Mastering the art of dental technology

By Marc Chalupsky, DTI

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of this material is that it can be used as a milled dense composite that was free of polymerisation shrinkage but cannot be sintered or glazed [9].

In early 1998, IPS Procera (Ivoclar Vivadent) was introduced as a leucite-reinforced ceramic, which was similar to IPS Empress but with a finer particle size; this material was designed to be used with the CEREC system (Sirona Dental) and part was available in different shades [2]. More recently, the introduction of IPS Empress CAD (Ivoclar Vivadent) and Paradigm C that according to the manufacturer (GM ESPE) is a 90–94 percent leucite reinforced glass ceramic with a fine particle size [10].

To overcome esthetic problems of most CAD/CAM blocks having a monochromatic restoration, a different version was developed as a multicoloured ceramic block, which

Table 1: Recommended dimensions for E-max CAD by Ivoclar Vivadent.

<table>
<thead>
<tr>
<th>Material thickness</th>
<th>Anterior</th>
<th>Premolar</th>
<th>Molar</th>
<th>Veners</th>
</tr>
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<tbody>
<tr>
<td>Staining technique</td>
<td>1.0</td>
<td>1.5</td>
<td>1.5</td>
<td>0.6</td>
</tr>
<tr>
<td>Cut-back technique</td>
<td>1.0</td>
<td>1.5</td>
<td>1.5</td>
<td>0.6</td>
</tr>
<tr>
<td>Layering technique</td>
<td>0.8</td>
<td>0.8</td>
<td>0.6</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1: Number of steps comparison between traditional methods of all-ceramic restorations and CAD/CAM restorations.

Fig. 2: Vista Mark II block.

Fig. 3: In-house milled crown from an E Max block.

Fig. 4: Full arch implant supported prosthesis milled from a partially sintered (green state) zirconia puck.

Fig. 5: STL file of an in vitro scan.

torations and information that is saved in a computer and constitutes an extraordinary communication tool for evaluation.

The incorporation of dental technology has not only brought a new range of manufacturing methods and material options, but also some concerns about the processes involving restorations, fit, quality, accuracy, short and long term prognosis [6].

The purpose of this document is to provide a review of the literature regarding the different materials and systems available up until 2015 in the USA.

CAD/CAM materials

Glass ceramics

The first in-office ceramic material was Vita Block (Ivoclar Vivadent), it was a feldspathic-based ceramic composed into a block that was milled into a dental restoration. After the invention of the Mark I block, the next generation of materials for CAD/CAM milling fabrication of all-ceramic restorations were Vita Mark II (Vident) and Celay, which replaced the original Mark I in 1987 for fine feldspathic porcelains primarily composed of silica oxide and alumina oxide [2,3]. Mark II blocks are fabricated from feldspathic powders that contain particles embedded in a glass matrix and used for single unit restorations available in polychromatic blanks nowadays. On the other hand, Celay ceramic inlays have been considered clinically acceptable by traditional criteria for marginal fit evaluation [4].

Dioec MGC was a glass ceramic material composed of 70 percent tetra- silicic fluorocera crystals precipitated in a glass matrix, but this material is no longer available on the market [5]. Studies from Isenberg et al. suggested that this type of ceramics were classified as clinically successful in a range from 3–5 years of clinical service [6–8]. In 1997, Par- digma F10zio blocks (GM ESPE) were introduced as highly filled ultrafine silica ceramic particles embedded in a resin matrix, the main advantage called VITA TriLuxe (Vident) and also IPS Empress CAD Multiblock, the base of the block is a dark opaque layer, while the outer layer is more translucent; the CAD software al- lows the clinician to position or align the restoration into the block for the desired outcome of the restoration [11,12].

In 2014, the Enamic (VITA) material was released as a ceramic material infiltrated with a reinforcing poly- mernet that has the benefits of a ceramic and resin in one material, but no clinical data are available [4].

Alumina-based ceramics

Alumina blocks (Vitablocs In-Ceram Alumina, VITA) are available for milled- out restorations, a modification of the In-Ceram (VITA) and can now be used with all ceramic milling machines as well. Due to the opacity of alumina-based ce- ramic materials, the In-Ceram Spi- nell (VITA) blocks were developed as an alternative for anterior esthetic restorations; it is a mixture of alumina and leucite, but the thickness is less than In-Ceram Alu- mina, but veneering with feldspathic porcelain for a more esthetic result could follow it after the milling process [4,13].

Nobel Biocare developed Procera material; for its fabrication high pur- ity aluminium oxide is compacted into an enlarged die that is fabricated from the scanned data [6]. The en- larged fabricated core shrinkage to the dimensions of the working die when sintered at 1,550 °C; this material of- fers a very high strength core for all ceramic restorations; the crown is finished with the application of feld-spathic porcelain [14]. More recently, In-Coro AL (Siroma Dental) has been introduced as a high-strength alu- minum oxide block with similar me- chanical properties as Procera [8].

Lithium disilicate

Lithium disilicate is composed of quartz, lithium disilicate, phosphor oxide, alumina, potassium oxide and other components. According to Saint-Jean (2014) the crystallization of lithium disilicate is heterogeneous and can be achieved through a two or three stage process depending if the glass ceramic is intended to be used as a mill block (e-max CAD) or as a press ingot (e-max press). Lithium disilicate blocks (Fig. 3) are partially sintered and relatively soft, they are easier to mill and form to the desired restoration compared to fully sin- tered blocks; after this process the material is usually heated to 800 °C for 20 to 30 minutes to precipitate the final phase. This crystallization step is usually associated with a 0.2 percent shrinkage accounted for the designing software [9]. Nowadays, blocks of lithium disilicate are available for both in-office and in-laboratory fabrication of all-ceramic restorations, monolithic blocks require layering or staining to achieve good esthetic results [8]. Different in vitro studies that evaluate the marginal accuracy of milled lithium disilicate reveal that these restorations could be as accurate as 56 to 61 microns [10].

According to the manufacturer spec- ifications, the designs of principles for lithium disilicate are produced by first in the design software; in full in all-ceramic crown in the abutment the minimum thickness must be applied in the preparation design (Table 1). During the crystallisation process, the ceramic is converted from a lithium metasilicate crystal phase to lithium disilicate. Some commercial types of ceramics are Empress CAD (Ivoclar Vivadent) and IPS E-max. The first one is a leucite-based glass ceramic with a composition similar to Empress ceramic. IPS E-max was introduced in 2006 as a mate- rial with a flexural strength of 560 to 600 MPa (two to three times stronger than glass ceramics), the blocks are blue in the partially crystallised state and it achieves the final shade after it is subverted to the firing process in a porcelain oven for 20 minutes in order to complete the crystallisation; the final result is a glass-ceramic with a flexural size of approximately 1.5 mm and 70 percent crystall volume incorporated in a glass matrix [20].

In 2014, Vident released Suprinity, the first ceramic block with reinforced zirconium oxide that is heated to a temperature between 1,540 °C and 2,000 °C and cooled, a volume shrinkage of 25 to 35 percent can occur that could affect marginal fit or passiveness of the restorations [22]. This feature limited the use of zirconia until 1970 when Bier and Gupta developed the yttria-tetragonal zirconia polycrystal (Y-TZP) concept in order to minimize this effect [10].

One of the most interesting prop- erties of zirconia is transformation toughening, Kelly (2008) describes it as: A phenomenon that happens when a fracture takes place by the extension of an already formed crack in the material; this process affects the opacity of alumina- based ceramics, but veneering with feldspathic porcelain claims that fitness of restorations is better because it avoid volumetric changes during the fabrication process. On the other hand, the partially sintered zirconia (Fig. 4) is easier and faster to mill and proponents of milling partially sintered blocks claim that milling partially sintered blocks can affect the fitness of the restoration during the milling process and it also requires more time, and intensive milling procedures; this micro defects or surface flaws can affect the flexural strength of the fi- nal restoration and could potentially chip the marginal areas, however further research is needed about this topic [10].

One of the first systems that used zirconia was In-Ceram Zirconia (Vident), which is a modification of the In-Cer- am Alumina but with the addition of partially sintered zirconium oxide blanks (green-state). Propo- nent of milling fully sintered zirco- nia claim that fitness of restorations is better because it avoid volumetric changes during the fabrication process. On the other hand, the partially sintered zirconia (Fig. 4) is easier and faster to mill and proponents of milling partially sintered blocks claim that milling partially sintered blocks can affect the fitness of the restoration during the milling process and it also requires more time, and intensive milling procedures; this micro defects or surface flaws can affect the flexural strength of the fi- nal restoration and could potentially chip the marginal areas, however further research is needed about this topic [10].

Different manufacturers are using zirconia as one of their main mate- rials such as: Ceramill Zolid (Amann Girrbach, Patzelt, Germany), Cer- con (DENTSPLY, BrassGo (Gladewell Laboratories), IPS Zirkodoc (Ivoclar Vivadent)), Zirconium Z (Siroma Dental), In-Coro Z (Siroma Dental), VITA In- Ceram Y2 (Vident), among others. Comparables with introduced mate- rials that are in combination with zirconia to improve its properties
in different clinical situations. Lava Plus, for example, is a combination of zirconia and a nano-ceramic.

**CAD/CAM systems**

A company's CAD/CAM manufacturer is providing CAD/CAM systems that generally consist of a scanner, design computer and a milling machine or a 3D printer. Laboratories are able to receive digital impression files from dental bodies or scan a computer to create digital models that are used for the design of all-ceramic restorations. scanners vary in size, speed, axes, and also in which restorative materials can be milled, in this category milling machines come of different models. As long as the materials require it, the development of dental CAD/CAM systems occurred around the introduction of the SOPRA system developed by Dr. Franzoni Durst. A few years after that event, Dr. Werner Mommern and the electrical engineer Marco Brandestini developed the CBEC system in 1994, the first full digital dental system created that allows dentists to design and fabricate in-office restorations. Since then, the continuous evolution of systems dedicated to this field has continued and has exponentially increased in the last decade.

**Table 2: Most popular dental CAD systems available for 2015.**

<table>
<thead>
<tr>
<th>System</th>
<th>Manufacturer</th>
<th>File output</th>
</tr>
</thead>
<tbody>
<tr>
<td>InLab</td>
<td>Nobel Biocare</td>
<td>Proprietary/STL</td>
</tr>
<tr>
<td>PlanCAD</td>
<td>Planmeca</td>
<td>STL</td>
</tr>
<tr>
<td>Dental Wings</td>
<td>Dental Wings</td>
<td>STL</td>
</tr>
<tr>
<td>ARTI / Modelliere</td>
<td>Zirkonzahn</td>
<td>STL</td>
</tr>
<tr>
<td>CAD System</td>
<td>Manufacturer</td>
<td>File output</td>
</tr>
</tbody>
</table>

**Table 3: Most popular dental CAM systems available for 2015.**

<table>
<thead>
<tr>
<th>System</th>
<th>Manufacturer</th>
<th>Type</th>
<th>Milling materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEREC</td>
<td>Sirona</td>
<td>Wet/dry</td>
<td>Zirconia, wax, PMMA</td>
</tr>
<tr>
<td>Delcam</td>
<td>Dentsply</td>
<td>Dry</td>
<td>Zirconia, Glass ceramic, resin, lithium disilicate, chromium cobalt, PMMA, wax, titanium</td>
</tr>
<tr>
<td>Dental Wings</td>
<td>Proprietary/STL</td>
<td>Wet/dry</td>
<td>Zirconia, Glass ceramic, resin, lithium disilicate, chromium cobalt, PMMA, wax, titanium</td>
</tr>
<tr>
<td>Planmeca</td>
<td>Procter</td>
<td>Wet/dry</td>
<td>Zirconia, Glass ceramic, resin, lithium disilicate, chromium cobalt, PMMA, wax, titanium</td>
</tr>
<tr>
<td>Exocad</td>
<td>Nobel Biocare</td>
<td>Wet/dry</td>
<td>Zirconia, Glass ceramic, resin, lithium disilicate, chromium cobalt, PMMA, wax, titanium</td>
</tr>
<tr>
<td>InLab</td>
<td>锣钛</td>
<td>Wet/dry</td>
<td>Zirconia, Glass ceramic, resin, lithium disilicate, chromium cobalt, PMMA, wax, titanium</td>
</tr>
<tr>
<td>Problem Solving</td>
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</tr>
</tbody>
</table>

Some of the main concerns from clinicians about all-ceramic CAD/CAM restorations and their future perspectives are high production times as an overview. Dent Mater 2008; 24:289–98.

**Discussion**

Some advantages can be drawn from the CEREC CAD/CAM system. The systems use a combination of 3D scanning and the use of manual tools for all-ceramic restorations. Though clinical studies have shown that marginal fit of CAD/CAM restorations is comparable to conventional restorations the fabrication of dental restorations is still a complex task that requires experience, knowledge and skills.

The incorporation of new systems and materials brings along a lot of questions regarding system implementation, capabilities and mechanical properties of the different materials. One B. R. Close was able to show that CAD/CAM dentistry is the accuracy of each step in the CAD/ CAM chain, from digital impression to the milling step. Using computer aided manufacturing is dependent on the calibration of software in the workflow. Furthermore, the virtual configuration of the die spacer between the tooth and the restorations is essential for the accuracy of the margin adaptation and has to be calibrated for each of the restorations. Witzum et al demonstrated that the difference of fit between CAD/CAM restorations is directly related to the gap parameters from the computer program and also related to the intrinsic properties of the CAD/CAM system.

**Conclusion**

This review of current and past literature regarding the evolution, characteristics, and marginal fit of all-ceramic CAD/CAM all-ceramic restorations and materials systems and show that it is possible to fabricate restorations with the same marginal fit expected from conventional methods and within the range of clinically accepted restorations. When comparing both methods the advantage of using CAD/CAM technology not only the most precise level of fit, but rather to obtain a high level of re- liability in a larger number of restorations; especially when high productivity levels are expected. However, there are a limited number of clinical studies and the diversity of the re sults between systems and protocols does not allow us to give a definitive conclusion.

**References**


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