to be carefully bonded with a correct adhesive technique. Previously, the profession has

been informed that acid-etching the porcelain, as necessary procedure for adhesive cementation, would weaken the porcelain surface compared to alumina abrasion treatment. But, also, composite polymerisation shrinkage may help to strengthen the porcelain surface, providing the beneficial compressive stress on the porcelain surface [86].

At the moment, when it appears that all the dilemmas related to the porcelain veneers profession have been discussed and clarified, the new (old) chapter is opened, which promotes minimally aggressive modality in its true sense – no preparation porcelain veneers. Often, this professional thinking is referred to as „returning to the future“ (back to the future). The proponents of this direction consider expanded indications for application of the porcelain veneers do not fall within the slightly invasive procedure, and that there is nothing conservative about leaving only a quarter of the tooth unprepared. Also, it is emphasized that dental materials do not determine preparation for the treatment that has to be accomplished, but depending on the case (quality of dental tissues), it is necessary to define the use of dental materials. The consecutive development of aesthetic dentistry should reconsider aggressive media advertisements, and the procedures of accelerated „before and after“ images, that resulted mostly with miscommunication going between patients and therapists. All this, to some extent, helped to promote that no-prep (aration) veneers last five years, confirming electivity of aesthetic dentistry as a discipline (Figures 1 and 2) [87,88].

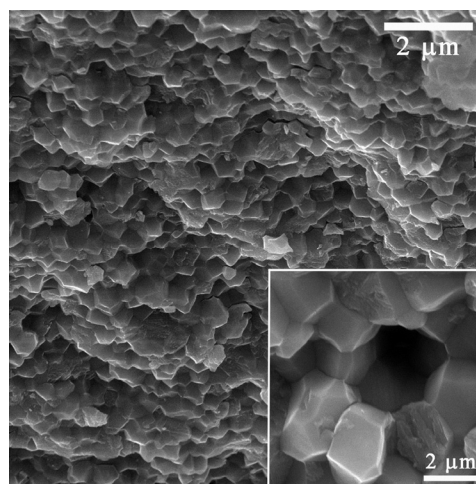


Figure 1. SEM Micrograph of high strength and zirconia ceramic material (Wieland, Germany) with uniform microstructure, used in porcelain veneer fabrication, unpublished authors date.

Porcelain veneers, designed for no prepared or minimally prepared tooth surfaces, are facets with the thickness of 0.3–0.5 mm, similar to thickness of the contact lens. Generally, minority of cases are consi-

dered as ideal for no-prep veneers: individuals with pleasing teeth arrangements as well as minor tooth damage and discolorations able to tolerate an increase in tooth bulk [89]. Practically, the clinical situations that can be regarded appropriate for minimally invasive porcelain veneers are much wider: changing natural tooth shades, masking tooth discolorations, overlaying existing composite restorations (III, IV or V class), closing diastemas, reshaping undersize teeth and peg-shaped incisors, restoring worn, chipped, and fractured teeth, changing the minor misalignments of anterior teeth and repairing existing porcelain restorations through resurfacing [90–92].

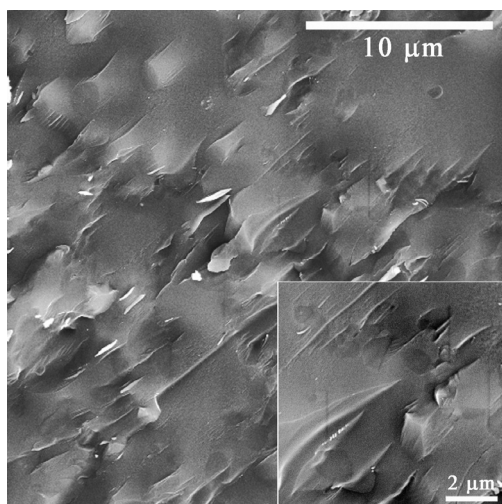


Figure 2. SEM Micrograph of aesthetic, high-strength translucent lithium disilicate ceramic (Ivoclar, Lichtenstein), often used in porcelain veneer fabrication, unpublished authors date.

This type of porcelain veneer offers several advantages for both the patient and therapist: lack of need for anesthesia, painless procedure, elimination of post-operative sensitivity, conservation of the tooth structure, no need for provisionals, longer-lasting restorations due to enamel bonding, higher level of acceptance by the patients, and the others. The great disadvantages of no-prep veneers are: bulky or overcountered appearance, opaque, monotone look with limited translucence, periodontal problems, inability to significant changes of tooth width, possible overcontouring of margins and inadvertent alteration of occlusion [91–93].

To optimize the outcome of no-prep porcelain veneers, it is necessary to perform a comprehensive aesthetic examination of the patients before selecting and planning the therapy. That include: patients expectations, midline position, lip fullness, incisal edge position, tooth shape, disered color change and occlusal schemes. Additionally, only such a detailed concept will facilitate the therapist decision if some degree of

tooth preparation is necessary (slight modification of enamel 0.3–0.5 mm with untouched dentin) or not [94].

All the websites of commercial examples of no/minimal-preparation veneer products (Lumineers by cerinate, Vivaneers, DURAthIn veneers, da Vinci Veneers, MAC Veneers, IPS e.max Press lithium disilicate veneers) have the same advertising claims, but there is very little evidence in the literature about these types of veneers. The exceptions are Lumineers by Cerinate, which have proved clinical successful longevity for peroid of 20 years (94% survival rate) [95]. Certainly, it is essential for unlocking the problems with no-prep technique, to make the proper selection of the patient/case (small teeth with space, with slight lingual alignment). A stronger emphasis on the minimal preparation veneers concept compared to no-preparation veneers is highly advised [96,97].

Still, there are actual polemics about the current trend toward ceramic veneers for everybody, which is negative phenomena that needs correction by the profession. Different modalities, that should be considered as porcelain veneers alternatives, which is overused in everyday practice, are well known: orthodontic therapy, bleaching/whitening teeth, periodontal plastic surgery, tooth recontouring, conservative resin-based composite restorations, all ceramic crowns, and the combination of the above therapies. Most of these mentioned procedures can preserve the tooth structure and grant the patient a pleasant appearance for lifetime [98].

Enclosing this literature review, it must be admitted that tooth preparation design, especially incisal edge design, continues to be one of the most contravercial aspects of porcelain veneers. For now, there are four types of preparation designs proposed as optimal: the window preparation (limited to the labial surface); the feather incisal edge preparation (extended to the incisal margin, but without definite demarcation line); shoulder finish line, butt joint design; and overlapped incisal edge preparation with a palatal chemfer. All the design possibilities have the advantages and weak points, but the very recent studies promote incisal butt joint design with an addition of palatal chamfer as most promising especially in worn tooth structure [99].

The therapist choice is in a large degree determined by the specificity of the clinical case and should be in advance detailed planned through the close communication with the patient and ceramist. Also, it should not be forgotten that the porcelain veneers are extremely demanding conservative modality. Therefore, the satisfying final expectations as well as their clinical longevity could be reached only with the great respect to the next stages in porcelain veneers realization (impression and cementation protocols).

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IZVOD

PORCELANSKE FASETE – PREPARATIVNI DIZAJN: REVIJALNI PREGLED

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Rad diskutuje preparativni dizajn zuba u izradi porcelanskih faseta kroz literaturni revijalni osvrt duži od tri decenije. Upoznajući se sa porcelanskim faseta, dentalna profesija nije prepoznavala na pravi način značaj preparacije zuba koji će nositi fasete, pa su fasete aplikovane na nepreparirane površine zuba. Veliki korak napred u kliničkoj prihvatljivosti porcelanskih faseta donela je tehnika nagrižanja površine gleđi i kontrolisana redukcija ovog tkiva. Poseban akcenat u uspešnoj ekspanziji faseta predstavlja iznalaženje odgovarajućeg dizajna incizalne ivice, kao i rešavanje problema fraktura tankih porcelanskih faseta. U vezi sa tim, rad diskutuje jedan od modaliteta u preparaciji incizalne ivice koji uključuje samo njeno skraćivanje do 2mm, but joint dizajn. Istraživanja pokazuju niz prednosti ovog dizajna u odnosu na palatinalni žleb: optimalan odnos keramike i cementa na palatinalnoj strani, smanjen rizik od postcemetirajućeg loma nastalog polimerizacionom kontrakcijom i prirodnim temperaturnim varijacijama u ustima i dr. Uz to, ovaj dizajn omogućava prezervaciju perifernog sloja gleđi, koji je kritičan u eliminaciji mikropukotine na palatinalnom spoju fasete i zuba, jasno se suprostavljajući silama smicanja. Skraćivanje incizalne ivice je jednostavnije, brže, a laboratorijski model je jasniji. Ravna površina ostavlja bolji oslonac keramičkoj faseti, pa su i rizici loma tankih palatinalnih ivica keramike kontrolisani ovim dizajnom. U novije vreme, prošireno indikativno polje u izradi faseta, koje je donelo brojne specifičnosti u preparativnoj tehnici i dizajnu zuba, biva kritikovano od „back to future“ promotera u struci, koji se zalažu za upotrebu tankih non-prep porcelanskih faseta. Uz to, revijalni pregled apostrofira značaj poštovanja veoma zahtevnih, različitih kliničkih faza u preparaciji zuba za prihvatanje sofisticiranog konzervativnog modaliteta u struci, kakve su porcelanske fasete.

Ključne reči: Literaturni pregled • Porcelanske fasete • Preparativni dizajn