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Review

Dental Ceramics: Fabrication Methods and Aesthetic Characterization

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Abstract: This study aimed to describe different staining protocols for the main dental ceramics. A bibliographic search was conducted in the main health databases PubMed and Scholar Google, in which 100 studies published were collected. In vitro and in silico studies, case reports, and systematic and literature reviews, on ceramic materials, were included. Therefore, articles that did not deal with the topic addressed were excluded. Ceramics can be classified into glass-matrix ceramics (etchable), polycrystalline (non-etchable), and hybrid ceramics. In this context, different fabrication methods, method indications, and characterization layers can be used for each ceramic group and numerous protocols differ according to the choice of material. Several ceramic systems are available, thus professionals in the prosthetic area need constant updates on dental ceramic restorations and their proper characterizations.

Keywords: ceramics; dental materials; dentistry; dental research

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1. Introduction

In recent decades, the dentistry community has studied restorative materials with excellent optical properties and able to restore form and function, given the mechanical requirements of the anterior and posterior areas [1,2].

Metal-free restorations have gained notoriety, especially for rehabilitation with superior aesthetic outcomes [3]. These materials have properties that justify their use, including high resistance to compression and abrasion, high chemical stability, high tensile strength, biocompatibility, favorable aesthetics, translucency, opalescence, opacity, fluorescence, and coefficient thermal expansion similar to the natural tooth [4]. Thus, several ceramic systems are available, and they can be classified as glass-matrix, polycrystalline, or hybrid (resin-matrix) ceramics [5].

To reduce the failures caused by different coefficients of linear thermal expansion between framework and veneer ceramics, it was proposed to simplify the technique and use monolithic ceramic restorations [6]. However, single-crown restorations can present an aesthetic compromise, especially in cases that require greater detail [7,8].

To eliminate this aesthetic issue, it was proposed to add staining layers on the surface of ceramic materials [9,10]. These characterizations make it possible to personalize the restorations and guarantee a satisfactory aesthetic [11,12]. In turn, this characterization layer can suffer dissolution of the pigments, presenting lower color stability than the intrinsic stain [13–15].

The glaze layer added over the characterization layer plays a very important role in the long-term preservation of ceramic pigments, as it limits color changes and wear of ceramic pigments. The wear of restorative materials occurs due to the adversities of the oral environment, such as the presence of microorganisms, parafunctional habits, and contact between antagonists during chewing activities. Studies indicate that this layer of glaze applied over a sintered or crystallized ceramic could remain in function for up to 12 years [16–19].

Despite the routine use of stains in monolithic restorations, these are still performed without a protocol that allows reproducibility of the procedure. In this sense, the present study aimed to expose the main ceramics and their characterization protocol based on a literature review. Added to this is the lack of information in the literature regarding the best method of characterizing the surface layer of ceramic structures, since this procedure is heterogeneous, carried out by the professionals.

2. Materials and Methods

Source Selection

A bibliographic search was conducted in the main health databases PubMed and Google Scholar (accessed on 3 March 2022), in which studies published from 1980 to 2022 were collected. In the second stage, the studies were selected by reading the full contents. Two authors (JDMM and GRSL) performed stages 1 and 2. In vitro and in silico studies, case reports, and systematic and literature reviews, collected on ceramic materials with information on the staining layer on the ceramic restorations, the thickness of restorations, monolithic restorations, aesthetic characterization of the surface of ceramics, and analysis of the properties of roughness and hardness in ceramic materials written in English, were included. Therefore, articles that did not deal with the topic addressed were excluded.

3. Results

Through bibliographic research, 100 articles were selected, of these, 90 were extracted from PubMed and 10 from Google Scholar. The following titles of specific medical subjects and keywords were used: Ceramics (DeCS/MeSH Terms), Dental Materials (DeCS/MeSH Terms), Dentistry (DeCS/MeSH Terms), Dental Research (DeCS/MeSH Terms).

4. Literature Review and Discussion

Ceramics can be classified into glass-matrix (etchable), polycrystalline (non-etchable), and hybrid ceramics (etchable and non-etchable). In this context, different characterization layers can be used for each ceramic group and the numerous protocols differ according to the material [4,5,20–24]. The staining layer applied on the ceramic surface must be fired at specific temperatures [25].

Etchable ceramics (feldspathic, leucites, silicates, and lithium disilicates) have a high glass content, thus, a high silica content is present in this material, offering a better aesthetic property [4,5,20,26–28]. In contrast, non-etchable ceramics (zirconia, alumina) have a low silica content, but a high crystalline content, allowing the material to present a high mechanical performance [4,5,20,26–29]. A characterization protocol commonly used by laboratories for these two ceramic groups is the powder and liquid application technique (layering). For lithium silicate or disilicates, an initial crystallization is necessary, as the material is pre-crystallized, so after the firing procedure, the material undergoes nucleation followed by the growth of crystals to obtain lithium metasilicate [21–25,30–32]. As for polycrystalline ceramics, for example, zirconia needs a sintering firing, as the material before going to the oven is pre-sintered, to heat the particles below their melting point, promoting densification of the components [4,5,9,24,33,34]. This property of zirconia prevents the growth of cracks with the transformation of the phase from tetragonal to monoclinic [4,5,24]. Immediately after this initial firing, with the aid of a brush, a paste made up of powder (stain) specific to each manufacturer and modeling liquid should be prepared [24,25,31,32]. The liquid can be distilled water mixed with rheological modifiers, or a manufacturer-specific fluid mixer [24,25,31,32]. The prepared paste is then applied to the external surfaces of the ceramic restorations, accompanied by one or more characterization firing cycles until reaching the aesthetic color of interest [24,25,31,32].

In this context, to achieve a satisfactory aesthetic, several subsequent firing procedures may be necessary [35]. These processes, in turn, promote the stress concentration on the ceramic surfaces [36]. Therefore, a commonly discussed concern is the relationship by which the characterization procedures can lead to a modification of the crystalline content of the ceramic, changing the mechanical properties of the material [35]. However, there is no consensus in the literature regarding the different firing protocols and their effect on the mechanical behavior of the application of ceramic stains in indirect restorative materials [37].

The characterization of hybrid ceramics occurs differently from other ceramics since this process occurs through photoactivation [23–25,31,32,38]. Therefore, it cannot be oven treated because it is a material that has a network of polymers in its composition, so at high temperatures, it would suffer deformation of its structure [23–25,31,32,38]. It is worth mentioning that the staining technique is the only possible characterization for this ceramic group since it is obtained by a CAD–CAM block [38].

4.1. Ceramic Restorations

Metal-ceramic crowns have been used for many years as the first treatment option for compromised teeth. The metal provides great resistance to fracture but presents an unfavorable aesthetic. However, this application is made in layers, sculpting the anatomy of the tooth associated with the use of different porcelain colors. The association of different masses intrinsically allows greater control of the more opaque and more translucent regions (Figure 1). The literature points out that some ceramic materials can successfully replace metal alloys, giving rise to metal-free restorations [39–41].

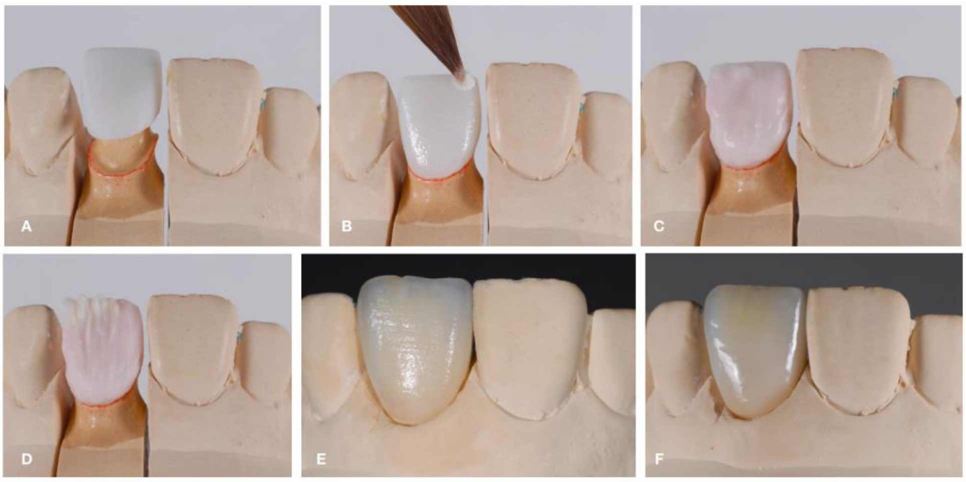

Figure 1. Layering technique. (**A**) Polycrystalline Framework; (**B**) Feldspathic ceramic build-up (wash bake); (**C**) Feldspathic ceramic build-up (intensive chrome + dentin); (**D**) Feldspathic ceramic build-up (enamel layer); (**E**) Feldspathic ceramic after firing; (**F**) Feldspathic ceramic after thermal and mechanical glaze.

The technical and scientific advances in the mechanical and chemical properties of ceramics have broadened their clinical indication, becoming the restorative material of choice for professionals and patients with aesthetic needs [3,41]. Several ceramic systems can be used in metal-free restorations, both etchable and non-etchable. In this sense, other forms of processing stand out, including press and milling, but extrinsic painting is necessary to obtain the final shape of the part [42].

Among ceramic materials, zirconia is the one with the greatest resistance, in addition to high fracture strength [43]. In turn, exposing a peculiar characteristic called martensitic transformation, which is a mechanism characterized by the change from tetragonal to monoclinic phase during compression stresses in the crystalline matrix, guarantees an increase in the granular volume of approximately 3% and inhibition of crack propagation [44,45].

In addition, another important advance in contemporary dentistry is monolithic single-crown ceramics, which appeared to minimize the chipping of the veneer ceramics when applied over crystalline frameworks, mainly explained by the differences in the thermal expansion coefficient between these two materials [6].

Professionals must know the chemical composition and clinical performance of current dental materials, thus allowing the choice of the most suitable restorative material for each treatment and consequently, providing greater longevity. To study the behavior of a material, it can be subjected to clinical simulations, although with some limitations in controlling variables, such as masticatory forces and individual oral conditions [46,47].

4.2. Ceramic Restorations Thickness

Ceramic restorations can have different thicknesses depending on the ceramic system used, tooth preparation design, and the interocclusal space. In general, there are specific recommendations for a minimum thickness that offers mechanical strength for each category of ceramic material, depending on the region and the type of restoration, such as feldspathic ceramics, which must have a minimum thickness of 2.0 mm, leucite with 1.5 mm and lithium disilicate with 1.0 mm. Polycrystalline ceramics, alumina, and zirconia, on the other hand, must have a minimum space of 0.3 mm. It is worth mentioning that traditionally, polycrystalline ceramics can present an aesthetic compromise due to the high crystalline content in their composition. Ceramics behave with inversely proportional quantities, that is, the greater the aesthetics, the lower the resistance [48]. Seeking to overcome this limitation, high-translucency zirconia (Y-ZHT) has emerged, an yttrium-stabilized tetragonal zirconia polycrystalline ceramic (Y-TZP), but with differences in the microstructure of its precursor material and the size of the grains, giving this material better optical properties [49]. It is worth mentioning that all the mentioned restorative materials can be used in the form of monolithic ceramics from prefabricated blocks for CAD–CAM systems.

In bilayer ceramic systems (zirconia framework + glass-matrix ceramic veneer), chippings or cracks usually start at the interface between the framework and the veneer ceramic [50]. In addition, another disadvantage observed is the weak connections caused by the residual tensile stress developed during the application process of the veneer ceramic [51]. To overcome such failures, monolithic crowns have been indicated, as they present a better performance during masticatory function since the final restoration consists of only one material [52,53].

The thickness of the ceramics is directly related to their optical and mechanical properties, that is, each material needs a minimum thickness to perform the restorative needs [50]. However, this thickness can influence the polymerization of resin cement and, consequently, change the bond strength of the materials used and compromise the restorative treatment [54].

Martins et al. (2018) [55] evaluated the influence of the different thicknesses of lithium silicate restorations on the degree of conversion of resin cement, through a systematic review. The results showed that the translucency imposed on lithium silicate significantly reduced light transmission when activated through the ceramic. It is concluded that the finer the ceramic material, the greater the polymerization of the cementing agent, in turn, a thickness greater than 1.0 mm drastically reduces the polymerization of resin cement.

Turp et al. (2018) [54] studied the influence of the thickness of monolithic restorations in zirconia and lithium disilicate on the polymerization efficiency of dual resin cement. Twelve ceramic discs (4.0 mm diameter) with thicknesses of 0.5, 1, 1.5, 2, 2.5, and 3 mm were prepared from monolithic zirconia (Previous Prettau®, Zirconzahn; n = 6) and lithium disilicate (IPS e.max® CAD HT, Ivoclar Vivadent; n = 6). Three dual-curing resin cements (Panavia F 2.0—Kuararay, DuoLink Universal ™—Bisco, and RelyX ™ U200—3M Espe) were used for polymerization under ceramic discs. For each resin cement, 10 specimens were prepared by light-curing under monolithic zirconia and lithium disilicate discs of each thickness. The Vickers microhardness of resin cement decreased significantly with increasing measurement depth and increasing thickness of monolithic zirconia or lithium disilicate ($p < 0.001$). Cement polymerized under lithium disilicate had higher microhardness values than those polymerized under zirconia ($p < 0.001$). For both ceramics, Panavia F 2.0 exhibited the highest microhardness, followed by DuoLink Universal and RelyX ™ U200 ($p < 0.001$). It is concluded that different dual-cure resin cements can have different polymerization efficiencies, and the type and thickness of the overlapping ceramic can directly influence the polymerization. It is interesting to elucidate that the findings of this study suggest that an increase in the thickness of monolithic lithium disilicate or monolithic zirconia restorations significantly decreases the microhardness of the dual-cure resin cement. Resin cement can also be used for the cementation of anterior monolithic zirconia restorations up to 2 mm thick and for monolithic lithium disilicate restorations up to. However, for lithium disilicate with restorations $\geq$ 2.5 mm thick and zirconia $\geq$ 2 mm thick, cementation approaches need further study.

4.3. Monolithic Restorations

Monolithic glass-matrix ceramics are increasingly presented as an alternative treatment for aesthetic dentistry [34,56]. Digital dentistry has simplified the manufacture of these restorations, including ceramics that seek to combine aesthetics and mechanical resistance [57]. These restorations have durability compatible with metal-ceramic restorations and superior aesthetic outcomes, even with color limitations in the single block [58]. The color of these restorations can be influenced by manufacturing processes, laboratory procedures, and clinical factors [57]. The manufacturing processes determine the basic optical properties of this class of ceramic; however, several laboratory resources are available to improve these properties [59]. It is worth mentioning that clinical factors such as the characteristics of the dental substrate, the cement, and the material itself can influence the final result of the restorative treatment [60]. An advantage of the CAD–CAM system is the fact that the sintering of the porcelain block is carried out by the manufacturer in an optimized way, as it presents a reduction in porosities, thus improving the final quality of the restoration obtained. The disadvantage of this block is that it is a monolithic restoration, and its aesthetics are difficult. Different ceramics are available for the CAD/CAM system. To obtain these restorations, different companies offer feldspathic, glass-ceramic, and polycrystalline ceramic blocks [61].

Monteiro et al. (2018) [62] evaluated the effect of ceramic thickness on the fatigue failure of two glass-matrix ceramics composed of lithium silicate reinforced with zirconia (ZLS), cemented to a material similar to dentin. Disc-shaped specimens were allocated into eight groups (n = 25) considering two factors of the study: ceramic type ZLS (Vita Suprinity—VS; and Celtra Duo—CD) and ceramic thickness (1.0; 1.5; 2, 0, and 2.5 mm). A "trilayer" set (ϕ = 10 mm; thickness = 3.5 mm) was designed to mimic a cemented monolithic restoration. Before cementation (Variolink N), all-ceramic discs were conditioned and silanized. The fatigue failure load was determined using the "Staircase" method (100,000 cycles at 20 Hz; initial fatigue load ∼60% of the average monotonic load to failure; step size ∼5% of the initial fatigue load). A stainless-steel piston (ϕ = 40 mm) applied the load to the center of the specimens in water. Fractographic analysis and finite element analysis (FEA) were also performed. The thickness of the ceramic influenced the fatigue failure load for both ZLS materials: Suprinity (716 to 1119 N); Celtra (404 to 1126 N). Results of the FEA showed that the decrease in the thickness of the ceramic led to a higher concentration of stress in the cementation interface and that the thicker it is, the lower the concentration of stress in the tensile surface. Different thicknesses of ZLS glass-ceramic influenced the fatigue failure load of the cemented system (the thicker the glass-matrix ceramic, the greater the fatigue failure load). It was concluded that differences in the microstructure of these ceramics can influence their behavior under fatigue.

Riccitiello et al. (2018) [63] evaluated the internal and marginal adaptation of monolithic zirconia and lithium disilicate crowns, produced by different manufacturing procedures. Forty-five human premolars were prepared for single crowns using standardized preparations. Ceramic crowns were manufactured using CAD–CAM or press procedures and cemented with universal resin cement. The non-destructive scanning of the micro-CT was used to evaluate the marginal and internal adaptations in the coronal and sagittal planes, then the measures of the precision of adjustment were calculated in software and the results were analyzed through one-way ANOVA and Tukey test. The injected lithium disilicate crowns were significantly less accurate at the prosthesis margins ($p < 0.05$), while they performed better on the occlusal surface ($p < 0.05$). No significant differences were observed between CAD–CAM zirconia and lithium disilicate crowns ($p > 0.05$). As for the thickness of the cement layer, reduced amounts of the cementing agent were observed on the preparation margins, while a thicker layer was reported on the occlusal surface. It was concluded that the marginal gaps registered were within the limit of clinical acceptance, regardless of the restorative material and manufacturing procedures. CAD–CAM processing techniques for zirconia and lithium disilicate produced marginal gaps that were more consistent than press procedures.

Nishioka et al. (2018) [64] evaluated the fatigue strength of five different ceramic materials indicated for monolithic restorations: feldspathic ceramic (FC), hybrid ceramic or polymer infiltrated ceramic (PIC), lithium disilicate (LD) glass-ceramic, lithium silicate glass-ceramic reinforced with zirconia (ZLS), and high translucency yttrium-stabilized polycrystalline tetragonal zirconia (YZHT). The samples were made in a disc shape according to the ISO 6872 standard. After obtaining the average of each material (n = 5) of the monotonic load-to-failure tests, the specimens (n= 20) were subjected to "Staircase" fatigue tests using a biaxial bending configuration (piston-in-three balls), to determine fatigue strength. The parameters used for the tests were: 100,000 cycles at 10 Hz, the initial load of 60% of the average load for failure, and a step size of 5% of the initial load (specific for each ceramic material). The Kruskal–Wallis and Bonferroni test ($\alpha = 0.05$) were used to analyze the fatigue resistance data. The difference in fatigue strength (MPa) of the materials was statistically significant, with the following values: YZHT (370.2 ± 38.7) > LD (175.2 ± 7.5) > ZLS (152.1 ± 7.5) > PIC (81.8 ± 3.9) > FC (50.8 ± 1.9). Thus, it can be concluded that, in terms of fatigue, high translucency polycrystalline zirconia showed the best performance as a restorative material, since it supports the greatest load before fracturing.

Given the analyses under clinical conditions and the mechanical behavior of dental ceramics, it is known that different compositions, microstructures, and properties can change performance when exposed to fatigue loading. Thus, to better understand the susceptibility to crack propagation under intermittent loads, it is relevant to compare the fatigue strength of new ceramic materials indicated for monolithic restorations [65].

4.4. Aesthetic Characterization of the Ceramic Surface

Major developments have occurred with dental ceramic materials, mainly due to the use of CAD/CAM technology, which has enabled the milling of highly rigid ceramics. However, the pre-defined color of the block is a difficulty found in the biomimetics of clinical cases with greater aesthetic requirements [19].

To improve aesthetic properties and achieve similarity to natural teeth, techniques for characterization of the surface are performed on monolithic glass-ceramic restorations [66,67]. In this context, there are three main processing methods: layering, pressed, and milled techniques (Table 1, Figures 1–3).

Table 1. Processing Methods.

Layering and/ or Staining	(1st) Making a suspension (Paste): Union of porcelain powder + distilled water mixed with rheological modifiers and/or manufacturer's specific diluent = Formation of viscous suspension, in which the indirect restoration of the ceramic can be built. (2nd) The restoration is made by mixing the porcelain powder with the styling liquid until a paste is formed and applied with a brush on the refractory die. This application is done in layers, to conform to the anatomical shape of the tooth. Another reason for applying several layers is the use of different porcelain colors, to allow greater reproduction of details of both dentin and enamel. The addition of metallic oxides (Al, Ca, Li, Mg, K, Na, Zr, Ti, among others) in dental ceramics will determine its final color, resulting from the firing of the material at high temperatures. For each layer applied, it is necessary to condense the paste by removing excess water. This can be done by vibrating with subsequent application of an absorbent paper or through specific dental vibrators for this processing. After completing the characterization steps, the restoration must be taken to a specific oven for dental ceramics, where the firing will be carried out. This process acts directly on the union of the dust particles, increasing the density of the mass by reducing porosities [23–25,31,38]. (3rd) Initially there is a preheating (drying) of the condensed porcelain mass at temperatures of approximately 400–500 °C for 5 min in the door of the preheated oven. This step ensures that the water slowly evaporates without causing damage to the mass. In the next step, once inside the oven, the restoration is heated to a maximum firing temperature of approximately 700–980 °C for 1 min at a speed of 40 to 90 °C/min. During this process, a vacuum pump is activated and guarantees a low-pressure vacuum (0.1 atm) inside the oven. When the maximum cycle temperature is reached, the pump is turned off and the external air (with a pressure of 1 atm) enters the oven again, increasing the pressure inside the muffle by 10 times. Thus, sintering/crystallization is a procedure for coalescing solid particles, not changing the chemical composition, only allowing the sculpting of the anatomy of a dental piece. It is worth mentioning that professionals should always follow the manufacturers' recommendations. Ceramic restorations at elevated temperatures do not melt the particles, they just expand and modify. As a result, deformation can occur in the prosthetic structure. On the other hand, at low temperatures, the material cannot adhere to the restoration.
Pressed	(1st) Initially, the wax pattern is made and included in a coating ring. Then, this set must be heated in an oven. (2nd) The press phase of the pre-ceramic ingot is a crucial step for the press processing technique, where it is performed in a specific oven. The glass-matrix ceramic ingot is placed inside the ring's feeding duct followed by an alumina plunger that will be responsible for injecting the vitro-ceramic when it is fluid. The ring-ingot-plunger assembly is taken into the injection furnace where it will undergo a thermal cycle lasting approximately 30 min. When reaching the maximum temperature, in which the ceramic is high fluidity, a plunger present inside the oven touches the alumina piston, pushing it into the ring. The result is the injection of the ingot, which takes the form of the restoration molded by the coating. (3rd) After the end of the cycle and the cooling of the ring, the coating is cut with a carbide disc and the part is removed from the inside, therefore, adjustments are necessary; especially in the case of glass-matrix ceramics, as the prosthetic structures receive a final characterization with a staining layer and glaze, since the restoration just out of the oven is monochromatic.

Table 1. *Cont.*

Milling—Computer Aided Design and Computer Aided Manufacturing (CAD–CAM)	(1st) Initially, a digital image is acquired in a three-dimensional plane of the prepared tooth, and then it is constructed on a computer (.STL file). This image can be obtained directly from the prepared tooth with a digital intraoral scanner or scanning a plaster model with a desktop scanner. On the digital image of the prepared tooth, the digital image of the final restoration is constructed with the help of specific software. The dimension and shape information of the restoration is then sent to a milling unit in which the ceramic restoration is made [25,68–79]. (2nd) After obtaining all the digital information, the milling step of a previously sintered/crystallized block is started under ideal conditions by the manufacturer. This block is milled by two diamond tips coupled in fully articulated arms until acquiring the final shape of the restoration, proposed in the software. (3rd) After the milling step is finished and marginally adjusted, the subsequent finishing (glaze or polishing) is performed. In some cases, it is necessary to stain the prosthetic restoration associated with a characterization firing. It is interesting to clarify that in ceramics with polymers in their composition, after the pigmentation stage, the structure must be light-cured.

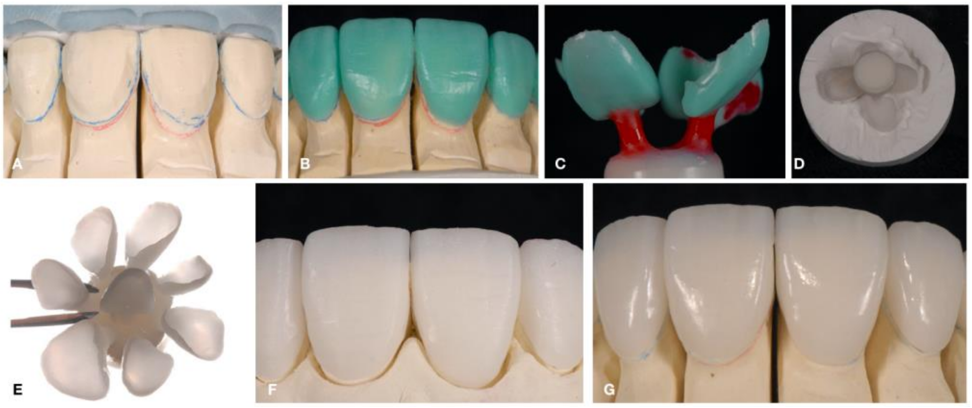

Figure 2. Pressed technique. (**A**) Stone model and putty matrix from diagnostic wax-up; (**B**) Wax-up; (**C**) Sprueing, investing, and pressing; (**D**) Divesting; (**E**) Removing the reacting layer; (**F**) Staining, firing, and glaze; (**G**) Final restoration.

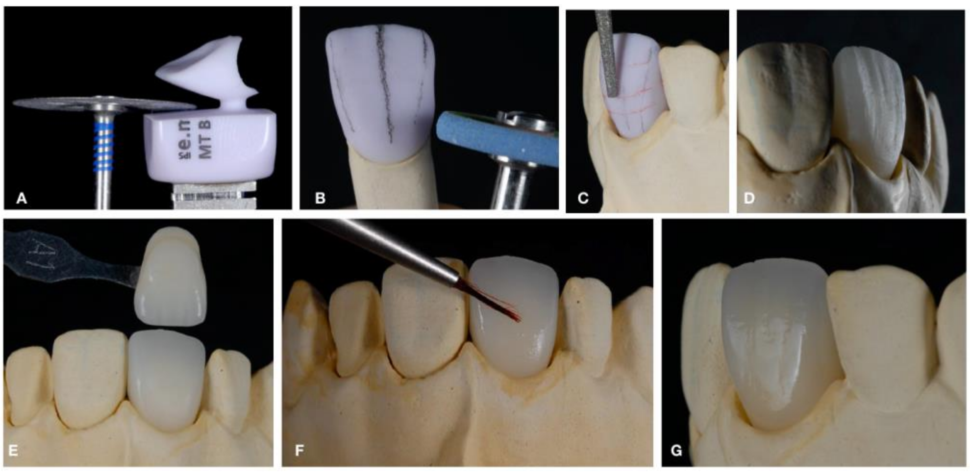

Figure 3. Milled technique. (**A**) Cutting out milled restoration from CAD/CAM block; (**B**) Controlling the margin's thickness (emergence profile); (**C**) Controlling macro- and micro-texture (finishing); (**D**) After crystallization; (**E**) Stain technique; (**F**) Glaze; (**G**) Final restoration.

One type of material used to carry out this characterization, whether in glass-matrix or polycrystalline ceramics, is composed of SiO_2, Li_2O, K_2O, P_2O_5, Al_2O_3, ZrO_2, CeO_2, Na_2O, CaO, TiO_2, ZrO_2, Y_2O_3, HFO_2, respectively, in addition to colored oxides or pigments, called effect stains or stain fixation, composed of two contents, one powder, and the other liquid [25,31,38]. The two contents must be agglutinated to obtain a homogeneous paste, which must be applied on the external surface of the ceramic. This paste allows for masking of opaque structures and increasing or reducing the translucency and intensity of the pigmentation proposed for restorations [31,80,81].

Another characterization used for dental ceramics that have a more crystalline content is the application of glaze, which allows superficial smoothness, thus preventing the accommodation of microorganisms, in addition to providing a translucency compatible with the natural tooth [21,31]. There are reports that this type of extrinsic characterization of ceramics can remain for up to 12 years, however, the surface roughness may increase over the years, mainly in areas that do not receive a functional load [17,82,83].

These property changes need further studies since ceramics with a rough surface have already been shown to be more susceptible to the coloring of external sources [65]. The texture can still influence the final result of the restorative treatment, since the surface texture changes the reflection of light and consequently, the color value of the ceramic. Excessive texturing can still result in the artificiality of the restoration [19,21,22,84]. Other possible deleterious actions caused by superficial roughness are easier plaque accumulation and greater wear of antagonistic teeth [19,84].

However, there is still no protocol established for the use of extrinsic characterizations of ceramics that guarantees a reliable final result [22]. In most cases, the crystallization, polishing, and glaze procedures are carried out arbitrarily, which makes it difficult to understand the behavior of these materials [22,84,85].

The different ceramics of the CAD/CAM system have high survival rates in long-term follow-up when single crowns or even fixed partial prostheses are used, as long as the clinician uses the ceramic according to their indications. The studies make it clear that more clinical studies should be carried out to have more long-term information on these ceramics [39,64,72].

4.5. Analysis of the Roughness and Hardness Properties of Ceramic Materials

The roughness description is presented by linear or bidimensional parameters (Ra, Rq, Rz, RSM, and Rmax) and by three-dimensional parameters (Sa, Sq, Sz, Scx, Str, and Sdr) [86]. Ra is defined by the average arithmetic value of all absolute distances within the measured length, which is the parameter most used to evaluate ceramic surfaces [87,88].

Roughness is one of the properties that influences the wear behavior of antagonistic teeth [89] and can also interfere with the fatigue resistance of the material [90]. Another property able to interfere with the performance of restorative materials is hardness. The enamel hardness value ranges from 300 to 600 HV [91], these values are close to the hardness of glass-matrix ceramics, such as zirconia-reinforced lithium silicate [62,92–95]. Thus, glass-matrix ceramics prevent excessive wear of antagonistic teeth, while also presenting a satisfactory survival rate for a restorative material [35,96]. Feldspathic ceramics have a lower hardness value when compared to silicates, so physiological wear simulations can show a greater fragility of these materials [97–100], while polycrystalline ceramics, such as tetragonal zirconia partially stabilized by yttrium, present high hardness values and when subjected to physiological tests can promote excessive wear of antagonists [75,76,97].

5. Conclusions

Several ceramic systems are available, thus professionals in the prosthetic area need to be updated about the techniques, materials, and their proper characterizations. Aesthetic results with ceramics are not achieved exclusively by the type of material used, but by the standard adopted in the characterization of the veneer ceramic. The characterization of ceramic restorations becomes clinical routine; however, these are not performed with a protocol that allows the reproducibility of the procedure. There is still no best method for characterization of the surface layer of ceramic structures since the data is discrepant in the literature. Therefore, further studies are needed concerning the staining layer on ceramics.

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