

A New Method for Fabricating Ceramic Inlays: the CAD/CIM System Technology for the 21st Century

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Summary

The CAD/CIM method is a new technology in dental medicine which was first introduced in 1996. The paper presents the development of technology and its possibilities. The method of application and fabrication of inlays and veneers is presented and advantages and disadvantages compared to existing conventional methods. The main advantages of the method are that fabrication of an inlay and veneer can be carried out during one appointment in the dental surgery, technicians work in laboratory is unnecessary and the fabricated inlays and veneers are of standardised quality. Phases of the fabrication of an inlay and its final appearance in the mouth are presented. In conclusion it is emphasised that the method offers the possibility of rapid and relatively simple fabrication of inlays, comparable in quality to those produced in the laboratory. Further investigations are needed in order to solve the problem of the width of marginal fractures and application of optimal materials for cementation of the inlay, and to achieve the best possible clinical function of inlays and veneers fabricated by CAD/CIM technology. Clinical results indicate that this technological method has a bright future for use in contemporary dental practice.

Key words: CAM/CIM technology, Cerec, ceramic inlay

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Introduction

The problem of aesthetic restorations of hard dental tissues has long been present in dental medicine, not only in the replacement of dental tissue destroyed by caries but also in the treatment of traumatic injuries, endogenic and exogenic discoloration, hypoplastic defects of hard dental tissue, disorders in the contour and size of teeth and other malformations. For this purpose, apart from the

classical composite restorations, onlays and inlays, laboratory produced composites and ceramic inlays and veneers are also used (1).

CAD/CAM (Computer Aided Design / Computer Aided Manufacture) system first appeared in dental medicine in 1989 with the device CEREC (CEramic REConstruction) for the fabrication of inlays, onlays and labial veneers during one appointment in the dental surgery. An optical "impression" is used instead of the classical impression procedure, and

the dentist's own evaluation of the contour and size of the inlay, onlay or veneer. The development of the technological method enabled complete integration of all phases of fabrication, and this is offered by the CAD/CIM system (Computer Aided Design / Computer Integrated Manufacturing (2, 3, 4).

The advantages of the method are its simplicity: the laboratory is not required, there is no classical impression procedure (the method can be repeated as necessary), rapid fabrication (it is possible to fabricate several veneers during one appointment), acceptable cost (no laboratory costs, time saving), and the fabricated restoration is of the same or higher quality than the laboratory fabricated restoration (3,5,6,7).

The main disadvantages of the CAD/CAM system are the high costs of the CEREC apparatus and mastering the technique.

The first CAD/CAM apparatus for the fabrication of veneers and inlays was developed by Mormann and Brandestini in 1985, although earlier attempts had been made (8-14). The system experienced significant progress in 1986 when it was taken over by Siemens. During the following period materials were developed which were suitable for the Cerec system - Vita CEREC Mark 1 (Vita Zahnfabrik, Bad Säckingen, Germany), DICOR MGC (Dicor, De Trey Dentsply Int., Wiesbaden, Germany) in the form of porcelain blocks which, according to their physical properties (hardness) most resemble enamel (15,16). In 1991 Siemens improved the computation of the edges of the cavity surface and the marginal edge by introducing the COS 2.0 programme for the computer (CEREC Operating System 2.0 software, Siemens, Bensheim, Germany) (17,18,19). Introduction of the electric "E" turbine in place of the existing water (turbine) occurred in 1992, enabling 3-4 times better milling quality and thus more accurate margins of veneers and inlays. A new programme was also introduced for the CEREC 2.1 computer (CEREC Operating System 2.1 software, Siemens, Bensheim, Germany) (6,20,21). With the new programme software introduced in 1997. - C.O.S. 4.24 (CEREC Operating System 4.24 software, Siemens, Bensheim, Germany) and CROWN 1.0 (CEREC Crown 1.0 software, Siemens, Bensheim, Germany) it was possible to fabricate ceramic crowns as well as fillings and veneers.

The Cerec system for fabricating inlays, onlays and veneers consists of the following parts:

1. 3-D oral video camera
2. Monitor
3. Keyboard
4. Indicator (Track ball)
5. Computer programme keys for modelling the veneer/inlay
6. Integrated units for milling

The schematic CEREC system functions in the following way: the oral video camera transfers the image onto the screen of the monitor where it is memorised and the edges of the veneer/inlay determined. The information is then processed by the computer and sent to the milling device which fabricates the veneer/inlay from the ceramic block (5,6) (Fig. 1).

The ceramic block is positioned on a metal stub which enables its fixation in the milling chamber. Cutting is carried out by diamond disks and drills, with simultaneous cooling by a water spray. While the ceramic block rotates on its axis the diamond disk and drill also rotate and translate up and down over the porcelain block, during which the block is cut. A series of approximately 200-400 cuts is necessary to cut a veneer/inlay from one ceramic block (3). The motion of the diamond disk is driven by an electric drive (20,22).

The principle of optical impression

Optical impression can be defined as a method of transferring the image of a prepared cavity onto the monitor of a small computer (4). The method is performed by placing a small video camera with a lens of 1 cm and CCD (Charge Coupled Device) sensor (Fig. 2) with 256 x 256 pixels above the occlusal surface of the cavity of the prepared tooth (2,4,16,23,24).

When the camera is positioned above the prepared tooth the scanner emits infrared light through the lens, which passes through an internal grid consisting of parallel lines. The pattern of light and dark lines which fall on the surface of the prepared tooth is reflected back onto the photoreceptor. The intensity of the reflected light is recorded as voltage which is later converted into digital form (3,5,

16,24). The dark areas of the prepared tooth are of higher voltage and the light areas lower voltage (5,25). This information is later transmitted to the computer. Information on the cavity depth is obtained by means of the distortion of the grid of parallel lines, which depend on the depth of the prepared cavity (2,5,23). The scanner works on the principle of active triangulation (several optical canals exist) and the phenomena of a parallax, which is causally connected - a ray of light is projected through the opening onto the surface of the cavity, creating three points of light (according to distance): near, medial and distant. The reflected ray of light passes through the other opening and forms three images which are shifted laterally due to the parallax effect. In this way it is possible to accurately calculate the position of each particular point in the space (2,16,26) (Fig. 3).

Modelling of a CEREC inlay

The basis for designing a CEREC inlay comprises three-dimensional presentation of data, obtained by scanning (optical impression) during which the size and value of the phase (voltage) for each scanned point (pixel) is obtained. This value is directly connected with the depth of the scanned point (cavity). Consequently, different areas of the prepared tooth can be seen on the screen: the lighter areas show the elevated areas and the dark grey areas show the deeper, undermined areas (27).

By using such interpreted data the three-dimensional design can be accomplished in several layers, marking the floor, equator and the occlusal plane:

While designing the inlay or veneer the floor of the cavity is marked. When the floor has been marked the programme automatically records the left and right wall, from the mesial side towards the distal side. Thus all surfaces of the inlay which are in direct contact with the cavity are established. After which proximal areas are established, which must be in contact with adjacent teeth. The contact point is automatically determined in the equator plane. However, this can be monitored in the cross-cut and if necessary corrected (27). The height of the contact points can also be raised or lowered if necessary (3,5,16,27) (Table 1).

Materials for fabrication of a CEREC inlay

The CEREC system for fabrication of ceramic inlays involves the use of a ceramic block mounted on a metal stub from which the veneer or inlay is fabricated by milling (9,14,15,28,29).

These ceramic blocks have an advantage over dental ceramic which is prepared in the laboratory, because of its unified, easily controlled and standardised properties, which are resistant to dimensional changes during laboratory production and firing, and which are adaptable to mechanical processing (30,31,32). The blocks can be of various dimensions, consistent with the size and contour of the inlay or veneer to be fabricated.

The type of ceramic material most often used in the fabrication of veneers and inlays by the CEREC method is ceramic produced from natural mineral clays (feldspat) (32).

Indications for fabrication of CEREC restorations

In general, indications for fabrication of CEREC veneers and inlays can be classified as general and specific, during which contraindications should be taken into account (6,7,16,29,33,34,35).

General indications require the following conditions:

1. Periodontal tissue with no inflammation and exudation.
2. Good oral hygiene.
3. Supragingival preparation (because of the use of adhesive cementing technique the edges of the preparation must be exposed because of scanning with the CEREC camera).
4. Precise and clean preparation.

Specific indications for fabrication of a CEREC inlay or veneer laminate:

1. Crown fracture.
2. Hypoplasia of enamel.
3. Correction following orthodontic therapy.
4. Cosmetic correction - diastema, reduction of interdental spaces, elongation of the dental crown, discoloration.

5. Erosion of dental tissue.
6. Renewal of existing fillings (composite, amalgam).

The following are some of the contraindications:

1. Bad oral hygiene with persistent gingival inflammatory changes.
2. Occlusal trauma - bruxism, bruxomania.
3. Insufficient surface for application of the adhesive cementing system.
4. Devitalized teeth.
5. Limitation of the CEREC system - veneers or inlays larger than 14 x 12 mm cannot be fabricated.

Cavity preparation

Preparation of the cavity prior to taking the "optical impression" is basically the most important procedure, on which depends the accuracy of the fabricated veneer or inlay. In order for the "optical impression" to be clear and precise, with sharply defined edges, several rules should be observed (Fig. 4):

- The cavity must have a flat floor and vertical walls.
- Supragingival preparation, because of the need for adhesive cementing technique.
- Mesiodistal inclination of inner side of the cavity walls of 4-6° for the length of the cavity.
- Occlusal depth of the preparation should be at least 2 mm.
- The width of the preparation on the isthmus should be 1/3 of the intercuspal range, and not less than 2 mm.
- Preparation of the proximal part of the cavity i.e. divergence of bucal and oral cavity walls from cervical step 4-7° towards the occlusal part.
- When preparing a veneer the thickness of the veneer must be at least 0.7 mm (3,5,15, 16,29,31,36,37).

Clinical procedure for taking an optical impression

Preparation

In order for the walls of the cavity to adequately reflect light, i.e. in order for them to be seen clearly and with as much detail as possible on the screen, they need to be covered with a reflecting agent. For this purpose CEREC solution (CEREC Liquid, Vita Zahnfabrik, Bad Säckingen, Germany) is used which is applied to the surface of the cavity with a brush, ensuring adhesion of the CEREC powder (CEREC Powder, Vita Zahnfabrik, Bad Säckingen, Germany) (reflecting) which is applied with an aerosol at an angle (Fig. 5) to the bottom of the cavity, not directly as this would cause the layer of powder to be too thick and possibly effect the adaptation of the inlay or veneer (2,3,4,5,6). Apart from CEREC powder SCAN'WHITE (Dentaco, Bad Homburg, Germany) can also be used in the form of a solution which is applied to the cavity surface with a brush. Again, the layer of the powder or solution must not be too thick or thin (affecting the quality of the impression). After impression both the powder and solution can be easily removed with a water spray (38).

Taking the impression

After the designing procedure and preparation of the cavity the camera is taken off the stub and placed over the cavity and the peddle at the bottom of the apparatus pressed. Adjustment should be carried out with both hands, taking care that the camera lens is not touching the tooth, which can cause damage to the lens (scratches), or in the case that the lens comes into contact with the reflecting powder the powder particles can effect the quality of the image. Orientation and quality of the image is continually monitored on the screen. When the presentation of the cavity, with regard to accuracy of the image, sharpness, orientation of the cavity, has been satisfactorily coordinated the peddle is released, enabling the optical impression to be "taken" (2,3,5,6,15,16,23,24,26).

Modelling restorations

In the frame for dialogue, "Design mode", select 'Inlay'. Several design models can be chosen: *extrapolation, correlation I and correlation II*.

Extrapolation - design includes several levels: the cavity floor, proximal contact line, cavosurface edge, marginal edge and fissure line. The designing procedure starts by tracing the lines of the cavity floor, and at the end of each phase automatically moves on to a new phase. When fabricating an onlay, where replacement of the cusp is necessary, it is possible to determine the height of the cusp and depth of the fissure. The basis for reconstruction of dental tissues are existing data on the tooth and the traced lines.

Correlation I - is chosen when there is no intact occlusal morphology, which is consequently modelled in plastic material in the mouth or on a model. It is necessary to take two optical impressions. The first is an impression of the prepared cavity and the second of the prepared occlusal surface (functional optical impression). The modelling of the inlay is the same as for the extrapolation programme.

Correlation II - is chosen when acceptable occlusal morphology exists (e.g. an old filling). First an impression of the existing occlusal morphology is taken (functional impression) and then an impression of the prepared cavity. Designing of the inlay is the same as for the extrapolation programme (2,35,39,40).

When tracing the equator line (proximal line), the height and angle of the cusp, it is possible to monitor the design on the vertical and horizontal cross-cuts (windows) and to carry out the necessary corrections to the contact points and the height and angle of the cusps (2,35,39,40).

Modelling veneers

When modelling a veneer it is possible to chose from several different design models:

- extension of the incisal edge
- lateral extension
- construction of the incisal angle
- free shaping of the surface

The design itself is similar to the inlay design. First the cavity floor is traced and then the proximal contacts (contact point). The extension or incisal edge and the surface (top line) line are then modelled (6,37,41,42).

After designing the inlay or veneer a ceramic block of the size marked on the screen is placed in the milling chamber. The function of the additional cutting should also be marked. This is used to mark the separate cutting of the lower side of the inlay or veneer, which is seated on the prepared cavity (5). The screen shows how long the cutting operation is expected to last. After the cutting has been completed the inlay or veneer is taken out of the milling chamber and tested on the tooth (5) (Figs. 6 a and b, and Fig.7).

Cementation of an inlay or veneer

Cementation of an inlay or veneer is performed by adhesive technique, which includes preparation of the enamel and dentine ("total etch") and application of the adhesive system onto the surface of the enamel and dentine. The surface of the ceramic inlay or veneer is etched with 5% hydrofluoric acid (HF) or ammoniac bifluoride (5,6,7,15,16,29,31). After etching a silane coupling agent (e.g. Monobond S, Vivadent Schaan, Liechtenstein) and organic resin are applied, followed by polymerisation. The microhybrid composite cementation material (e.g. Tetric, Vivadent, Schaan, Liechtenstein) is then applied and with the help of an ultrasound apparatus the inlay or veneer is placed in the optimal position. Excess cementing material is removed and polymerisation performed. The veneer is polymerised first from the palatinal side for 60 seconds, followed by the buccal side for 60 seconds. The inlay is also polymerised from all sides for 60 seconds to improve polymerisation of adhesive device.

After polymerisation the inlay or veneer is finished with diamond drills and polished with different combinations of polishing techniques - sof-lex disks, diamond stones, steel brushes for polishing ceramic, pastes for polishing ceramic, rubbers etc. (5,6,7,15,16,29,31) (Fig. 8).

Discussion and conclusion

Fabrication of an inlay by the Cerec system greatly alleviates the clinical procedure as it avoids the classical impression procedure and laboratory work, and several inlays can be fabricated during one appointment. The quality of such fillings is comparable to those produced in the laboratory. Clinical studies have shown the edge of the inlay to be intact even after several years (23,43-48). As there is no laboratory phase in the procedure the quality of the material does not depend on manipulation in the laboratory, thus it is of standardised and known mechanical and chemical properties (28,30).

The possibility of polishing ceramic materials is excellent, which significantly contributes to the

aesthetic effect of the inlay. According to clinical investigations tolerance of the periodontal structures is very good, and due to the adhesive cementing technique and the small marginal cracks which are filled with composite materials, irritation of the pulp and secondary caries are very rare (16,23,43-48).

The possibility of fabricating ceramic restorations by the CAD/CIM method can significantly advance clinical practice, by speeding up and improving the clinical procedure, while ensuring better quality of work. The materials used are of well-known, standardised properties, biocompatible and easily polished. Further development of this technology and integration of the fabrication of ceramic crowns promises a bright future for CAD/CIM technology.