Digital dentistry: an overview of recent developments for CAD/CAM generated restorations F. Beuer,1 J. Schweiger2 and D. Edelhoff3 VERIFIABLE CPD PAPER As in many other industries, production stages are increasingly becoming automated in dental technology.McLean J W, von Fraunhofer J A. The estimation of cement film thickness by an in vivo technique.At least a 4 milling axis is required for the milling unit to fabricate a substructure for this situation Table 1 Selection of resin materials for CAD/CAM systems Name Manufacturer CAD/CAM system Description CAD-Waxx Vita inLab 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 CAD-Temp Block Vita Cerec 3, inLab Fibre-free acrylic polymer with micro-filler for long-term temporary full and partial crowns and FPDs up to two pontics Everest C-Temp KaVo Everest Fibre 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 the respective production system.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 pro- gression of cracks in the ceramic (Trans- formation strengthening).24-27 Examples of Zirconium oxide blocks: Lava Frame (3M ESPE), Cercon Smart Ceramics (Degu- Dent), Everest ZS und ZH (KaVo), inCoris Zr (Sirona), In-Ceram YZ (Vita), zerion (etkon) and Zeno Zr (Wieland-Imes) Processing can take place in different density stages a) Green stage processing Green stage: blank without heat treat- ment, ie an object pressed from ceramic powder and binding agents.As a result of the thermal pre-treatment the organic compressing additives have vanished and the blank has an adequate PRACTICE BRITISH DENTAL JOURNAL VOLUME 204 NO. 9 MAY 10 2008 509 (C) 2008 Nature Publishing Group PRACTICE Table 2 Selection of glass ceramic materials for CAD/CAM systems Name Manufacturer CAD/CAM system Description Vitablocs Mark II Vita Cerec 3, inLab Monochrome for inlays, onlays, veneers and full crowns IPS e.max CAD Ivoclar Vivadent inLab, Everest Monochrome for full anatomical crowns, copings and anterior three-unit FPDs Vitablocs TriLuxe Vita Cerec 3, inLab Polychromatic for inlays, onlays, veneers and full crowns IPS Empress CAD Multi Ivoclar Vivadent inLab Polychromatic for inlays, onlays, veneers and full crowns stability.A digitalisation tool/scanner that transforms geometry into digital data that can be processed by the computer 1*Assistant Professor, 2Head of Laboratory, 3Associate Professor, Department of Prosthodontics, Ludwig- Maximilians University, Munich, Germany *Correspondence to: Dr Florian Beuer, Pacific Dental Institute, 12750 SW 68th Avenue, Portland, Oregon, 97223, USA Email: florian.beuer@med.uni-muenchen.de Refereed Paper Accepted 28 March 2008 DOI: 10.1038/sj.bdj.2008.350 (C)British Dental Journal 2008; 204: 505-511 2.Due to their higher stability values, lithium disilicate ceramic blocks are particularly important in this group; they can be used for full anatomical ante- rior and posterior crowns, for copings in the anterior and posterior region and for three-unit FPD frameworks in the ante- rior region due to their high mechanical stability of 360 MPa.12-15 Glass ceramics are particularly well suited to chairside application as a result of their trans- lucent characteristics, similar to that of natural tooth structure; they pro- vide aesthetically pleasing results even without veneering.The precision of fit that can be achieved with the assistance of CAD/CAM sys- tems is reported to be 10-50 um in the 510 BRITISH DENTAL JOURNAL VOLUME 204 NO. 9 MAY 10 2008 (C) 2008 Nature Publishing Group PRACTICE marginal area.8,29,32-34 Thus, the demands of the literature concerning marginal adaptation of dental restorations can be reached with this technology;35,36 in addi- tion, this production process achieves an industrial standard that does not have to deal with the variations of manually produced prostheses.23 8.In recent years, CAD/CAM production has clearly expanded the palette of materials for dental prosthe- ses by providing access to new ceramic materials with high dependability.15,28-31 The stability values of zirconium oxide ceramics permit, in many areas of indi- cation, the use of this material as an alternative to metal frames for perma- nent prostheses.30 The production of long-term temporary prostheses has, as a result of the use of a virtual wax up on the computer, become faster, more convenient and more pre- dictable.This type of scanner is distinguished by a high scanning accu- racy, 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.5,10 The drawbacks of this data measurement technique are to be seen in the inordinately complicated mechanics, which make the apparatus very expen- sive with long processing times com- pared to optical systems. As a result of their relatively high portion of glass, these ceramics are, in contrast to oxide ceram- ics, etchable with hydrofluoric acid and thus can be inserted very well using adhesive systems.16,17 d) Infiltration ceramics Grindable blocks of infiltration ceramics are processed in porous, chalky condi- tion and then infiltrated with lanthanum glass.Thanks to its superior masking ability this ceramic is suitable for discoloured abutment teeth19,20 o VITA In-Ceram Spinell ($MgAl_2O_4$): has the highest translucency of all oxide ceramics and is thus recom- mended for the production of highly aesthetic anterior crown copings, in particular on vital abutment teeth and in the case of young patients.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 standardised chain of production; an improve- ment in precision and planning, as well as an increase in efficiency.c) Silica based ceramics Grindable silica based ceramic blocks are offered by several CAD/CAM systems 508 BRITISH DENTAL JOURNAL VOLUME 204 NO. 9 MAY 10 2008 (C) 2008 Nature Publishing Group for the production of inlays, onlays, veneers, partial crowns and full crowns (fully anatomical, anatomically par- tially reduced) (Table 2).In addition to monochromatic blocks, various manu- facturers now offer blanks with multi-coloured layers [Vitablocs TriLuxe (Vita), IPS Empress CAD Multi (IvoclarVi- vadent)], for the purpose of full anatom- ical crowns.2); on the other hand, some systems also offer the opportunity to design full anatomi- cal crowns, partial crowns, inlays, inlay retained FPDs, as well as adhesive FPDs and telescopic primary crowns.11 The software of CAD/CAM systems presently available on the market is being continu- ously improved.All blanks for infiltration ceram- ics originate from the Vita In-Ceram system (Vita) and are offered in three variations: o Vita In-Ceram Alumina (Al_2O_3): suit- able for crown copings in the anterior and posterior region, three-unit FPD frameworks in the anterior region18 o 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.Sjogren G, Molin M, van Dijken J W. A 10-year pro- spective evaluation of CAD/CAM-manufactured (Cerec) ceramic inlays cemented with a chemically cured or dual-cured resin composite.The ceramist carries out the veneering of the frameworks in a powder layering or overpressing technique.4-7 c) Centralised production The third option of computer-assisted production of dental prostheses is cen- tralised production in a milling centre.The ground frames can be individually stained in several colours with Vita In-Ceram AL Coloring Liquid.5,21-23 Examples of grindable alu- minum oxide blocks: In-Ceram AL Block (Vita), inCoris Al (Sirona) available in an ivory-like colour (Color F 0.7).Tinschert J, Natt G, Mautsch W, Augthun M, Spiekermann H. Fracture resistance of lithium dis- ilicate-, alumina-, and zirconia-based three-unit fixed partial dentures: a laboratory study.The following can be named as examples of optical scanners on the dental market: o Lava Scan ST (3M ESPE, white light projections) o Everest Scan (KaVo, white light projections) o es1 (etkon, laser beam).Pre- fabricated semi-individual polymer blanks (semi-finished) with a dentine enamel layer are provided by one manufacturer (artegral imCrown, Merz Dental).Its high flexural strength and fracture toughness compared with other dental ceramics offer the possibil- ity of using this material as framework material for crowns and FPDs, and, in appropriate indications, for individual implant abutments.This enables the milling of complex geometries with subsections, as for example, lower jaw FPDs on converg- ing abutment teeth (end molar tipped towards the medial plane) (Fig.4), or also crown and FPD substructures that, BRITISH DENTAL JOURNAL VOLUME 204 NO. 9 MAY 10 2008 507 (C) 2008 Nature Publishing Group PRACTICE as a result of anatomically reduced for- mation, demonstrate converging areas in the exterior of the frame. 5 Enlarged zirconium oxide after the milling process before sintering to the desired dimensions e) Oxide high performance ceramics At present, aluminum oxide and zir- conium oxide are offered as blocks for CAD/CAM technology.6 Reverse bevel preparation making the preparation border hardly detectable by the CAD-software on the surface of the prepared tooth as well as the 'creation of troughs' with a reverse bevel preparation margin can be inadequately recognised by many scan- ners (Fig.Reich S, Wichmann M, Nkenke E, Proeschel P. Clini- cal fit of all-ceramic three-unit fixed partial den- tures, generated with three different CAD/CAM systems.Webber B, McDonald A, Knowles J. An in vitro study of the compressive load at fracture of Procera AllCeram crowns with varying thickness of veneer porcelain.Tinschert J, Zwez D, Marx R, Anusavice K J. Struc- tural reliability of alumina-, feldspar-, leucite-, mica- and zirconia-based ceramics.Tinschert J, Natt G, Mautsch W, Spiekermann H, Anusavice K J. Marginal fit of alumina- and zirconia-based fixed partial dentures produced by a CAD/CAM system.Stappert C F, Denner N, Gerds T, Strub J R. Marginal adaptation of different types of all-ceramic partial coverage restorations after exposure to an artifi- cial mouth.b) Laboratory production This variant of production is the equiva- lent to the traditional working sequence BRITISH DENTAL JOURNAL VOLUME 204 NO. 9 MAY 10 2008 505 (C) 2008 Nature Publishing Group IN BRIEF o CAD/CAM technology is widely available, but little is known about it by the general dental practitioner.This offers several benefits: o Minimal investment costs for the milling device o No moisture absorption by the die ZrO2 mould, as a result of which there are no initial drying times for the ZrO2 frame prior to sintering.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 production of the defini- tive prosthesis should also be carried out by CAD/CAM technology and represents merely a copying process of the tempo- rary prosthesis into the definitive pros- thesis by a different material.Otto T, De Nisco S. Computer-aided direct ceramic restorations: a 10- year prospective clinical study of Cerec CAD/CAM inlays and onlays.Sorensen J A, Cruz M, Mito W T, Raffeiner O et al. A clinical investigation on three-unit fixed partial dentures fabricated with a lithium disilicate glass- ceramic.Kosmac T, Oblak C, Jevnikar P, Funduk N, Marion L. The effect of surface grinding and sandblasting on flexural strength and reliability of Y-TZP zirconia ceramic.DEFINITION The term 'CAD/CAM' in dental technol- ogy is currently used as a synonym for prostheses produced by 'milling technol- ogy'.CAD/CAM PRODUCTION CONCEPTS IN DENTISTRY Depending on the location of the com- ponents of the CAD/CAM systems, in dentistry three different production concepts are available: o chairside production o laboratory production o centralised fabrication in a production centre.Scientific literature reported success rates for CAD/CAM produced inlays of 90% after ten years and 85% after 12 and 16 years.1-3 Historically, this system was the first CAD/CAM system in dentistry and is currently available in its third product generation.3 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) (C) 2008 Nature Publishing Group from producing the framework, since it is fabricated in the production centre.The basis therefore is often standard transformation language (STL) data.9 Many manufacturers, how- ever, use their own data formats, spe- cific to that particular manufacturer, with the result that data of the construc- tion programs are not compatible with each other.As a result it is possible to adjust bridge constructions with a large verti- cal height displacement into the usual mould dimensions and thus save mate- rial and milling time.Aluminium oxide is indicated in the case of crown copings in the anterior and posterior area, primary crowns and three-unit anterior FPD frameworks.On the other hand this increase in productivity leads to a competitive capability to pro- duce dental prostheses independent of the manufacturing site, which might be a major factor for the high wage countries to keep business volume in the country.Swain M V, Hannink R H J. Metastability of the martensitic transformation in a 12 mol% ceria- zirconia alloy: grinding studies.Sailer I, Feher A, Filser F, Gauckler L J et al. Five year clinical results of zirconia frameworks for posterior fixed partial dentures.Vult von Steyern P, Carlson P, Nilner K. All-ceramic fixed partial dentures designed according to the DC-Zirkon technique.As the price of dental laboratory work has become a major factor in treatment planning and therapy, automation could enable more competitive production in high-wage areas like Western Europe and the USA.Many production centres also offer laboratories without a scanner the pos- sibility of sending the master cast to the centre for scanning, designing and fab- rication.CAD/CAM COMPONENTS 3.1 Scanner Under the term 'scanner' one under- stands, in the area of dentistry, data collection tools that measure three- dimensional jaw and tooth structures and transform them into digital data sets.PRACTICE 3.3 Processing devices The construction data produced with the CAD software are converted into mill- ing strips for the CAM-processing and finally loaded into the milling device.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 rotat- ing the milling spindle (5th axis) (Fig.The exterior contour conforms to an anatomi- cally complete anterior tooth crown, while the internal aspect of the crown is milled out of the internal volume of the blank. Yttrium stabilised zirconium oxide (ZrO , Y-TZP) 2 Zirconium dioxide is a high-performance oxide ceramic with excellent mechanical characteristics. The advantages and disadvan- tages are as follows. 15,29,30 Advantages: o No sinter shrinkage, as a result no sinter distortions o No sinter furnace necessary o No additional time needed for sintering procedure. Disadvantages: o Devices with high rigidity and stability necessary o Longer milling times, resulting in lower utilisation of devices o High wear of the cutters o No coloured blanks available on the market yet. shoulders in a ceramic res- toration can result in a concentration of tension; in addition sharp edges cannot be milled exactly using rounded grind- ers in the milling device. A 360 degree shoulder or cham- fer preparation is considered to be the appropriate marginal preparation geometries for CAD/CAM produced all-ceramic restorations. Taskonak B, Sertgoz A. Two-year clinical evaluation of lithia-disilicate based all-ceramic crowns and fixed partial dentures. Vult von Steyern P, Jonsson O, Nilner K. Five-year evaluation of posterior all-ceramic three-unit (In- Ceram) FPDs. Raigrodski A J, Chiche G J, Swift E J Jr. All-ceramic fixed partial dentures, Part III: clinical studies. Bindl A, Mormann W H. Marginal and internal fit of all-ceramic CAD/CAM crown-copings on chamfer preparations. Sulaiman F, Chai J, Jameson L M, Wozniak W T. A comparison of the marginal fit of In-Ceram, IPS Empress, and Procera crowns. 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. Examples: Everest (KaVo), Zeno 8060 (Wieland-Imes), inLab (Sirona). 1.2.3.

1).3).3).3).4.5.6.7.6). 1.2.3.4.5.6.7.8.9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19.20.21.22.23.24.25.26.27.28.29.30.3 .1.32.33.34.35.36