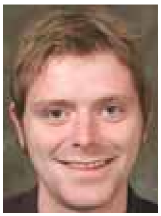

Will Palin

FJ Trevor Burke

Trends in Indirect Dentistry: 8. CAD/CAM Technology

Abstract: Computer-aided design (CAD) and computer-aided manufacturing (CAM) of indirect restorations became available to dentistry over 15 years ago, providing replication and digitization of the complex topography of tooth structure. There are now many applications, providing better mechanical properties, improved marginal integrity and enhanced aesthetics, compared with traditional indirect techniques. Whether a restoration is fabricated by traditional or modern computerized systems, three functional stages are required; data acquisition, design and manufacture. It is the purpose of this paper to describe the applications of CAD and CAM in contemporary indirect dentistry.

Clinical Relevance: Reliable CAD/CAM techniques, some of which may reduce the number of patient visits, are now available for the production of a variety of ceramic restorations.

Dent Update 2005; 32: 566-572

The development of dental material science has provided the modern dentist with an extensive armoury of materials for restorative procedures, where appropriate material properties can be utilized for specific indications. The use of indirect methods for constructing dental prostheses further extends the choice of material, since alternative fabrication procedures can be used which may optimize the mechanical and physical properties of indirect restorations. By comparison, the material properties of direct restoratives are limited by the need to place these into the oral environment. In this respect, the advent of high-performance machinable ceramics and composite materials and improved luting agents and adhesive techniques has widened the potential applications for indirect restorative procedures in general dental practice today.

WM Palin, Biomaterials and **FJT Burke**, Primary Dental Care Research Group, University Birmingham School of Dentistry, St Chad's Queensway, Birmingham B4 6NN, UK.

Computer-aided design (CAD) and computer-aided manufacturing (CAM)

Computer-aided design (CAD) and computer-aided manufacturing (CAM) of indirect dental restorations commenced 20 years ago, and the rapid development of computer-based technology has provided increasingly sophisticated replication and digitization of the complex topography of tooth structures. This has added many advantages to traditional indirect

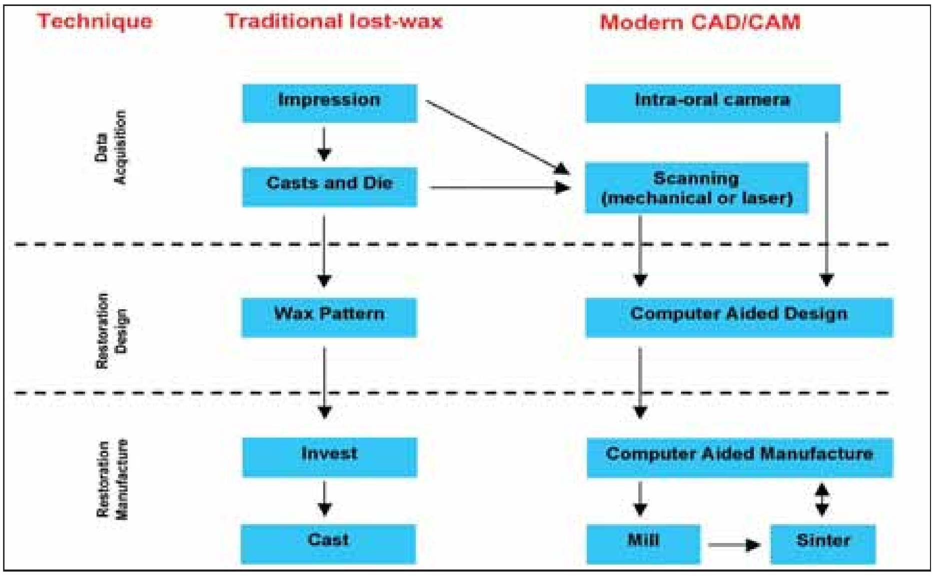

Figure 1. A flow diagram to illustrate the functional stages in the manufacture of an indirect dental prosthesis by a traditional lost-wax casting or a modern CAD/CAM technique (adapted from Rekow[1]).

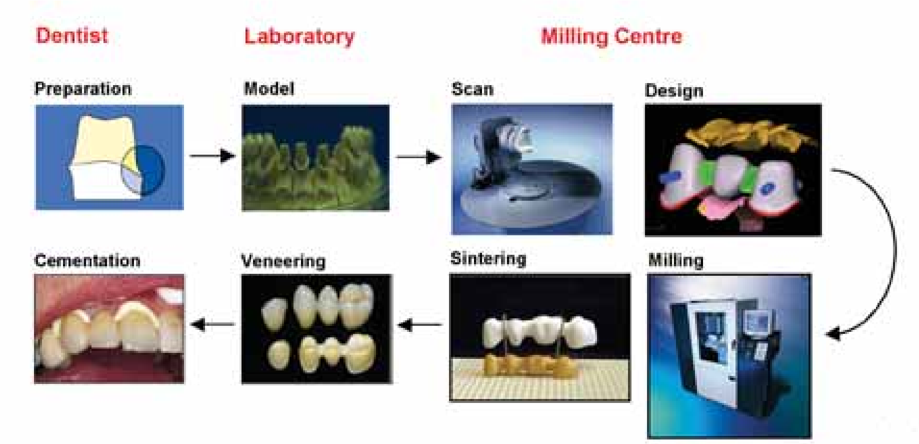

Figure 2. The typical work flow of a modern CAD/CAM system (Lava: 3M ESPE) which operates through a milling centre (images courtesy of 3M ESPE).

techniques, which include:

- No impressioning or casting, which reduces the number of manufacturing steps and may improve the potential accuracy of the final restoration.
- 'Direct' chairside fabrication of various types of restoration in one appointment without the need for a provisional prosthesis.
- No additional costs for laboratory fees or additional chairside time, although initial expenditure on the CAD/CAM equipment may be high.

An increasing number of indirect restorative technologies are available today, given the advancement in CAD/CAM technology over the last decade. This has led to the manufacture of reliable and consistent prostheses, often with optimal mechanical properties, improved marginal integrity and enhanced aesthetics compared with traditional indirect techniques. Whether a restoration is fabricated by traditional or modern computerized systems, three functional stages are required (Figure 1):

- Data acquisition;
- Design; and
- Manufacture.

The process of data acquisition involves collecting information on the patient's occlusal topography, shape and size of the teeth, location of proximal contacts and the static and dynamic positions of the occluding teeth.[1] Like traditional lost-wax casting techniques, the initial stages of data acquisition of the majority of indirect CAD/CAM technologies require impression-taking and model fabrication. The subsequent work flow of a typical modern CAD/CAM system is illustrated in Figure 2. For contemporary CAD/CAM systems, the precise geometry of the model can be digitized using mechanical profilometry or optical laser surface scanning. The major limitation with a method of mechanical scanning is the size of the contact stylus. Large periods of scanning time are required to achieve high resolution, which is dependent upon the distance between the scanned lines. A contact stylus may also produce inaccuracies in measuring cusp slopes with high gradients.[2] The development of non-contact laser scanning (by optical triangulation) has superseded mechanical profilometry in the majority of CAD/CAM systems owing to significantly increased resolution with markedly reduced scan times. However, because of the high reflectance of prefabricated ceramic blocks, restoration surfaces must be coated with a non-reflective powder to reduce optical scatter. This may result in a reduced marginal fitting accuracy (*vide infra*).

Following digitization of the cast model, the sophisticated CAD systems are able to process three-dimensional images of the model, which may then be manipulated to design the final prosthetic model for machining. Machining of the final restoration can be carried out at specified fabrication centres or, with systems such as CEREC (Sirona, Bensheim, Germany), machining may be carried out at the chairside. Conventional all-ceramic core materials are usually milled in their sintered or white body state (Figure 3). However, with the advent of high-performance ceramics, restorations may be processed in their pre-sintered, or green-body state, to reduce milling time and avoid extensive chipping at the marginal edges.

The rapid growth of computer-aided technology has facilitated the development and introduction of several advanced dental CAD/CAM systems. These include, CEREC 3 (Sirona, Bensheim, Germany), Procera (NobelBiocare, Göteborg, Sweden), CERCON Ceramics (DeguDent, Dentsply International Co., Germany), Everest (KaVO, Lake Zurich, IL, USA), Lava (3M ESPE, Seefeld, Germany) and DentaCad (Hint-ELS, Griesheim, Germany). This article outlines a variety of modern commercial CAD/CAM technologies and the core materials used for all-ceramic indirect restorations.

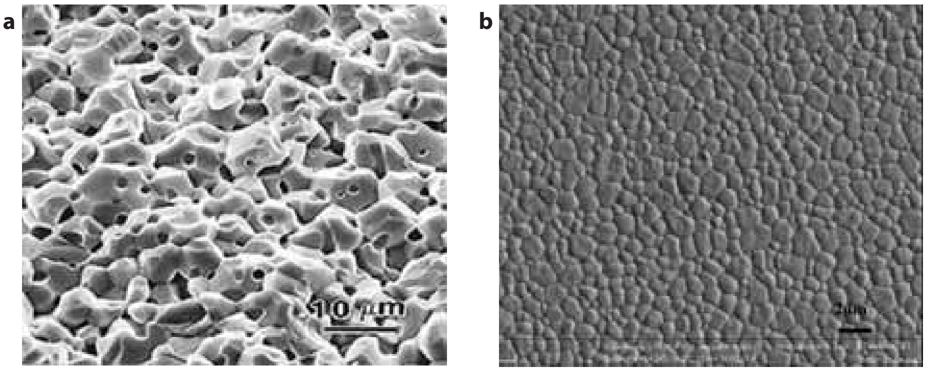

Figure 3. SEM micrographs of the surface of **(a)** pre-sintered (green body) and **(b)** fully sintered (white body) of a Y-TZP-based ceramic core material. (Images courtesy of 3M ESPE.)

Figure 4. The design and milling chamber units of the CEREC 3 CAD/CAM system.

CEREC

Throughout the 1980s, the development of computer technology gave birth to several dental-based CAD/CAM systems. The most promising of that period, which remains commercially available today (albeit in a much advanced form), is the CEREC (CERamic REConstruction) system. CEREC was developed by Professor W Mörmann and Dr M Brandestini in 1980 at the University of Zurich, Switzerland. In 1985, the first patients were treated with CEREC 1 (Brains, Zurich, Switzerland), receiving ceramic inlays, and the system became commercially available from 1988, with many further developments over subsequent years, with the introduction of CEREC 2 (Siemens, Bensheim, Germany) in 1994 and CEREC 3 (Sirona, Bensheim, Germany) in 2000.

The essential working of a CEREC system is an intra-oral camera which provides a three-dimensional 'optical impression'.[3] Following the scanning procedure, the digital information is stored as an 'x,y,z' data model and displayed as a video freeze-frame image, which can then be modified by the practitioner (CAD). The processed data is adapted within the computer system to operate a milling unit to form the prosthesis from industrial blocks of feldspathic ceramic and glass-ceramic, prefabricated under optimum and controlled conditions. The materials used initially were Vita Mark I (Vita Zahnfabrik, Bad Sackingen, Germany) or Dicor MGC (Corning Inc., Acton, MA, US), although these materials have been surpassed by other ceramics supplied by Vita such as Vita Mark II and Vita In-Ceram Zirconia. At the time of its introduction in 1988, the CEREC system was limited to the fabrication of simple inlays. However, it has since been improved in terms of both hardware and software to allow for the manufacture of a wide variety of 'chairside' ceramic restorations, including onlays, partial crowns, veneers and crowns for the anterior, premolar and molar regions. With such a subtractive fabrication method of preformed ceramic blocks, very sharp internal angles of the restorations could not be administered with the large grinding wheels associated with the original CEREC system.[4] Consequently, the grinding precision of CEREC 2 was significantly improved, compared with its predecessor, by the addition of a further cylindrical grinder, allowing for the addition of occlusal pits and fissures and concave and biconvex contouring of veneers.[5] Design specifications of CEREC 3 include a radio-controlled operating system whereby the design and milling chamber units can be deployed separately, allowing for data acquisition and milling to be carried out simultaneously (Figure 4). The milling unit of CEREC 3 is also equipped with a laser scanner (CEREC Scan, CEREC inLab, Sirona) which may be purchased separately from the imaging unit for indirect application of preformed tooth models. The milling wheels of CEREC 1 are replaced in CEREC 3 with a cylindrical floor and wall and a tapered cylindrical rotary diamond milling tool (coated with 64 µm-grit diamonds). The angle of taper, which is 45°, is used to shape the occlusal surface of the restoration. It has been suggested, by the manufacturers, that the CEREC 3 system provides a more flexible and detailed milling procedure than its predecessors, allowing for greater accuracy in fit and occlusion. CEREC 3-D is the latest version of CEREC technology, which allows a three-dimensional view of the preparation and proposed restoration.[6]

The clinical performance of restorations machined by CAD/CAM systems such as CEREC is dependent on several factors, including (adapted from Martin and Jedynakiewicz):[7]

- Hardware and software limitations: accuracy of the intra-oral camera, milling unit and confines of the software program and design algorithms;
- Adhesion: performance of the luting cement and operator variability in cementation;
- Finishing: ability of accurate finishing technique and appropriate occlusion;
- Operator-induced variability: clinical skill and expertise with the system. In this respect, for the majority of operators, there may be a steep learning curve. It is beholden to the manufacturers/suppliers to provide support to clinicians during this period.

Indeed, with the ever-increasing development of computer-based technology, hardware and software limitations become less significant. Nonetheless, limitations with regard to operator technique sensitivity of such CAD/CAM systems still remain. To provide an accurate 'optical impression' with the CEREC intra-oral camera, the tooth surface must be coated with an anti-reflection substance, usually a titanium dioxide powder spray. Previous reports have suggested that titanium dioxide powder layers from 20–600 µm may accumulate in some areas of the cavity preparation and that this may vary between different operators.[8] The optical impression cannot distinguish between the anti-reflection powder and the surface of the cavity preparation, which may significantly affect the marginal fit of the restoration at a critical powder thickness. A previous study reported a significantly improved fit of a CEREC inlay following coating of the cavity preparation with a water-soluble paint compared with the conventional powder aerosol.[9] Cementation and finishing procedures remain highly technique sensitive and will greatly influence the clinical performance of the final restoration. A previous study reported improved clinical longevity of CEREC 2 inlays luted with a chemically-cured, compared with a dual-cured, resin cement,[10] whereas other investigators reported no significant differences in restorative durability for either luting material.[11] The discrepancies were attributed to either insufficiencies of irradiating light intensity or inadequate polymerization of dual-cured cements in certain areas of the cavity preparation. Nevertheless, the estimated average survival rate following 10-years' service was reported as 89% (77% dual-cured and 100% chemically-cured resin cement). Although the performance of CEREC restorations is limited by operator technique, the clinical

Figure 5. The combined scanning and milling unit of the CERCON CAD/CAM system.

performance and patient satisfaction, thus far, appears acceptable.[12]

CEREC is among the most widely investigated and reported CAD/CAM system, with clinical studies being numerous. The systematic review by Martin and Jedynakiewicz reported a high mean survival rate of 97.4% over a period of 4.2 years, with predominant reasons for failure being ceramic fracture, fracture of the supporting tooth, post-operative hypersensitivity and wear of the adhesive interface.[7] Manhart and co-workers reviewed the clinical survival of direct and indirect restorations, including CAD/CAM ceramic restorations implemented in the CEREC system, and reported an annual failure rate between 0 and 5.6% for CEREC 1 and 2.[13] The authors reported a significantly lower mean annual failure rate for indirect restorations (CEREC and cast gold inlays and onlays) compared with direct techniques, and summarized that principal reasons for failure were material-, patient- and dentist-related. There are limited clinical investigations since the transition to the CEREC 3 system, although it has recently been reported that system characteristics, such as enhanced finishing techniques and improved occlusion of CEREC 3 restorations, will lead to improved fit of restorations.[5]

Densely sintered alumina CAD/CAM cores

Procera (Nobel Biocare, Göteborg, Sweden) introduced their all-ceramic concept in 1993. In this process, technicians cast dies in the conventional manner, and send them to a number of specially-equipped centres where the dies are scanned and an enlarged model of the original die is manufactured. The CAD/CAM technology then lays down a dense core of 99.9% alumina by compacting alumina powder on to the enlarged die, which is then sintered. This process compensates for the 15–20 vol% shrinkage of alumina during the sintering process. Feldspathic porcelain is fired on to the alumina coping to achieve the desired aesthetics. The applications of Procera include, 0.6–0.4 mm thick copings for crowns, anterior and posterior three-unit bridges, and also customized titanium implant abutments. Previous *in vitro* investigations have identified the Procera AllCeram system to exhibit flexural strengths in the region of 500–700 MPa, compared with 420–800 MPa for Vita In-Ceram Zirconia,[14] which is a glass-infiltrated alumina with 35% partially-stabilized zirconia (utilized in the CERCON system described below). Results of a previous study also indicate a good prognosis for Procera AllCeram crowns, with a 5- and 10-year cumulative survival rate of 97.7% and 93.5% being identified for anterior and posterior teeth, respectively,[15] and a 100% survival following five years for restorations placed in anterior teeth.[16]

Yttrium tetragonal zirconia polycrystals (Y-TZP)

The need for high strength materials for dental prostheses, in particular, all-ceramic bridgework, has led to the use of additional indirect restorative materials and CAD/CAM systems. The most recent core materials for all-ceramic restorations utilize yttrium tetragonal zirconia polycrystals (Y-TZP)-based materials. These materials were first introduced for replacement acetabular cups in total hip replacement owing to their superior mechanical properties.[17] The popularity of Y-TZP-based ceramics for use in dental prostheses has increased because of the inherent material properties of this multiphase material, which is known to exhibit increased flexural strength and fracture toughness compared with all-ceramic materials (900–1200 compared with 400–800 MPa, respectively).[14] This can be attributed to the addition of yttrium oxide to pure zirconia, which results in a partially stabilized structure capable of transformation of molecular structure to increase resistance to tensile stresses. Y-TZPs used as an all-ceramic core material for indirect dental restorations are utilized in several CAD/CAM systems, including CERCON (DeguDent, Dentsply International Co., Germany), DCS-Precident (DCS Production, Allschwill, Switzerland) and Lava (3M ESPE Dental Products, Seefeld, Germany).

CERCON

The CERCON system (DeguDent, Dentsply International Co., Germany), introduced in 2001, fabricates ceramic dental restorations from unsintered Y-TZP-based ceramic core materials. The CERCON system allows the technician to choose the preferred method of fabrication using either the 'Classic' (CAM) or 'Art' (CAD/CAM) options. With the 'Classic' (CAM) option, the technician designs and produces a traditional wax-pattern of the load-bearing framework, similar in design to that previously prepared for lost-wax casting techniques. The wax model is mounted in a scanning frame which is then anchored to a combined scanning and milling unit (CERCON 'Brain'; Figure 5). Following laser scanning of the wax-pattern, computerized calculations produce a milled form of the Y-TZP framework from the unsintered zirconia blank. In the 'Art' (CAD) mode, the 'Brain's' laser scans the actual die model to produce a digitized screen image of a virtual coping which can then be altered and adjusted at will by the operator. The stored data are then used to produce the milled framework in the same manner as described above. CERCON 'Art' currently offers scanning of single dies only but a new 'bolt-on' scanning device (due to be introduced by the end of 2005), will enable full arch scanning of the model to be undertaken (Bonner K, personal communication, August 2005).

The use of a partially sintered material framework decreases milling time, reduces the wear of the milling components[18] and reduces the potential for the inclusion of material defects throughout the milling procedure.[19] The dimensions of the digitized image of the wax model must be increased to compensate for the inherent shrinkage of the pre-sintered ceramic (15–30 vol%) following final sintering.[19,20] Since volumetric shrinkage is not a factor in manufacture of restorations milled with fully sintered ceramic blocks, some workers consider that such prostheses

Figure 6. Poorly designed metal-ceramic bridge replacing 1/1 (following crown lengthening surgery).

have a superior marginal fit.[18,21]

DCS-Precident

The DCS-Precident CAD/CAM system (DCS Production, Allschwill, Switzerland) was introduced in 1990 and mills core and crown copings from fully sintered blocks of Y-TZP. A conventional wax model is required from the technician, which is subsequently digitized with the Preciscan laser scanner, with the Precimill machining centre milling the substructure from the fully sintered DC-Zirkon (Y-TZP) blank. Since DC-Zirkon is also a relatively new arrival to the dental market, there are few clinical studies on this system and material technology. A recent study has suggested that the use of a DC-Zirkon core material with veneering porcelain provides an acceptable alternative to metal-ceramic bridgework following a two-year clinical follow-up.[22]

Although Y-TZP-based core ceramics are known to exhibit superior flexural strength and fracture toughness to conventional all-ceramic materials, excellent aesthetic properties of these new material components are also essential. It has been suggested that some zirconia-based systems, namely CERCON and DCS-Precident, utilize an opaque, white-coloured core material which may limit aesthetic quality.[14]

Lava

The Lava all-ceramic system (3M ESPE Dental Products, Seefeld, Germany) also uses a CAD/CAM procedure, to produce a framework consisting of a Y-TZP-based ceramic supplemented by a specially designed veneer ceramic. The frameworks are fabricated using contemporary CAD/CAM procedures (scanning, computer-aided framework design and milling) from pre-sintered Y-TZP blanks (Figure 2). The shade of the core material may also be stained to correspond with 1 to 7 shades of the Vita Classic shade system resulting in the ability to develop shading of the restoration which, in turn, may provide the technician with less of a challenge than when required to mask an opaque white ceramic or a grey metal core. This may also eliminate the need to veneer the lingual and gingival aspects of the bridgework connectors.[14] In this respect, the Y-TZP core utilized for the Lava system has been considered to exhibit increased translucency in comparison with other zirconia-based ceramic core materials. The manufacturers have suggested that an ideal translucency may be achieved as a result of inherent material properties and a low wall thickness.

Lava relies on non-contact, photo-optical recording of the surfaces of dies prepared from an impression of the teeth to be restored. The dies and bite registration are digitized by the scanner and are viewed three-dimensionally on the computer screen. The bridge or crown framework may be designed on the computer within the parameters of the system, which set the thickness of the framework and the square area ($9\ mm^2$) of bridge connectors. Pontic designs are retrieved from a library of designs held by the computer system. It could be considered that the solely computer–aided design is an advantage over other systems which require the technician to make a wax build-up.

Long-term clinical data on restorations formed in Lava are not yet available, but communication with a laboratory producing large numbers of Lava frameworks in the UK have not indicated any problems, such as fracture of the framework (Littlejohn L, personal communication, August 2005). Laboratory experimentation by Sorensen with the Lava system for CAD/CAM production of high-strength precision fixed prosthodontics[23] has demonstrated excellent marginal fit of Lava bridges, while results of a series of laboratory experiments carried out on Lava discs by Curtis and co-workers[24,25] have indicated that Lava:

- Does not lose strength in moist conditions;
- Is not adversely affected by grinding by a 20–40 μm bur with water coolant;
- Following surface loading at simulated masticatory loads flexural strength is not affected and the possibility of inducing a transformation toughening mechanism (counteracting crack propagation) may have been identified.

These are promising results, indicating that Lava does not suffer from a common problem with dental ceramics, namely, the adverse effect of oral fluids on their strength. For the clinician, these data show that, if adjustment of the framework is required, this should be carried out using a fine bur with water coolant.

At the time of writing, three Lava milling centres are in operation in the UK, while other countries with a number of milling centres include the USA, Italy and Germany. Technicians wishing to utilize the Lava system for construction of bridge or crown frameworks cast dies in the conventional manner, prior to sending these to the milling centre. When the framework has been constructed, this is returned to the ceramist for the placement of the veneering ceramic, with which good clinical results have been obtained (Figures 6 and 7).

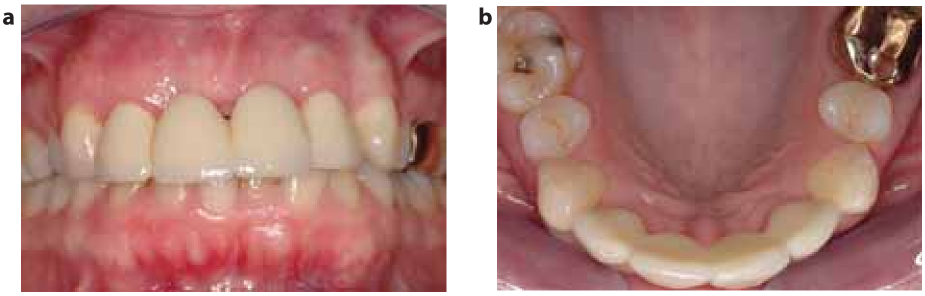

Figure 7(a). Bridge in Figure 6 replaced by a Lava (3M ESPE) all-ceramic bridge. **(b)** View from palatal aspect.

Conclusion

Modern indirect ceramic restorations are suitable for restorations in the anterior as well as the posterior region, and the technology and materials available to the dentist will satisfy the demand for high strength and optimal aesthetic restorative properties. The plethora of clinical studies of restorations placed using the CEREC system has provided encouraging longevity data for CAD/CAM. However, there are only a limited number of studies investigating clinical success rates of restorations fabricated from several of the modern CAD/CAM technologies and ceramic core materials that they utilize. Consequently, the production of long-term clinical data is critical for the accurate assessment of clinical longevity and to establish those CAD/CAM techniques which may decrease the failure rate of all-ceramic dental prostheses. Nevertheless, it could be hoped that replacement of the 'human factor' involved in impression-taking at the chairside and the construction of ceramic or metal frameworks by the technician in the dental production laboratory, and its replacement by CAD/CAM technology, should help the predictability of the final restoration, provided that the materials utilized in the systems have optimum physical properties.

References

1. Rekow ED. High-technology innovations and limitations for restorative dentistry. *Dent Clins N Am* 1993; **37**: 513–524.
2. Hewlett ER, Orro ME, Clark GT. Accuracy testing of three-dimensional digitizing systems. *Dent Mat* 1992; **8**: 49–53.
3. Mörmann WH, Bindl A. The new creativity in ceramic restorations: dental CAD-CIM. *Quintessence Int* 1996; **27**: 821–828.
4. Hickel R, Dasch W, Mehl A, Kremers L. CAD/CAM – Fillings of the future? *Int Dent J* 1997; **47**: 247–258.
5. Mörmann WH, Bindl A. All-ceramic chair-side computer-aided design/computer-aided machining restorations. *Dent Clins N Am* 2002; **46**: 405–426.
6. Allen KL, Schenkel AB, Estafan D. An overview of the CEREC 3D CAD/CAM system. *Gen Dent* 2004; **52**: 234–235.
7. Martin N, Jedynakiewicz NM. Clinical performance of CEREC ceramic inlays: a systematic review. *Dent Mat* 1999; **15**: 54–61.
8. Rekow DE. High-technology innovations and limitations for restorative dentistry. *Dent Clins N Am* 1993; **37**: 513–524.
9. Hembree JH Jr. Comparisons of fit of CAD-CAM restorations using three imaging surfaces. *Quintessence Int* 1995; **26**:145–147.
10. Sjögren G, Molin M, Van Dijken JWV. A 10-year prospective evaluation of CAD/CAM-manufactured (Cerec) ceramic inlays cemented with a chemically cured or dual-cured resin composite. *Int J Prosthodont* 2004; **17**: 241–246.
11. Van Dijken JWV, Hasselrot L, Örmin A, Olofsson A-L. Restorations with extensive dentin/enamel-bonded ceramic coverage. A 5-year follow up. *Eur J Oral Sci* 2001; **109**: 222–229.
12. Burke FJT. Trends in indirect dentistry: 4. Performance of adhesive restorations. *Dent Update* 2005; **32**: 312–325.
13. Manhart J, Chen HY, Hamm G, Hickel R. Review of the clinical survival of direct and indirect restorations in posterior teeth of deciduous dentition. *Oper Dent* 2004; **29**: 481–508.
14. Raigrodski AJ. Contemporary materials and technologies for all-ceramic fixed partial dentures: A review of the literature. *J Prosthet Dent* 2004; **92**: 557–562.
15. Odman P, Andersson B. Procera AllCeram crowns followed for 5 to 10.5 years: a prospective clinical study. *Int J Prosthodont* 2001; **14**: 504–509.
16. Fradeani M, D'Amelio M, Redemagni M, Corrado M. Five-year follow-up with Procera all-ceramic crowns. *Quintessence Int* 2005; **36**: 105–113.
17. Piconi C, Maccauro G. Zirconia as a ceramic biomaterial. *Biomaterials* 1999; **20**: 1–25.
18. Besimo CE, Speilmann HP, Rohner HP. Computer assisted generation of all-ceramic crowns and fixed partial dentures. *Int J Comput Dent* 2001; **4**: 243–262.
19. Luthardt RG, Holzhuter MS, Ruldolph H, Herold V, Walter MH. CAD/CAM machining effects on Y-TZP zirconia. *Dent Mat* 2004; **20**: 655–662.
20. Filser F, Kocher P, Weibel F, Luthy H, Scharer P, Gauckler LJ. Reliability and strength of all-ceramic dental restorations fabricated by direct ceramic machining (DCM). *Int J Comput Dent* 2001; **4**: 89–106.
21. Reich S, Wichmann M, Nkenke E, Proeschel P. Clinical fit of all-ceramic three-unit fixed partial dentures, generated with three different CAD/CAM systems. *Eur J Oral Sci* 2005; **113**: 174–179.
22. Vult von Steyern P, Carlson P, Nilner K. All-ceramic fixed partial dentures designed according to the DC-Zirkon technique. A 2-year clinical study. *J Oral Rehabil* 2005; **32**: 180–187.
23. Sorensen JA. *The LAVA System for CAD/CAM Production of High-Strength Precision Fixed Prosthodontics*. Chicago: Quintessence Publishing Co., 2003: pp. 57–67.
24. Curtis AR, Wright AJ, Fleming GJP. The influence of simulated masticatory loading regimes on the bi-axial flexure strength and reliability of a Y-TZP dental ceramic. *J Dent* 2005, in press.
25. Curtis AR, Wright AJ, Fleming GJP. The influence of surface modification techniques on the performance of a Y-TZP ceramic. *J Dent* 2005, in press.

CPD ANSWERS

November 2005

1. A,B
2. A, B, C
3. B, C
4. B
5. A, B, D
6. B, D
7. A, B, D
8. D
9. A, B, C
10. B, D