# DIGITAL WORKFLOW IN FIXED PROSTHODONTICS

جامِعة بابل
كُلية طب الاسنان

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# الاهداء

﴿ وَآخِرُ دَعْوَاهُمْ أَنِ الْحَمْدُ لِلَّهِ رَبِّ الْعَالَمِينَ ﴾

**الحمد لله الذي ما تم جهد و لا ختم سعي إلا بفضله ، و ما تخطيت هذه العقبات إلا بتوفيقه .**
**اللهم اجعل هذا العلم شفيعا لي يوم تسألني عن شبابي فيما افنيت ، و زدني علما و نفعا به.**
**كما نرفع كلمه الشكر و الامتنان الى الدكتور المشرف " د. سنان عبد الستار شويليه " لمساعدته لنا في انجاز بحثنا و لم يبخل علينا بالنصح و الارشاد .**

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# Digital Impression and Definition Of Intra Oral Scanners

## Cad – Cam Technology

**Computer-aided design and manufacturing were developed in the 1960s for theuse iaircraft and automotive industries. Dr. Francosis Duret was the first personto develop CAD/CAM device, making crowns based onan optical impression of theabutment tooth and usingnumerically controlled milling machine1971. Heproduced the first CAD/CAM dental restoration in 1983.**

**Dr. Andersson developed the Procera Methodmanufacturing high-precisiondental crowns in 1983. Dr. Duret later developed the Sopha system in 19844.**

**Dr. Anderssonthe first person to use CAD/CAM for composite veneeredrestorations In 1987, Mörmann and Brandestini discovered CEREC system, whichwas the first dental system to combine digital scanning withmilling unit. TheE4D Dentist system, which was introduced in 2008 permits same-day in-officerestorations along with CEREC system.**

## CAD/CAM component

### 1) Scanner

**Under the term 'scanner' one understands.the arealdentistry, datacollection tools that measure three-dimensional jaw and tooth structures and a transform them into digital data sets.**

**Basically there are two different scanning possibilities:**

- **optical scanners**
- **mechanical scanners**

### 2) Design software

**Special software is provided by the manufacturersdesign of variouskinds of dental restorations . With such software, crown and fixed partialdentures (FPD) frameworks can be constructed on the one hand on the other hand,some systems also offer the opportunity to design full anatomical crowns, partialcrowns, inlays, inlay retained FPDs, as well as adhesive FPDs and telescopic primarycrowns .**

### 3) Processing devices

**The construction data produced with the CAD software are converted intomilling strips for the CAM-processing and finally loaded into the milling**

**device.Processing devices are distinguished by means of the number of milling axes:**

- **3- axis devices.**
- **4-axis devices.**
- **5-axis devices.**

## *Digital Impression and Definition of Intra oral scanner*

**Digital impressions are dental scans taken with 3D scanning technology.The digital impression system captures the dentition with the use ofpolygons (triangles) and by that, it helps build up a highly accurate 3Dimage of the patient's dentition. There are different ways of getting to adigital impression: either a desktop scanner scans a gypsum model togenerate a digital model, or an intraoral scanner generates a digitalimpression directly from the patient's oral cavity. Intraoralscanning creates digital replicas of teeth and gums, and displays the resultdirectly on a computer or tablet screen. The dental specialist can then usethese digital teeth impressions for assessing whether there is a problem,what it is, what treatment could be required, and communicating about allthis with the patient.**

**The time It takes to take the Impression scan in the mouthdepends, first of all, on the digital Impression machine itself -scanner specifications differ from manufacturer to manufacturer.The next factor to consider is the case at hand. ScannIng for aclear aligner treatment for example, is different from scanningonly one specific area. And even scanning for the same case canbe different from patient to patient, depending on the complexityof the individual case. Another thing to keep in mind Is thedental specialist's experience in using digital impressiontechnologies. A study was performed among dental students ofSemmelweis University who used a 3Shape TRIOS 3 scanner tocompare the total time it took to scan and the number of images.It showed a significant difference between time needed fortaking the first and 10th impression for each student – the timewas decreasing remarkably.**

**From our own experiencee we can say that a full-archimpression can be taken in as little as 40 seconds, including bitealignment. But we must add to that 40 seconds is only realisticto aim for with extensive experience.**

## Impression taking method

As compared to traditionalimpression techniques, the method for recordingimpression is quite simple. The following steps that mustbe followed:

- First, make sure that the system's software is up to Date and that hold with the camera is ready for Scanning.
- Second, the prepared tooth must be dehydrated andseparated, and the tissue retracted with a gingivalcord. Retraction is necessary for taking digitalimpressions because the scannernot be able toscan the pro ile margin if they are not visible. After the tooth has dried, it is lightly coated with titaniumdioxide to give contrasting points for scanning . Increase recording speed, and improve 3D picturerecording.
- Third, a scanner, synonymous to an intraoral camera,is available to scan the images. The prepared toothand its nearby teeth are scanned from various angles,and its neighbours are created in software. Thepatient is then instructed to seal their mouth inmaximum interception while an image of the occlusion is taken.
- Fourth, the image data is then transferred to thesuitable laboratory or milling machine in the officetogether with the patient's information the prosthesis

### Traditional vs. digital impressions

**Conventional impression**: Abutment-proper traySelection-recantation of gingiva-impression takingSterilization-transporting lab equipment-cast filling Fabrication of restoration

**Digital impression**: Abutment-recantation of gingivaexaminesdigital transfer of impression to laboratory Classical design-fabrication of restoration

### The advantages of digital impression includes–

1. Less chair time.
2. Patient and dental team will have more comfortable And stress-free experience.
3. Using inserting impression materials and trays withIn patient's mouth, digitized impressions by IOS Reduces temporary pain [30.[
4. The screening of the participant's hard and soft Tissues reduces chair side duration. Steps that take Time, such as illing the casts, are omitted
5. Improve the impression quality for better bitting Restorations.
6. Reduce possibility of impression-taking errors.

7. There's no need to buy spoons or imprint materials، And there's no need to store them.
8. Air bubbles are not a concern with this procedure
9. The elimination of the "unclean" cabinet, as well as Patient distress.
10. The interaction between the physician and the patient Has increased since the introduction of IOS, and the Individual is much more integrated in the process and Also has a significantly better treatment efficacy
11. Classical optical imprints increase productivity, creativity، And correctness by allowing practitioners to e-mail a Digital imprint to the labs instead of sending a Conventional impression or stone replica through Ordinary mailing. Computerized impressions could also Be utilized to manufacture identical dental restorations، Minimizing the need for several o ce visits and speeding Up treatment for patients

**The disadvantages of digital impressions are**

1. The main drawback is lack of knowledge among Dentists
2. The identifyication of deeply positioned gingival Margins is a difficulty and IOS scanning is especially Problematic in cases of haemorrhage, as it might hide The prosthetic edges and cause the scan to be Imprecise
3. IOS unable to of dislodging soft tissue edges or Registering fluid tissue interactions.
4. The machinery is complicated, though it has recently Been considerably simplifieda and mastering the skill
5. Requires training and experience It's also not a well-known idea which everybody Understands.
6. The initial cost of the system is expensive, but after Devaluation, becomes much less expensive than Traditional method.
7. It needs long-term clinical trials.
8. For senior clinicians who have less willingness and Familiarity with internet and software, adapting the Learning Curve for IOS is tough.

# *Types Of Intra Oral Scanners*

1. **Optical scanners**
2. **laser scanners**
3. **confocal microscopey scanners**
4. **Structured light scanners**
5. **Ultrasound scanners**

**are the applications of intra oral scanners What ?**

**Intraoral scanners are widely used in dentistry for various applications such as**

1. **Digital Impressions: Intraoral scanners capture accurate 3D images of the teeth and soft tissues, replacing the need for traditional messy impression materials.**
2. **Orthodontics: They aid in treatment planning for orthodontic cases, including Invisalign and braces, by creating precise digital models of the teeth.**
3. **Prosthodontics: Intraoral scanners are used to design crowns, bridges, and other dental restorations with high precision for a better fit and aesthetic outcome.**
4. **Implantology: They help in planning and placing dental implants by creating detailed digital scans of the jaw and surrounding structures.**
5. **Patient Education: The 3D images from intraoral scanners can be used to educate patients about their oral health and treatment options more effectively.**
6. **Temporomandibular Joint (TMJ) Analysis: Intraoral scanners can assist in evaluating the TMJ and occlusion, aiding in diagnosis and treatment planning for TMJ disorders.**
7. **Monitoring Changes: They are used to track changes in the oral cavity over time, such as tooth wear, movement, or changes in soft tissue health.**

**rt in Overall, intraoral scanners improve efficiency, accuracy, and patient comfo dental procedures, making them an essential tool in modern dentistry.**

**What are the benefits of intra oral scanners?**

**The benefits of intraoral scanners in dentistry include:**

1. **Improved Accuracy: Intraoral scanners provide highly precise 3D images, reducing the margin of error compared to traditional impression methods.**

2. **Time Efficiency: They speed up the workflow by eliminating the need for physical impressions, reducing chair time for patients and enhancing overall efficiency in the dental clinic.**
3. **Enhanced Patient Comfort: Patients experience less discomfort during digital scans compared to traditional impression materials, leading to a more pleasant dental visit.**
4. **Better Communication: Intraoral scans can be easily shared with dental labs, specialists, or patients digitally, facilitating communication and collaboration for improved treatment outcomes.**
5. **Customization: The digital scans allow for customized and precise design of dental restorations, leading to better fitting crowns, bridges, and other prosthetic devices.**
6. **Cost-Effectiveness: While the initial investment in intraoral scanners may be higher, in the long run, they can help reduce material costs associated with traditional impressions and improve the overall economics of dental practices.**
7. **Digital Record Keeping: Intraoral scanners create digital records of patients' oral health, aiding in documentation, treatment planning, and follow-up care.**
8. **Improved Patient Experience: The use of intraoral scanners can enhance patient satisfaction due to their comfort, convenience, and modern technology.**
9. **These benefits make intraoral scanners a valuable tool for modern dental practices, improving both clinical outcomes and patient experience.**

**using intraoral scanners in dentistry typically involves the following steps:**

1. **Preparation: Ensure the intraoral scanner is properly set up, calibrated, and ready for use. Verify that the scanner's tip is clean and free of debris.**
2. **Patient Preparation: Position the patient comfortably in the dental chair and explain the scanning process to alleviate any concerns or anxiety.**
3. **Scan Acquisition: Start scanning the patient's oral cavity methodically, capturing images of the teeth, soft tissues, and surrounding structures. Follow the manufacturer's instructions for proper scanning technique.**

4. **Real-Time Visualization: Monitor the scan quality in real time on the computer screen to ensure all areas are adequately captured. Make any necessary adjustments during the scanning process.**
5. **Multiple Angles: Scan from different angles and perspectives to ensure comprehensive coverage and accurate 3D image reconstruction.**
6. **Check for Completion: Confirm that all necessary areas have been scanned and there are no missing or distorted areas in the digital impression.**
7. **Data Processing: Once the scan is complete, process the data using appropriate software to create a detailed 3D model of the patient's oral structures.**
8. **Review and Refinement: Review the digital impression for accuracy and detail. If needed, refine the scan or make any adjustments to ensure precision.**
9. **Storage and Sharing: Save the digital impression in the patient's electronic record for future reference. Share the scans with dental labs, specialists, or patients as needed.**

**By following these steps and mastering the technique of intraoral scanning, dental practitioners can leverage this advanced technology to enhance clinical workflows and improve patient care.**

**The Technology used in each type of intraoral scanner:**

1. **The optical scanner: The optical intraoral scanner works by using light and optical sensors to capture detailed 3D images of the inside of the mouth. The scanner emits a light source onto the teeth and soft tissues, and the reflections are picked up by the sensors. These reflections are then converted into digital images that create a precise virtual model of the oral structures. The scanner typically relies on a combination of structured light, confocal microscopy, and other optical technologies to accurately capture the details of the teeth and surrounding tissues. This digital model can then be used for various dental applications such as crown and bridge fabrication, orthodontic treatment planning, and smile design. The accuracy and speed of optical scanners make them a valuable tool in modern dentistry for improving patient outcomes and enhancing the overall treatment experience.**

2. **The laser scanner:**

   **The laser intraoral scanner uses light technology to capture detailed images of the teeth and oral cavity. The scanner emits a structured light pattern onto the surface being scanned, and sensors in the scanner detect the reflections of this pattern to create a 3D digital model of the teeth and gums. This model can then be used for various dental applications such as designing crowns, bridges, and aligners.**

3. **confocal microscopey scanners:**

   **Confocal microscopy intraoral scanners use a laser scanning system with a pinhole aperture to eliminate out-of-focus light and only capture light reflected from a specific focal plane. This allows for the precise imaging of different layers of tissue in the oral cavity. The laser beam scans the surface of the teeth and tissues, and the reflected light is collected by a detector. By scanning multiple points, a detailed 3D image of the oral structures is generated. This technology provides high-resolution images with depth information, making it useful for diagnostics, treatment planning, and monitoring dental conditions.**

4. **Structured light scanners:**

   **The structured light intraoral scanner works by projecting a series of light patterns onto the teeth and surrounding structures. By capturing the distortions in these patterns as they reflect off the surfaces, the scanner can create a 3D digital model of the patient's mouth. This model is then utilized for various dental applications such as crown and bridge fabrication, orthodontic treatment planning, and monitoring oral health changes over time.**

5. **Ultrasound scanners:**

   **The ultrasound intraoral scanner works by emitting high-frequency sound waves into theoral cavity. These sound waves bounce off the intraoral structures and are then captured by the scanner. The scanner measures the time taken for the sound waves to return, creating a 3D image of the intraoral structures. This technology enables dental professionals to obtain detailed images of the teeth, gums, and other oral structures for various dental procedures, such as treatment planning, restoration design, and orthodontic assessments.**

## Which intraoral scanner is the best؟

The best scanner for a particular dental practice will depend on various factors, such as the needs of the practice, the type of procedures performed, the budget, the speed and scanning, the quality of the scans and the level of expertise of the operator.

Some popular intraoral scanners on the market include:

- 3Shape Trios: This scanner is known for its fast-scanning speed, color capture, and accuracy. It also has a broad range of indications, including restorative, orthodontic, and implant dentistry.

- Align iTero Element: This scanner is designed for chairside restorations, orthodontics, and implant planning. It features a compact wand and a real-time imaging feedback system.

- Carestream CS 3600: This scanner is known for its fast-scanning speed, high accuracy, and ease of use. It also has a small wand and a unique light guidance system to help ensure accurate capture of all tooth surfaces.

- Medit i500: This scanner is known for its high accuracy and speed, making it ideal for restorative and implant dentistry. It also has a user-friendly interface and allows for easy integration with CAD/CAM systems.

## *Computer Assisted Design and Systems Used*

**Dental restorations produced with computer assistance have become more common in recent years. Most dental companies have access to CAD/CAM procedures, either in the dental practice, the dental laboratory or in the form of production centers.**

**The many benefits associated with CAD/CAM generated dental restorations include: the access to new, almost defect-free, industrially prefabricated and controlled materials; an increase in quality and reproducibility and also data storage commensurate with a standardized chain of production; an improvement in precision and planning, as well as an increase in efficiency.**

**As a result of continual developments in computer hardware and software, new methods of production and new treatment concepts are to be expected, which will enable an additional reduction in costs .**

### DEFINITION

**The term CAD is the abbreviation for 'computer-aided design' and CAM stands for 'computer-aided manufacturing .'**

**All CAD/CAM systems consist of three components :**

1. **A digitalization tool/scanner that transforms geometry into digital data that can be processed by the computer**
2. **Software that processes data and, depending on the application, produces a data set for the product to be fabricated**
3. **A production technology that transforms the data set into the desired product .**

### CAD/CAM PRODUCTION CONCEPTS IN DENTISTRY

**Depending on the location of the components of the CAD/CAM systems, in dentistry three different production concepts are available :**

a. **chair side production**
b. **laboratory production**
c. **centralized fabrication in a production center.**

a) Chair side production

- All components of the CAD/CAM system are located in the dental surgery. Fabrication of dental restorations can thus take place at chair side without a laboratory procedure .
- The digitalization instrument is an intra-oral camera, which replaces a conventional impression in most clinical situations. This saves time and offers the patient indirectly fabricated restorations at one appointment.

At present, only the *CEREC System (Sirona) offers this possibility .

CEREC (Chairside Economical Restoration of Esthetic Ceramic( is a method of creating dental restorations at dental office. These restorations are typically used to repair damage to tooth (or teeth) from decay or injury

According to the Journal of Dentistry and Oral Care, CEREC can be used to fabricate:

1. Crowns
2. Inlays and Onlays
3. Fixed bridges
4. Veneers
5. Dental implants
6. Dentures
7. Other orthodontic appliances

CEREC typically entails 4 steps:

1. After numbing and preparing the tooth that requires restoration, dental professional scans mouth or an impression of mouth.
2. dental professional utilizes specialized computer software to design a model of restoration, custom-made for teeth and mouth.
3. The design specifications are relayed to milling or grinding equipment that makes the restoration with a high degree of accuracy .
4. The restoration is then placed in patient mouth, and necessary adjustments are made .Finally, the restoration is bonded to tooth.

**CEREC boasts some incredible advantages:**

1. **Dental work can placed in a single appointment. This can be convenient for many as it limits the disruption to patient schedule and the stress of multiple dental visits.**
2. **The fabrication created by the milling or grinding unit is typically very accurate and allows dental professional to maintain more control over the process.**
3. **Completing the permanent restoration in a single appointment avoids the need for temporary solutions .**

**Potential Disadvantages**

1. **Because the technology requires specialized equipment and training, many dental practices do not offer this type of restoration.**
2. **Costs associated with this type of restoration may be higher than solutions requiring multiple visits or sending impressions out to laboratories.**
3. **Due to the fabrication process, choosing this type of restoration may limit choice of materials**

**b) Laboratory production**

- **This variant of production is the equivalent to the traditional working sequence between the dentist and the laboratory .**
- **The dentist sends the impression to the laboratory where a master cast is fabricated first .The remaining CAD/CAM production steps are carried out completely in the laboratory.**
- **With the assistance of a scanner, three-dimensional data are produced on the basis of the master die. These data are processed by means of dental design software .**
- **After the CAD-process the data will be sent to a special milling device that produces the real geometry in the dental laboratory.**
- **Finally the exact fit of the framework can be evaluated and, if necessary, corrected on the basis of the master cast. The ceramist carries out the veneering of the frameworks in a powder layering or over -pressing technique.**

**c) Centralized production**

- **The third option is centralized production in a milling center .**

- In this variation, it is possible for 'satellite scanners' in the dental laboratory to be connected with a production center via the Internet .
- Data sets produced in the dental laboratory are sent to the production center for the restorations to be produced with a CAD/CAM device .
- Finally, the production center sends the prosthesis to the responsible laboratory. Thus ‹production steps 1 and 2 take place in the dental laboratory, while the third step takes place in the center.

## CAD/CAM COMPONENTS

1. Scanner

its data collection tools that measure three dimensional jaw and tooth structures and transform them into digital data sets. Basically there are two different scanning possibilities :

a. optical scanners
b. mechanical scanners

### a) Optical scanners

- The basis of this type of scanner is the collection of three-dimensional structures in a socalled 'triangulation procedure .'
- Here, the source of light (e.g. laser) and the receptor unit are in a definite angle in their relationship to one another. Through this angle the computer can calculate a threedimensional data set from the image on the receptor unit. Either white light projections or a laser beam can serve as a source of illumination examples of optical scanners on the dental market:

- Lava Scan ST (3M ESPE, white light projection)(
- Everest Scan (KaVo, white light projections )
- es1 (etkon, laser beam)

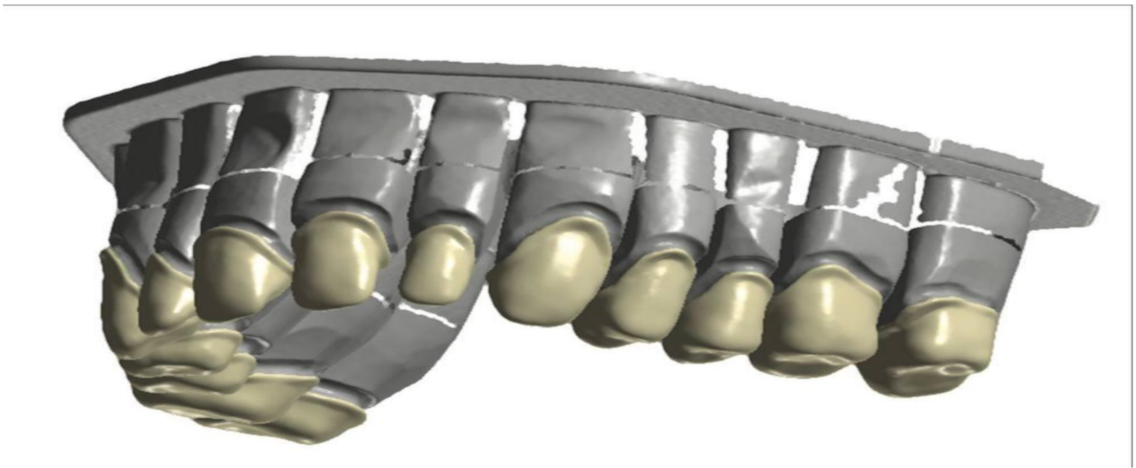
### b) Mechanical scanner

- In this scanner variant, the master cast is read mechanically line-by-line by means of a ruby ball and the three-dimensional structure measured .
- The Procera Scanner from Nobel Biocare (Göteborg) is the only example for mechanical scanners in dentistry .

- This type of scanner is distinguished by a high scanning accuracy, whereby the diameter of the ruby ball is set to the smallest grinder in the milling system, with the result that all data collected by the system can also be milled.
- The drawbacks of this data measurement technique are to be seen in the inordinately complicated mechanics, which make the apparatus very expensive with long processing times compared to optical systems.

2. Design software

Special software is provided by the manufacturers for the design of various kinds of dental restorations. With such software, crown and fixed partial dentures (FPD) frameworks can be constructed on the one hand ; on the other hand, some systems also offer the opportunity to design full anatomical crowns, partial crowns, inlays, inlay retained FPDs, as well as adhesive FPDs and telescopic primary crowns .



3. Processing devices

The construction data produced with the CAD software are converted into milling strips for the CAM-processing and finally loaded into the milling device.

# *Digital Smile Design*

**Starting with the use of photographs and more recently with the use of simple and accessible software, virtual or digital smile design has been used to analyze patient smiles and project 2D images to provide a guide for planning and communication. An important problem developed lately was the overlapping of 2D photos and the transfer of the proposed project to obtain dental prosthetic restoration, in physical or digital format. this is because ‹by the classic method, information can be lost from the moment of design by wax-up until the final realization of the restoration .**

**Digital technology is an affordable and easy way to transfer 2D data to 3D digital projects using a 3D computer graphics program - the goal was to transform a regular 2D (JPEG) 2D image into a standard 3D (STL) variant .**

**In order to achieve proper digital planning, it is important to have a protocol for taking and**

**analysing photos is to be considered:**

1- **They must be of the highest quality and precision**
2- **executed in a correct posture, using standardized techniques**
3- **the analysis must include reference facial lines - the commissural lines**
4- **the lip line and the interpupillary line, which are the basis of the smile design**

**Therefore, if a photo is not correctly taken, this will misrepresent the reference image and will lead to misdiagnosis, and subsequently, improper planning**

**Also, in order to get the best evaluation, there are necessary some photos, registered in static position, as mentioned in Table 1.**

**Table 1. type of photos used for digital smile design**

| Frontal view -3photo | Profile views-2photo | 12 o'clock view | Intra occlusal view |
|---|---|---|---|
| • Full face with a wide smile and the teeth apart<br>• Full face at rest and restracted view of the full maxillary and mandibular arch with teeth apart | • Side profile at rest<br>• Side profile with a full smile | Incisal edge of maxillary teeth and Resting on lower lip | Maxillary arch from second premolar to second premolar |

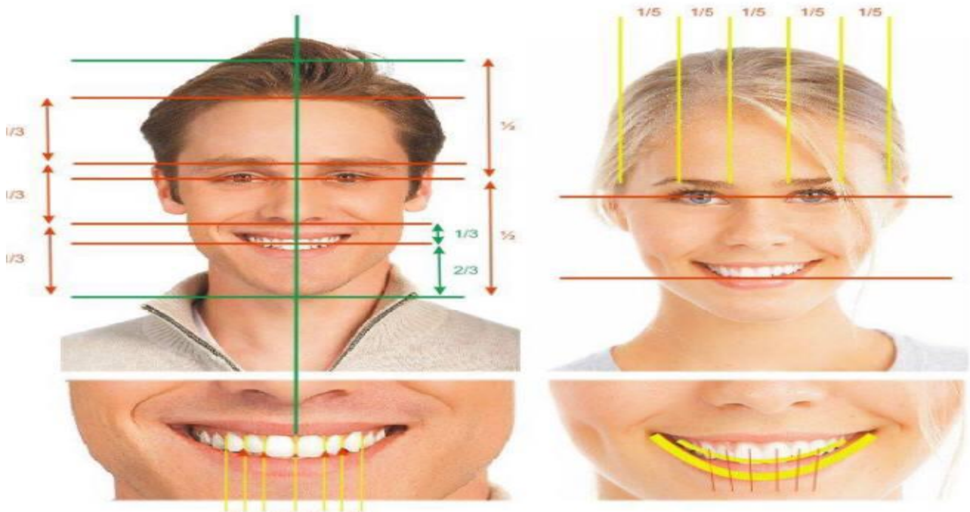
Figure 1. Dental Treatment Solution (DTS) -

Figure 2. 3Shape Smile Design

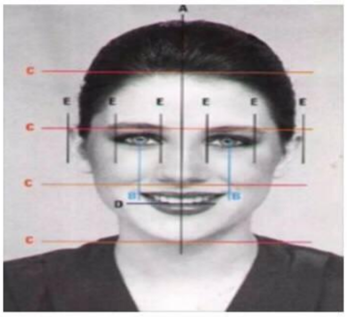
- There are many aesthetic parameters that guide smile evaluation and design such as the midline, height, and the curve of the smile and intra- and interdental proportion.
- Although the inclusion of aesthetic parameters in different DSD software varies, the basic procedure for designing a smile remains the same. All DSD software allows aesthetic design by drawing lines and reference shapes on extra- and intra-oral digital photos .
- Facial analysis is done by using reference lines from which uniform parameters are developed for the frontal view of the face. Horizontal reference lines consist of interpupillary and inter-commissural lines that provide a complete sense of balance and a pleasing aesthetic facial horizontal view, while the vertical reference line includes the midline of the face, passing through the glabella, nose and chin.
- The horizontal and vertical lines are crossed with each other to measure the symmetry and inclination of the face.

## Aesthetic consideration in smile design

definition of aesthetics: is the art and science of reality imitation which refers to natural harmony between teeth, supporting bones of jaw and soft tissues of face.



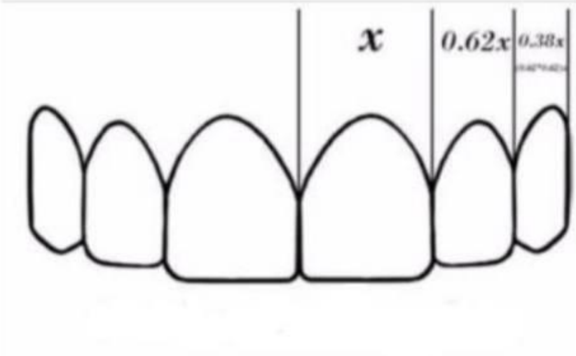
- Smile aesthetics consists of zirconium coating, gum treatment, whitening ، adjustment of tooth length ،bridge, lip shaping. It is the procedure in which the smile is made the most aesthetic. It covers all kinds of operations necessary to have a good smile. As a result of these procedures, your teeth and smile image is redesigned.



**Aesthetic formula:**

a. Facial component
b. Periodontal component
c. Dental component

- Smile is considered to be esthetically pleasing if each tooth in that smile (starting from the midline) is approximately 60% of the size of the tooth immediately mesial to it.




Graphic representation of the six maxillary anterior teeth in golden proportion.

- In order achieve optimal dental esthetics a basic knowledge of natural tooth anatomy is fundamental
  - shape and form
  - semmetry
  - position
  - surface texture
  - color
  - translucency

**Checking Of The Design**

After the facial analysis, the dento-gingival analysis is performed, checking the next protocol :

1. **Check the length of the upper lip at rest and smile, to determine the degree of gingival visibility .**
2. **The curve of the smile is established by correlating the curvature of the incisal edges of the anterior maxillary teeth, and the dental contour is made according to the proportions of the lower lips and the anterior-posterior curvature of the teeth. This facial photograph is then cropped to analyse only the intraoral image .**
3. **Three reference lines are marked on the teeth - a straight horizontal line drawn from the tip of one canine to the tip of the other canine, a horizontal line on the incisal edges of the central incisors and another vertical line passing through the interdental midline.**

**Few additional lines are drawn such as the gingival zenith, joining lines of the gingival and incisal battlements for complete dental analysis. For adequate teeth dimension the ideal size of dental width to length ratio can be incorporated by any one of the published theories which includes Golden proportion, Pound's theory Recurring aesthetic dental proportion,Dentogenic theory or Visagism**

## Wax Up (Mock Up):

**There was established a special workflow for Digital Smile Design, with a precise algorithm :**

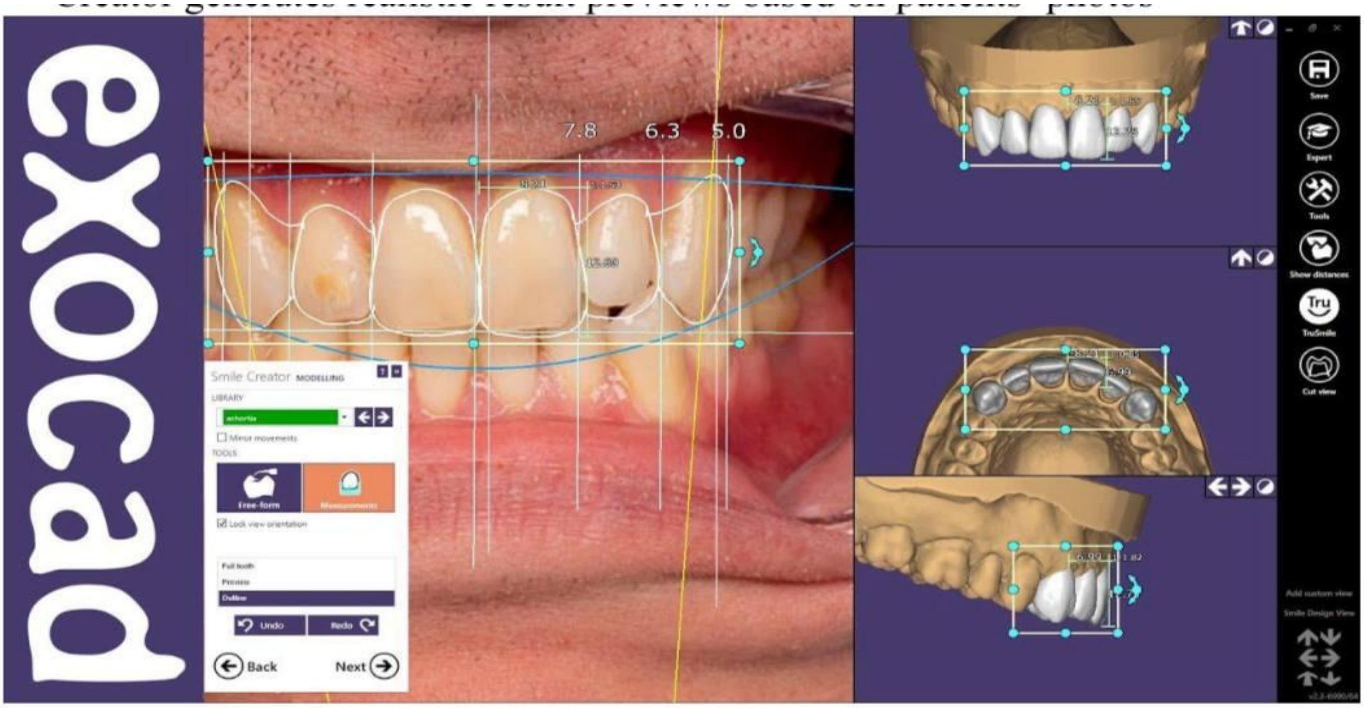
- ➔**Step 1: Photographs and Treatment Planning using the DSD Software**
- ➔**Step 2: Intraoral Scanner and Digital Wax-ups**
- ➔**Step 3: 3D-Printing of the Digital Wax-up**
- ➔**Step 4: Create a Silicone Index using 3D printed models**
- ➔**Step 5: Carry a provisional restoration in the Silicone Index**
- ➔**Step 6: Test-drive the mock-up in the patient’s mouth**

## Software Used For DSD

1. **3Shape Smile Design is one of the most exceptional software available on the market. The tool is built on the principles of Digital Smile Design - the software helps the dentist to create completely aesthetic smile models ‹based on the critical requirements of the patient. Using 3Shape Smile Design, 2D images can be processed and the proposed restorations drawn ‹directly from the patient's photo.**

2. Exocad Smile Creator software involves creating custom images for the identity and facial orientation of the patient. The tool allows dentists to design a smile based on the patient's emotions, behaviour, self-esteem and identity. The workflow for Exocad involves identifying the features, design and correct realization of the dental restoration :

- Predictable results for your restorative treatments
- Massive library of numerous natural teeth
- Seamless communication among dental labs, dentists, and patients
- A 3D tooth set up for providing the personalized experiences
- Fast and easy to use. No extensive knowledge or training is necessary
- Creator generates realistic result previews based on patients' photos




3. Dental Treatment Simulation (DTS) is one of the simplest and fastest dental simulation software developed by Artificial Intelligence. DTS is a useful tool for dentists in clinical practice to provide patients with optimal treatment. The main features of this software are structured as follows

•Realistic Natural Simulations within minutes

•Powered by Artificial Intelligence

•Digital smile designs for the desired personality

•Quick and easy dental restoration

•Tooth Whitening

- **•Extraoral changes after Orthodontics/ Orthognathic surgeries**
- **•Different types of braces**
- **•Orthodontic Tooth Movement**
- **•Replacement of missing tooth/teeth**
- **•STL Overlapping**

**In some studies, were evaluated and compared some of the most used systems for Digital Smile Design, by their main features – we mentioned them in Table 2.**

**Table2, software and their feathures , most frequently used**

| Software | Features |
|---|---|
| DTS Pro | Realistic natural simulations within minutes<br>Powered by artificial intelieigence<br>Quick and easy dental restoration |
| Planmeca romexis | Easy to install and use to design a new smile<br>Allows patients to design their own smile<br>Cloud-based digital smile database |
| Smile designer pro | Real-time smile simulation<br>CAD-CAM overlay features<br>Full automation assistance |
| 35hape | Easy and compeletly guided workflow<br>Simple to use designing tool<br>A faster way to achieve desired outcomes |
| Exocad | Massive library of numerous natural teeth<br>Seamless communisation<br>Fast and easy to use |

## Processing devices

The construction data produced with the CAD software are converted into milling strips for the CAM-processing and finally loaded into the milling device .

Processing devices are distinguished by means of the number of milling axes :

a. 3-axis milling devices

- This type of milling device has degrees of movement in the three spatial directions. Thus, the mill path points are uniquely defined by the X -, Y -, and Z – values . The calculation investment is therefore minimal .
- A milling of subsections, axis divergences and convergences, however, is not possible. This demands a virtual blocking in such areas .All 3-axis devices used in the dental area can also turn the component by 180° in the course of processing the inside and the outside .
- The advantages of these milling devices are short milling times and simplified control by means of the three axes. As a result, such milling devices are usually less costly than those with a higher number of axes .
- Examples of 3-axis devices: inLab (Sirona), Lava (3M ESPE), Cercon brain (DeguDent)

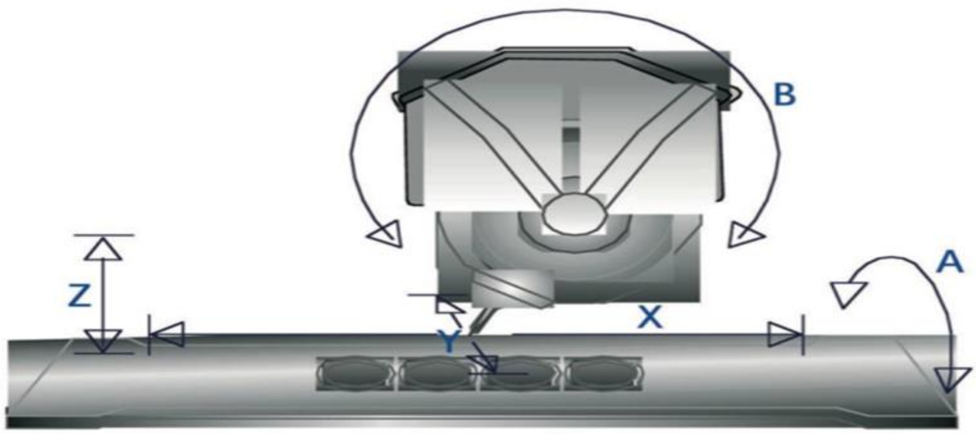
b. 4-axis milling devices

- In addition to the three spatial axes, the tension bridge for the component can also be turned infinitely variably .
- As a result it is possible to adjust bridge constructions with a large vertical height displacement into the usual mold dimensions and thus save material and milling time .
- Example: Zeno (Wieland-Imes)

c. 5-axis milling devices

- With a 5-axis milling device there is also, in addition to the three spatial dimensions and the rotatable tension bridge (4th axis), the possibility of rotating the milling spindle (5th axis)

- This enables the milling of complex geometries with subsections, as for example, lower jaw FPDs on converging abutment teeth (end molar tipped towards the medial plane) , or also crown and FPD substructures that, as a result of anatomically reduced formation, demonstrate converging areas in the exterior of the frame
- Example in the Laboratory Area: Everest Engine (KaVo)
- Example in the Production Centre: HSC Milling Device (etkon)
- The quality of the restoration does not necessarily increase with the number of processing axes. The quality results much more from the result of the digitalization, data processing and production process .




Different possibilities of the working axis: 3 spatial directions X, Y and Z (3 axis milling devices); 3 spatial directions X, Y, Z and tension bridge A (4 axis milling devices); 3 spatial directions X, Y, Z, tension bridge A and milling spindle B (5 axis milling devices

## MATERIALS FOR CAD/CAM PROCESSING

The list of various materials for processing by CAD/CAM devices depends on the respective production system .Some milling devices are specifically designed for the production ZrO2 frames, others cover the complete palette of materials from resins to glass ceramics and high performance ceramics .

The following materials can normally be processed on dental CAD/CAM devices :

a) Metals

- At present, titanium, titanium alloys and chrome cobalt alloys are processed using dental milling devices .

- The milling of precious metal alloys has been shown to be of no economic interest, due to the high metal attrition and the high material costs.
- Examples: coron (etkon: non-precious metal alloy), Everest Bio T-Blank (KaVo, pure titanium)

### b) Resin materials

- On the one hand, resin materials can be used for the milling of lost wax frames for casting technology; on the other hand, it is possible to use resin materials directly as crown and FPD frameworks for long-term provisional or for full anatomical longterm temporary prostheses .
- Prefabricated semi-individual polymer blanks (semi-finished) with a dentine enamel layer are provided by one manufacturer (artegral imCrown, Merz Dental)
- The exterior contour conforms to an anatomically complete anterior tooth crown, while the internal aspect of the crown is milled out of the internal volume of the blank .

Table 3 CAM systems\Select of resin materials for CAD

| Name | manufacturer | CAM \CAD system | Description |
|---|---|---|---|
| Wax-CAD | Vita | In Lab | Filler-free acrylic polymer for lost wax technique |
| Cercon base cast | DeguDent | Cercon | Residue-free cauterisable resin for lost wax technique |
| Everest c cast | KaVo | Everest | Residue-free cauterisable resin for lost wax technique |
| CADTemp block | Vita | Cerec 3 inlab | Fiber-free acrylic polymer with micro-filler for long-term temporary full and partial crowns and fpds up to two pontics |
| Everest c cast | kaVo | Everest | Fiber reinforced polymer for long-term temporary crowns and FPD frameworks, requiring an additional veneering |
| Artegral imCrown | Merz | Cerec 3 inlab | Semi individual blanks for anterior long-term provisional single crowns |

### c) Silica based ceramics

- **Grindable silica based ceramic blocks are offered by several CAD/CAM systems for the production of inlays ،onlays, veneers, partial crowns and full crowns (fully anatomical, anatomically partially reduced)**
- **In addition to monochromatic blocks, various manufacturers now offer blanks with multicoloured layers Vitablocs TriLuxe (Vita), IPS Empress CAD Multi (IvoclarVivadent), for the purpose of full anatomical crowns .**
- **Due to their higher stability values, lithium disilicate ceramic blocks are particularly important in this group; they can be used for full anatomical anterior and posterior crowns, for copings in the anterior and posterior region and for three-unit FPD frameworks in the anterior region due to their high mechanical stability of 360 MPa.**
- **Glass ceramics are particularly well suited to chairside application as a result of their translucent characteristics ،similar to that of natural tooth structure; they provide aesthetically pleasing results even without veneering .**
- **As a result of their relatively high portion of glass, these ceramics are, in contrast to oxide ceramics, etchable with hydrofluoric acid and thus can be inserted very well using adhesive systems.**

### d) Infiltration ceramics

**Grindable blocks of infiltration ceramics are processed in porous, chalky condition and then infiltrated with lanthanum glass. All blanks for infiltration ceramics originate from the Vita In-Ceram system (Vita) and are offered in three variations :**

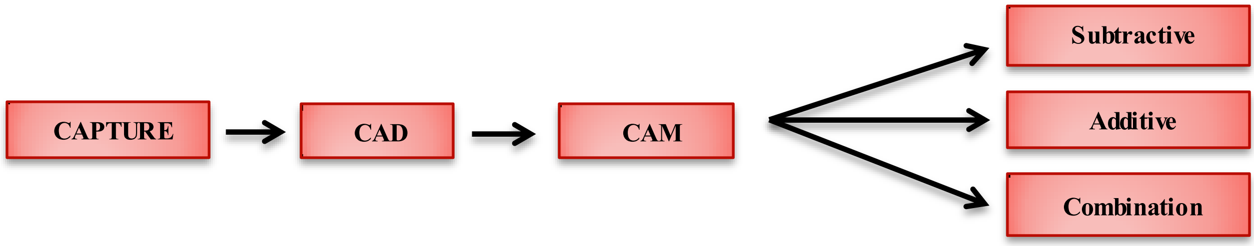
- **Vita In-Ceram Alumina ($Al_2O_3$ ): suitable for crown copings in the anterior and posterior region, three-unit FPD frameworks in the anterior region**
- **Vita In-Ceram Zirconia (70% $Al_2O_3$, 30% $zrO_2$ ): suitable for crown copings in the anterior and posterior region ،three-unit FPD frameworks in the anterior and posterior region. Thanks to its superior masking ability this ceramic is suitable for discoloured abutment teeth18**
- **VITA In-Ceram Spinell ($MgAl_2O_4$ ): has the highest translucency of all oxide ceramics and is thus recommended for the production of highly aesthetic anterior crown copings, in particular on vital abutment teeth and in the case of young patients .**

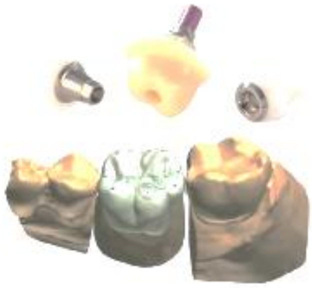
### e) Oxide high performance ceramics

At present, aluminum oxide and zirconium oxide are offered as blocks for CAD/CAM technology .

- Aluminum Oxide ($Al_2O_3$ ) This oxide high performance ceramic is ground in a pre-sintered phase and is then sintered at a temperature of 1520°C in the sintering furnace. Aluminium oxide is indicated in the case of crown copings in the anterior and posterior area, primary crowns and three-unit anterior FPD frameworks. The ground frames can be individually stained in several colours with Vita In-Ceram AL Coloring Liquid. Examples of grindable aluminum oxide blocks: In-Ceram AL Block (Vita), inCoris Al (Sirona) available in an ivory-like colour( Color F 0.7 )
- Yttrium stabilised zirconium oxide ($ZrO_2$ , Y-TZP) Zirconium dioxide is a high-performance oxide ceramic with excellent mechanical characteristics. Its high flexural strength and fracture toughness compared with other dental ceramics offer the possibility of using this material as framework material for crowns and FPDs, and, in appropriate indications, for individual implant abutments. The addition of three molecules of $Y_2O_3$ results in a stabilising tetragonal phase at room temperature, which, as a result of a transition to a monoclinic phase can prevent the progression of cracks in the ceramic (Transformation strengthening).22-25 Examples of Zirconium oxide blocks: Lava Frame (3M ESPE), Cercon Smart Ceramics (DeguDent), Everest ZS und ZH (KaVo), inCoris Zr (Sirona ‹(In-Ceram YZ (Vita), zerion (etkon) and Zeno Zr (Wieland-Imes )

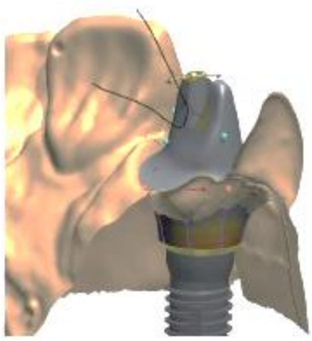
### CAM protocol and fabrication method\CAD





CAD of a single unit coping

CAM of an FPD framework



CAD/CAM implant abutment

- Acrylic single and multiple unit provisionals
- Resin-based compsite inlays, onlays, veneers and crons
- Feldspathic and leucite-glass inlays,onlays,veneers,and crowns

Customized zirconia and titanium abutmenr

**Implant abutment**

3-D printing technology for creating wax-ups of individual copings or FPD frameworks that can be subsequently scanned for CAM

**Full contour**

**Indirect restoration**

**Application**

**Wax-ups**

**Partial contour**

- Titanium and alloy FPD kframewor
- Lithium disilicate, zirconia, unit copings and -alumina single FPD frameworks

**Veneering dense ceramic cores**

**Models, splints and templates**

Solid free-form or stereolithographic prototyping for producing resin full arch models, occlusal splints and surgical templates for gulded implant placement

Fully automated production for multilayered strong and aesthetics restoration . high strength dense ceramic cores can be veneered with aesthetic hugh glad content silica-based ceramics using either direct write assembly , direct shell production casting or laser sintering.

## Materials available for the use with CAD CAM

**Almost all types of fixed (crowns, bridges, implant abutments, inlays and onlays) and removable (removable partial dentures) dental restorations in addition to orthodontic appliances can be constructed using CAD CAM technology**

**Different CAD CAM systems are compatible with different types of materials (table 4) Silicabased ceramics, infiltrated ceramics and oxide high performance ceramics (Aluminum Oxide and Yttrium stabilized Zirconium Oxide) are the most widely used materials with CAD CAM technology The materials are available in blocks and are either mono-chromatic or poly chromatic In addition to ceramics metals (Table 5), (titanium ‹titanium alloys and chrome cobalt alloys), waxes and resin materials may be used with dental CAD CAM systems .**

**Ceramic (zirconia) can be used in different stages of sintering (hardness): semi sintered and fully sintered .At the semi-sintered (green stage) stage, the material is used in a soft stage; during the design and milling the restoration is made over sized, to allow for a shrinkage of around 20.0 – 25.0 % during the sintering (firing) process used to confer superior physical properties. Fully sintered blocks can also be milled with some CAD CAM systems; with this type of density, there will be no shrinkage in the material, which is considered an advantage, because it will reduce the firing cycles and delivery time However, it takes more time to mill a fully sintered block and will cause more tool wear. There is therefore a tradeoff between the time for firing cycles for the presintered blocks and the time it takes to mill a fully sintered block, but on balance, the latter is likely to be more time efficient.**

| Table (4): List of CAD CAM systems, manufacturer and type of materials used | | | |
|---|---|---|---|
| Commercial name | manufacturer | Restorations | Materials |
| **Chair side systems** | | | |
| Cerec 3 | Sirona Dental System | Inlays , Onlays, Veneers, Crowns | Zirconia , Alumina , Oxide , Ceramic,Resin |
| E4D chairside | D4Dtechnologyies LLC | Inlays,Onlays,Venner,Crown, Bridge Frameworks, Copings | Zirconia,Ceramic, Composite |
| **Labrotary systems** | | | |
| Cercon | deguDent Gmbh | Crowns , Bridges | Zirconia |
| Cercon | deguDent Gmbh | Crowns , Bridges | Zirconia |
| Cerec MC XL | Sirona Dental System | Inlays,Onlays,Crowns ,Bridges ,Copings | Zirconia |
| Everest | Kavo Dental Corporation | Inlays,Onlays,Veneers ,Crowns ,Bridges | Zirconia,Titanium,Ceramic |
| Inlab CAD-CAM | Sirona Dental System | Inlays,Onlays,Veneers ,Crowns ,Bridges Framework , Copings | Zirconia,Alumina ,Ceramic |
| In visio DP 3D printer | 3Dsystem corporation | | Light Cured Resine |
| Lava | 3M ESPS | Crowns , Bridges | Zirconia |
| Neo system | Cynovad | Crowns , Bridges | Resine,Zirconia,Titanim |
| Perci fit | Popp dental ine | Crowns , Bridges | Zirconia,Titanium |
| Procera forte | Noble biocare | Bridges,Copings, Abutments | Zirconia,Alumina ,Titanium |
| Procera piccolo | Nobel biocare | Bridges,Copings, Abutments | Zirconia,Alumina ,Titanium |
| Turbodent | U-bast dental technology ine | Crowns , Bridges | Zirconia ,Titanium |
| Waxpro | Cynovad | Crowns , Bridges , Copings | Wax |

| Table (5) Shows different types of dental ceramics used with CAD CAM systems | |
|---|---|
| **Material name** | **Material type** |
| Virablock Mark II | Feldspathic ceramic |
| Cerec | Feldspathic ceramic |
| IPS Empress CAD-CAM | Leucite re-enforced glass-ceramic |
| In-ceram Alumina | Glass infiltrated alumina |
| In-ceram Zirconia | Glass infiltrated alumina with zirconia |
| Procera | Polycrystalline alumina |
| Lava Zirconia | Polycrystalline zirconia (Y-TZP) |

## Computer-aided manufacturing (CAM)

Third and the final stage is Computer-aided manufacturing (CAM). The CAM technologies can be divided in three groups according to the technique used

### a) Subtractive technique from a Solid Block :

In this stage the milling is done with computerized electrically driven diamond disks or burs which cut the restoration from ingots. The CAM technique most commonly applied in manufacturing frameworks for single crowns and the size of the material blocks available for the milling units limits the size of the FPDs

### b) Additive technique (by applying Material on Die)

Here in this technique Alumina or Zirconia is dry pressed on the die and the temperature is raised to a temperature similar to the pre sintering state. At this stage, enlarged and porous coping is stable. Its outer surface are milled to the desired shape and coping, removed from die, and sintered into the furnace for firing to full sintering

### c) Solid free form fabrication :

This category new technologies originating from the area of Rapid Prototyping (RP), which have been adapted to the needs of dental technology .

## Rapid Prototyping Techniques

1. Stereolithography
2. Selective Laser Sintering (SLS)
3. 3-DPrinting

4. Fused Deposition Modeling (FDM)
5. Solid GroundCuring
6. Laminated Object Manufacturing (LOM )

**Stereolithography (Perfactory, Delta Med, Frieberg, Germany):**

It is the technique for creating 3 dimensional objects in which a computer controlled moving laser beam is used to build up the required structure layer by layer.Occlusal splints and diagnostic templates for oral implantology can be produced withthis technique. .herence tomography (OCT )

**Selective Laser Sintering:**

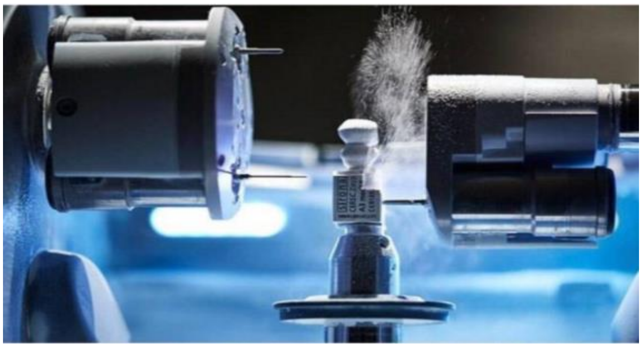
Starts by converting the CAD data in series of layer. These layers are transferred to the additive SLS machine which begins to lay the first layer of powder. As the laser scans the surface, the material is heated and fuse together. Once the single layer formation is completed, the powder bed is lowered and the next layer of powder is rolled out smooth and subjected to laser. Hence layer by layer formation of the object takes place

**3-D Printing:**

In which after computer-aided designing, the machine is used to build (print) a wax pattern of the restoration. Then this wax pattern is cast similar to normal lost-wax technique .Advancement has taken place in such a way that instead of wax ، resin- type material is being used to fabricate patterns

**CAD- CAM milling process**






## Quality Of Product and Comparison With Conventional Method

There are two main correlated factors that determine the overall accuracy of the workflow: accuracy of the acquired image and accuracy of the definitive prosthesis.

The accuracy of the acquired image primarily relies on the performance of the intra-oral scanner. It is also worth noting that different scanners vary significantly in their performance and accuracy. Nonetheless, in-vitro and limited in-vivo studies demonstrate high accuracy, ranging from 4 to 80µm for partial/sextant/quadrant impressions, depending on the type of scanner and study design. On the other hand, fullarch scanning using intra oral scanners demonstrates inferior accuracy when compared to conventional techniques or indirect 3D scanning of stone casts, as do full-arch stereolithographic models fabricated from digital scans, compared to Type IV dental stone casts fabricated from conventional impressions. Therefore, caution needs to be exercised when using full-arch intra-oral scans as they are significantly less accurate than partial scans .

### ADVANTAGES AND DISADVANTAGES OF COMPUTER-ASSISTED PRODUCTION.

**Advantages** of using CAD / CAM technology **for dentists** are :

- The patient spends less time in the office ؛
- A simplified procedure & easer way of producing؛
- Significantly reduced costs for dental technical laboratories ؛
- Reduced consumption of materials ؛
- Increased productivity ؛
- Precisely produced restorations ؛

**Advantages** of using CAD / CAM technology in **dental-technical laboratory** :

- Easier way of producing؛
- More precisely made restorations ؛
- Lower consumption of materials ؛
- Higher productivity .

**Advantages of using CAD / CAM technology to produce onlays:**

- **Very often saves the tooth structure compared to traditional crowns .**

**Advantages of using CAD / CAM technology to produce inlays:**

- **Much better restoration than traditional fillings.**

**Disadvantages**

- **The initial cost of the equipment and software is high, and the practitioner needs to spend time and money on training. Dentists without a large enough volume of restorations will have a difficult time making their investment pay off.**
- **Just as with conventional impressions, in taking an optical scan the dentist needs to obtain an accurate recording of the tooth in need of restoration. The scan needs to emphasize the finish line and precisely duplicate the surrounding and occlusiveteeth. Digital scanning requires the same type of soft-tissue management, retraction, moisture control ،and hemostasis that is so important for conventional impressions.**
- **Digital impression systems may not save time as they are currently used because of the need for multiple steps. For example, dentists who use certain scanners must first send the images for a cleanup process, which is followed by setting of the margins by a dental technician. The images next go to the clinician's dental laboratory for review and then back for model milling. Finally, the models and dies are then sent to the clinician's dental laboratory for fabrication of the restoration**

**Regarding the accuracy of the definitive prosthesis, reviews do indicate that there are no statistically significant differences between digital and conventional workflow techniques , both digital and conventional techniques demonstrated similar discrepancies for SCs and FPDs, with glass ceramics presenting the largest errors in both groups. In contrast, metal alloys demonstrated the least errors compared to glass ceramics and zirconia restorations in the digital group. The choice of using polyether or polyvinyl siloxane impressions did not affect the accuracy of resultant restoration.**

**No significant differences in marginal fit were detected between digital and conventional workflows with discrepancies ranging between 84µm and 142µm ؛**

however, conventionally manufactured crowns demonstrated significantly better cuspal and occlusal fit.

| Table 6: different between conventional & digital impression | |
|---|---|
| **Conventional impression** | **Digital impression** |
| • The technique is well know and acceptable | • Lack of patients familiarity with the concept |
| • Cost ranges from loe-to-modrate | •High initial cost of purchase |
| •Simple equipment need | •Complex digital equipment |
| •Discomfort for the patient | •Discomfort for patient is reduced |
| •Air bubbles or debris cause inaccuracies | • Comparative accuracy with conventional impression |
| •Relatively simple and predicatable clinical technique | •Simpler to use after a period of learning |
| •Stocking the materials and trays | •Eliminates the need for stocking materials and trays |
| •Need labrotary work (pouring the impression, making the base, and trimming) | •Tasks of pouring the impression, making the base, and trimming eliminated<br>• |
| •Creates mess | •Eliminates the mess |

There is no doubt that CAD/CAM will continue to play an increasing role as part of routine dental practice. It is obvious that the technology offers a more streamlined and efficient means of treatment planning and delivery of care through reduced chairside time. Improved patient satisfaction and reported preference is also a major advantage of CAD/CAM. Moreover, the fact that dentists-in-training experience less difficulty using CAD/CAM, reporting their willingness to adopt it upon graduation, compared to conventional techniques and experienced clinicians, indicates that the conventional workflow has reached, if not passed, its peak-use and will eventually be phased out in the near future. Nonetheless, at the moment, the accuracy and treatment outcomes of CAD/CAM treatment modalities are inconsistent and do not support a superior performance to conventional techniques, rather a comparable one. The introduction of a standardized testing method for

**noncontact intraoral scanning would greatly assist in comparing the results of varying studies and minimize existing conflict in findings. There is still much room for improvement. As the technology continues to develop, and our understanding of its capabilities, advantages and limitations, CAD/CAM will be more accessible and affordable, becoming an integral part of standard patient care, reaching its zenith .**

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