

Review of Different Materials that can be CAD/CAM Processed

Description, chemical composition, indications in dentistry areas

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The objective of this paper is to inform on the indications, appearance and advantages offered by each category of materials used in CAD / CAM technique for different prosthetic restorations. Modern techniques in restorative dentistry include CAD/CAM systems and materials that can be CAD/CAM processed. It is very important to know the physical-chemical properties and the indications of these materials to translate the patient's wishes to reality providing the ideal restoration. There are a variety of CAD/CAM materials to choose from, all designed to provide efficient restoration design and production. We can choose from available materials including glass ceramics, nano ceramics, zirconia, hybrid ceramics, BioHPP, in blocks or disks form.

Keywords: CAD/CAM technology, CAD/CAM materials, properties, indications

In dental medicine, the largest development of CAD / CAM systems occurred in the 1980s. Three pioneers contributed to the development of current CAD / CAM systems, the first of which was Dr. François Duret. From 1971 he started making crowns that had the functionally modeled occlusal surface, using a series of systems that started with the optic impression of the tooth, followed by the dental crown design, taking into account the functional occlusal movements and then, milling the prosthetic restoration using a numerically controlled milling machine [1,2].

Later he developed the Sopha system which had a major impact on the development of CAD / CAM dental systems worldwide. The second pioneer in the field of CAD / CAM systems in dental medicine was Dr. Werner Mörmann, who, in 1986, together with Dr. Marco Brandestini developed the first commercial CAD / CAM system: the CEREC system. He directly measured a prepared cavity with an intraoral scanner, followed by the design and milling of an inlay using a ceramic block and a compact machine. The third pioneer in the field of dental CAD / CAM systems was Dr. Matts Andersson, the developer of Procera system [1,2].

Dental materials that can be processed with CAD / CAM systems[3]:

1. Metals: titanium, titanium alloys, chromium-cobalt alloys
2. Resin based materials: these are based on methyl polymethylacrylate (PMMA)
3. Wax
4. Silica-based ceramics (fine-structure feldspar ceramics, leucite-reinforced feldspathic ceramics, lithium-disilicate ceramics)
5. Infiltrated ceramics
6. High performance oxide ceramics (aluminum oxide, zirconium dioxide)
7. Hybrid ceramics
8. Glass ceramics armed with zirconium

9. Nano-Ceramics

10. Polyether ether ketone (PEEK) and polyether ketone ketone (PEKK)

11. BioHPP

Depending on the CAD / CAM system, the list of materials that can be CAD/CAM processed may be wider or narrower, some materials requiring milling in wet environment, others in the dry or even dry-wet environment.

Generally, zirconium dioxide, wax and poly-methyl methacrylate used for temporary restorations, are milled in the dry environment. Zirconium dioxide and methyl poly-methacrylate can also be milled in the wet environment.

Wet milling is mandatory when milling disilicate lithium-based ceramics, feldspathic ceramics and composite resins.

1. Metals

- Co-Cr Alloys (fig.1) have advantages which include: the speed of the process, the high quality of work, the safety of the process due to wet processing, the clean, purely digital workflow.

Table1
CHEMICAL COMPOSITION [4]

Components	Specified as wt%:
Co	Rest at 100%
Cr	28.5 ± 1.5
Mo	6.0 ± 1.0
Mn	≤ 1.0
Si	≤ 1.0
Fe	≤ 0.75
Ni	≤ 0.1
C	≤ 0.02

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Indications in dentistry areas: Crown caps and crowns in the anterior and canine region, Bridges in the anterior and posterior regions with max. 2 pontics, Cone and telescoping crowns, Bars [4].



Fig. 1. CAD/CAM Co-Cr disk and blocks (InCoris CCB, Dentsply Sirona) [4]

- Titanium alloys (fig.2)

Titanium requires wet milling, and cobalt chromium is generally milled in the wet environment but in some situations may require dry milling. Precious metals are milled less because of the increased attrition of the material and the high cost price.

Chemical composition of titanium alloys : Ti 89.0%, Al 6.4%, V 4.1%, O 0.1%, Fe 0.13%, altele 0.1%.

This material is available in several sizes and lengths, for almost any type of device. It has the following characteristics: bending strength: 760-850MPa, elongation: 8-14, elasticity: 825-985MPa, density: 4.4g / cm³ [5].

Indications in dentistry areas: implant retained superstructures eg. Implant bars, individual abutments, crowns and bridges for the veneering with ceramic and composite [6].



Fig. 2. CAD/CAM Titanium disk and blocks (System Ti, Adentatec GmbH) [6]

2. Resin Based Materials (PMMA)

Resin-based materials: these are based on methyl polymethacrylate (PMMA) and are suitable for performing temporary prosthetic restorations, respectively for checking prosthetic restorations for a long time, before milling them out of zirconia, or other more expensive materials. At the same time, the models of the future prosthetic restorations can be made from calcinable PMMA.

Chemical composition: Polymethylmethacrylate (PMMA) and cross-linked polymers based on methacrylic ester, colorants [7].

Indications in dentistry areas: Anterior and posterior crowns, bridges with max. 2 pontics, surgical guides.



Fig. 3. Resin based materials (Ceramill PMMA clear, Ceramill Temp) [8]

Vita CAD Temp can be monochrome (Vita CAD Temp monoColor) or polychrome (Vita CAD Temp MultiColor) [7] and Ceramill PMMA is transparent and Ceramill Temp is monochrome (fig.3).

3. Wax

Wax is a cheaper alternative for the design of prosthetic restorations by CAD / CAM technique. This wax has a high melting point and resistance to fracture and deformation, allowing try-in of the restoration into the oral cavity. It comes in the form of blocks or disks and depending on the manufacturing company it can have different colors. Dentsply Sirona wax discs are available in two colors, gray and ivory and are suitable for casting and pressing metal and ceramic works.

The wax discs from Ivoclar Vivadent (ProArt Cad) are available in 3 colors: Blue-ideal for the manufacture of crown models and bridges for the casting technique; Pink - ideal for try-in wax models and personalized occlusion wax patterns for printing; Yellow wax discs used for pressing technique (fig. 4).

Chemical composition : 10-80% polyethylene wax, 10-70% low density polyethylene homopol (LD Polyethylene Homopol), 1 % - 20 % Esther of hydrogenated colophony constituents [9].

Indications in dentistry areas: metallo-ceramic restoration try-in, crowns and bridges obtained by the casting technique, restoration model obtained by pressing technique, digital wax-up

The CAD CAM wax from Kulzer is available in three colors, with different hardness (from hard, to elastic), the gray one is indicated for the digital wax-up technique and the crown layouts in the front area, the blue one is indicated for the crown layout. and the bridges for the lateral area, and the green one is indicated for obtaining the metallic skeleton of the partial prostheses (fig.5).

4. Silicate ceramics

Silicate ceramics are the most used ceramics for CAD/CAM systems.

-Feldspathic ceramics with fine structure

Table 2
CHEMICAL COMPOSITION OF FELDSPATHIC CERAMICS

Oxide	% of total weight
SiO ₂	56 - 64
Al ₂ O ₃	20 - 23
Na ₂ O	6 - 9
K ₂ O	6 - 8
CaO	0,3 - 0,6
TiO ₂	0,0 - 0,1

Indications in dentistry areas: inlay, onlay, veneers, partial crowns, anterior or posterior crowns

The blocks can be monochrome or polychrome.

The two types of monochrome blocks have abrasive properties similar to enamel; they have a special



Fig. 4. CAD/CAM wax disks

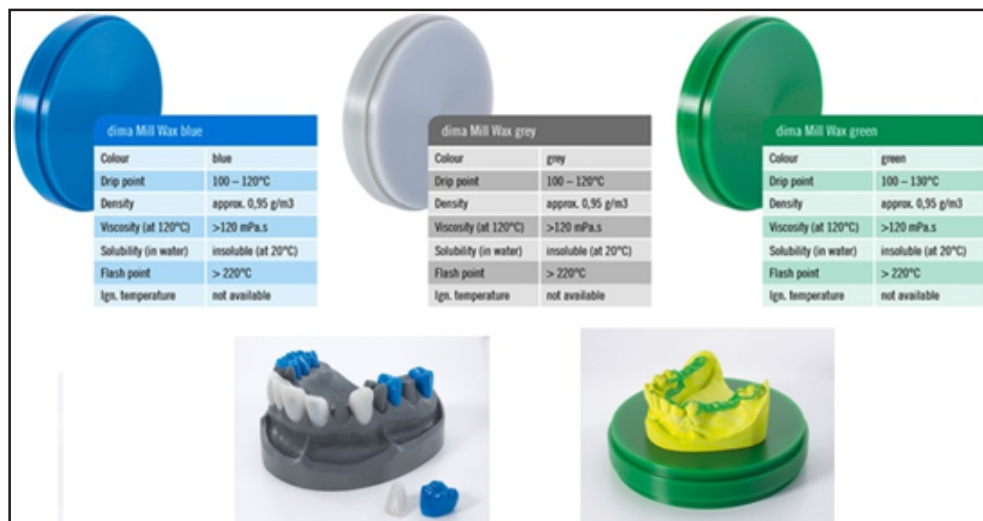


Fig. 5.CAD/CAM wax from Kulzer: properties and indications [10]

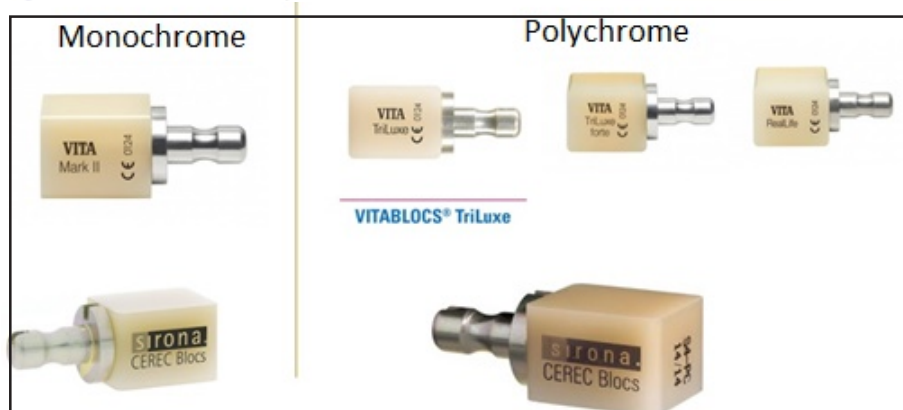


Fig. 6. Feldspathic ceramic CAD/CAM blocks [11,12] 13]

translucency and special finishing properties that most often do not require the application of glaze.

The polychrome blocks, besides the above mentioned properties, have 3 levels of color intensity present in a single block, being able to better imitate the dental structure - Leucite-reinforced feldspathic ceramics

Table 3

CHEMICAL COMPOSITION OF LEUCITE-REINFORCED FELDSPATHIC CERAMICS [

Standard composition:	(in weight %)
SiO ₂	60.0 - 65.0
Al ₂ O ₃	16.0 - 20.0
K ₂ O	10.0 - 14.0
Na ₂ O	3.5 - 6.5
Other oxides	0.5 - 7.0
Pigments	0.2 - 1.0

Indications in dentistry areas : Inlay, onlay, veneers, endo crowns, anterior/posterior partial or full crowns

Monochrome IPS Empress CAD - these blocks have a bending resistance of 160 Mpa; it presents outstanding color properties, being able to choose between shades from A to D on the classic color key as well as shades for whitened teeth; These blocks can be HT (high translucency), LT (low translucency) or MO (medium opacity) - indicated for masking colored teeth [14].

Polychrome IPS Empress CAD Multi- These blocks have chameleon effect as well as fluorescence similar to neighboring dental structures.



Fig. 7. IPS Empress CAD blocks [15]



- Lithium disilicate ceramics

Table 4

CHEMICAL COMPOSITION OF LITHIUM DISILICATE CERAMICS [16]

Standard composition:	(in % by weight)
SiO ₂	57.0 – 80.0
Li ₂ O	11.0 – 19.0
K ₂ O	0.0 – 13.0
P ₂ O ₅	0.0 – 11.0
ZrO ₂	0.0 – 8.0
ZnO	0.0 – 8.0
Al ₂ O ₃	0.0 – 5.0
MgO	0.0 – 5.0
Colouring oxides	0.0 – 8.0



Fig. 8. Lithium disilicate ceramics CAD/CAM blocks and disk [18,19]

Indications in dentistry areas: Veneers (0.4 mm), inlay, onlay, table tops and partial crowns, - Minimally invasive crowns (≥ 1 mm), Supraimplant structures, Bridges of three elements whose distal element is at most the second premolar.

IPS e-max CADs have a rolling resistance of 360 Mpa

They have a great color stability, abrasion resistance and superior aesthetics which makes this material very useful [17].

5. Infiltrated ceramics, which involves obtaining the milling blocks to create a porous core which is then sintered and infiltrated with a lantern-based glass, producing two continuous interlocking networks: a glass phase and a crystalline infrastructure that can be alumina, spinel or zirconia alumina.

- In-Ceram ALUMINA (Al_2O_3)

- In-Ceram Zirconia (ZrO_2)

- In-Ceram Spinell ($MgAl_2O_4$)

Indications in dentistry areas: In-Ceram Spinell is indicated for the anterior single crowns, inlays, onlays and veneers. In Ceram Alumina is indicated for the anterior/posterior single crowns and bridges up to 3 elements for the frontal area. In-Ceram Zirconia is indicated for the anterior/posterior single crowns, bridges of 3 elements up to the molar area, single crown and bridges of 3 supraimplant elements [20, 21]



Fig. 9. Vita In-Ceram Alumina, In-Ceram Spinell and In-Ceram Zirconia CAD/CAM blocks [22]

Components	VITA YZ T [wt. %]	VITA YZ HT [wt. %]
ZrO_2	90.9 – 94.5	90.4 – 94.5
Y_2O_3	4 – 6	4 – 6
HfO_2	1.5 – 2.5	1.5 – 2.5
Al_2O_3	0 – 0.3	0 – 0.3
Er_2O_3	0	0 – 0.5
Fe_2O_3	0 – 0.3	0 – 0.3

Table 5
CHEMICAL COMPOSITION OF DENTAL CAD/CAM ZIRCONIUM OXIDE (VITA YZ T, VITA YZ HT)[23]



Fig. 10. Different forms of Vita YZ: T-translucent, ST- super translucent, XT-extra translucent, HT- high translucent [24]

6. High performance oxide ceramics (aluminum oxide, zirconium dioxide)

High performance oxide ceramics, of which at present aluminum oxide and zirconium dioxide are used to obtain CAD / CAM blocks.

Indications in dentistry areas: fully anatomical crowns and bridges up to 14 units in the anterior and posterior region, structures for bridges up to 14 units, fully or partially covered, inlay, onlay, veneers, partial crowns, occlusal veneers (table tops) [21].

- BruxZir Solid Zirconia

The chipping resistance of this material indicates to bruxism patients who have destroyed their natural teeth, or previous restorations.

Indications in dentistry areas: single crowns, bridges, veneers, inlay, onlay, screw-retained crown restorations of single implants [25].

7. Hybrid ceramics

Indications in dentistry areas: reconstructions with reduced thickness of the walls that preserve the structure of natural teeth, posterior crowns that offer high loading capacity in cases with limited available space, accurate repair of minor defects (indirect cervical reconstructions / inlays), minimal-invasive / non-invasive reconstruction of the occlusal surfaces, monolithic structures for hybrid bridges [11].

From the category of hybrid ceramics we mention Vita Enamic, which comes in the form of discs (diameter 98.4 mm and can be 14 or 18 mm thick) or blocks EM-14 (12x14x18) and those with increased translucency EM-12 (8x10x15) (fig. 11).

8. Glass ceramics armed with zirconium

Indications in dentistry areas: anterior/posterior single crowns, supraimplantar single crowns, veneers.

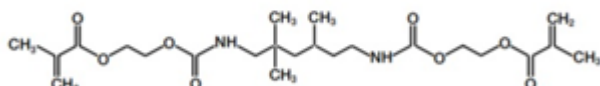
Table 6
CHEMICAL COMPOSITION OF HYBRID CERAMICS [26]

Composition of the ceramic part (86 wt% / 75 vol%)

Silicon dioxide	SiO ₂	58 – 63%
Aluminum oxide	Al ₂ O ₃	20 – 23%
Sodium oxide	Na ₂ O	9 – 11%
Potassium oxide	K ₂ O	4 – 6%
Boron trioxide	B ₂ O ₃	0,5 – 2%
Zirconia	ZrO ₂	< 1%
Calcium oxide	CaO	< 1%

Composition of the polymer part (14 wt% / 25 vol%)

UDMA (urethane dimethacrylate)



TEGDMA (triethylene glycol dimethacrylate)

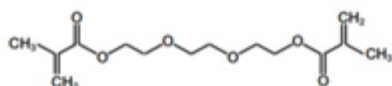


Fig. 11. Vita Enamic disk and blocks [27]

Vita Suprinity is fabricated only as blocks (fig.12)



Fig. 12. Vita Suprinity CAD/CAM blocks [29]

9.Nano-Ceramics

The nano-ceramic resin material is less fragile than the glass ceramic, it is resistant to crushing and cracking when milled. Thus a better quality of the edges and smooth edges can be obtained for a prosthetic restoration.

Table 7
CHEMICAL COMPOSITION OF NANO-CERAMICS [30]

Silica nanomers	20 nm
Zirconia nanomers	4-11nm
Silica-zirconia nanoclusters	0.6-10 micrometers
Fillers	80% by weight
Matrix is Bis-GMA, Bis-EMA, UDMA, TEGDMA	

Table 8
CHEMICAL COMPOSITION OF GLASS CERAMICS ARMED WITH ZIRCONIU [28]

Components	Wt%
ZrO ₂ (zirconia)	8 – 12
SiO ₂ (silicon dioxide)	56 – 64
Li ₂ O (lithium oxide)	15 – 21
Pigments	< 10
Various	> 10

Indications in dentistry areas: inlay, onlay, veneers, single crown

The world's first nano-ceramic resin material, LavaTM Ultimate Restorative is designed for precise efficiency. It is sold as blocks of 12 or 14 mm. Each box contains five blocks of the same color (A1, A2, A3, A3.5, B1, C2, D2 or tooth whitening) [31].

10.Poliether ether ketone (PEEK) and Poliether ketone ketone (PEKK)

It is a high performance polymer, long used in the industry. For many years it was successfully used in many fields of medicine (cranial plates, components of the knee and fingers, joints, intervertebral joints), in recent years finding its use in the field of dental medicine, being closely linked to CAD / CAM. PEEK is characterized by excellent mechanical, chemical properties and superior biocompatibility. This material has a high resistance to weight, elastic properties similar to human bone, zero corrosion, very low water absorption, and in the last ten years there has been no indication of allergic reactions due to it. Within the CAD / CAM technology, a major advantage is that the mechanical properties of the material are not affected during the milling process, being able to make different prosthetic restorations such as supraimplantar abutments, the framework of fixed or removable prosthetic prosthesis, including special precision systems.

The differences between these two materials are significant: PEKK is 80% more resistant to PEEK, PEKK has elasticity similar to that of natural dentine to PEEK which is too elastic, PEKK is harder and easier to polish because PEEK is softer and harder to polish, PEKK is indicated in definitive restorations whereas PEEK restorations may last maximum 180 days [32] (fig. 13).

PEKK has a single manufacturer that produces it exclusively for Cendres Metaux, as a finished product under the name PeKKton. This material is the easiest material possible for permanent restorations. It is ideal for composite layering due to chemical bonding and has a better shock absorption. The density is similar to that of human bone and dentine, 100% biocompatible and suitable for definitive restorations. It has excellent resistance to abrasion and erosion and 0% liquid absorption from the mouth. This material can be milled or pressed, can be sterilized and it is radiolucent [32].

11.BioHPP= biocompatible high performance polymer (fig. 14)

BioHPP is a high performance polymer developed especially for intra-oral use. It is based on PEEK and was obtained by adding a special ceramic filling, which led to the improvement of mechanical and physical properties [33] (fig. 15).

Indications in dentistry areas: single crowns, bridges (maximum 2 pontics), adhesive bridges (Maryland), suprastructures with or without frictional elements,

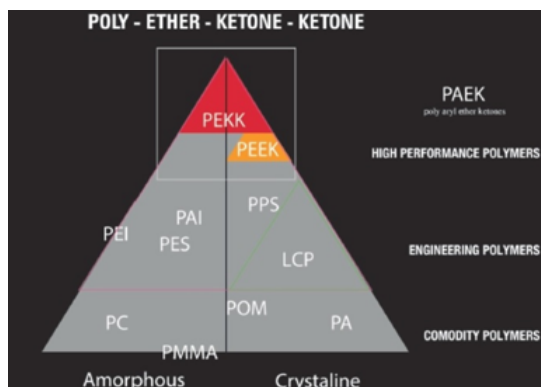


Fig. 13. Chemical composition for PEEK and PEKK [32]

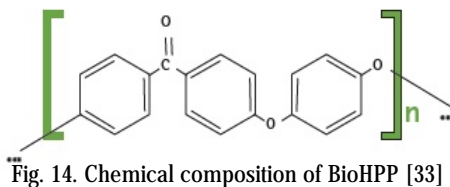


Fig. 14. Chemical composition of BioHPP [33]



Fig. 15. BioHPP CAD/CAM disk [34]

secondary parts for telescopic crown technique and bar suprastructures, suprainplant restorations, crowns and bridges (cemented or screwed), primary crowns, removable suprastructures, Toronto bridge [33].

Conclusions

As CAD/CAM becomes a more common technology the materials used in dentistry continue to evolve. Digitally produced restorations offer patients a more accurate fit, also reduce production time and costs. Taking the time to choose the best material for each case will ensure a strong, esthetic restoration that will last for years to come.

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Manuscript received: 5.11.2019