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CAD / CAM dental systems in implant dentistry: Update

Mª Ángeles Fuster-Torres [1], Salvador Albalat-Estela [2], Mariano Alcañiz-Raya [3], María Peñarrocha-Diago [4]

[1] Master of Oral Surgery and Implantology. Barcelona University
[2] MedicLab Medical Director .Polytechnic University of Valencia
[3] Doctor of Industrial Engineering. Professor of Polytechnic University of Valencia
[4] Professor of Oral Surgery. Valencia University Medical and Dental School. Valencia, Spain

Correspondence:
C/ Gascó Oliag nº1
46021 Valencia. Spain
maria.penarrocha@uv.es

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Abstract
CAD/CAM systems (computer-aided design / computer aided manufacturing) used for decades in restorative dentistry have expanded its application to implant dentistry.
This study aimed to look through CAD/CAM systems used in implant dentistry, especially emphasizing implant abutments and surgical templates manufacturing. A search of articles published in English at Medline and Scopus databases at present was conducted, introducing "dental CAD/CAM", "implants abutments" and "surgical guide CAD/CAM" as key words.
These systems consist of three components: 1) data capture using optical systems or laser scanning, 2) CAD for the design of the restoration, and 3) CAM to produce the restoration through the information generated by computer.
CAD/CAM abutments present the advantages of being specific to each patient and providing a better fit than the rest of abutments, in addition to being much more tough as they employ materials such as titanium, alumina and zirconium.
In order to improve accuracy during implant placement we use stereolithography to manufacture CAD/CAM surgical templates. Using this method, minimally invasive surgery is performed without a flap, and the prosthesis is delivered, achieving immediate functional loading to the implants.

Key words: *Dental CAD/CAM, implant abutments, surgical template, dental implants.*

Introduction
CAD/CAM (computer-aided design/computer aided manufacturing) systems have evolved over the last two decades and have been used by dental health professionals for over twenty years (1).
In 1971, Francois Duret introduced CAD/CAM in restorative dentistry (1) and, in 1983, the first dental CAD/CAM restoration was manufactured (2).
One of the main lines of implementation was the intraoperative use for dental restoration using prefabricated ceramic monoblocks (3).
The CAD / CAM systems have been used mostly for the manufacturing of prosthetic fixed restorations, such as inlays, onlays, veneers and crowns. During the last decade technological developments in these systems have provided alternative restorations using different

materials such as porcelain, composite resin and metallic blocks, which could not be prosecuted previously because of technical limitations (4).
Nowadays there is a greater interest in the CAD/CAM systems for implant-supported prosthesis, as they have been used for the manufacture of implant abutments (5) and diagnostic templates in implant dentistry (6).
The aim of this paper is to review the CAD/CAM systems used in implant dentistry, and describe its application in the construction of implant abutments and surgical templates.

Material and Methods

A search of articles published in English at Medline and Scopus databases at present was conducted, introducing “dental CAD/CAM”, “implants abutments” and “surgical guide CAD/CAM” as key words. 59 articles were found using this search strategy. All articles that described the construction of implant abutments and surgical templates using CAD/CAM technology were included, not excluding articles about clinical cases or in vitro studies. 29 articles were used finally.

Results

CAD/CAM components
CAD/CAM systems are compound of three basic functional components (7):
1. Data capture or scanning to obtain the oral information. To conduct this process there are different trading systems:
- Intraoral capture. This method uses 3D optical systems for capturing single components anatomy. Some examples are: Interférométrie Moire, laser scan, color-coding (such as CEREC (8) and Evolution 4D (Evolution 4D)) (9).
- Anatomical dental duplicate capture (plaster cast), usually using a laser scan method. Comercial products such as RapidForm® (RapidForm), Slim® (Slim), polyWorks® (polyWorks) and Geometric Studio® (Geometric Studio) are used for the 3D meshes post-process.
2. CAD for the geometric design of the restoration. These CAD systems have some simple functions to change the restauration geometry.
3. CAM to manufacture the restoration. CAM systems use computer-assisted information to shape a physical object, using subtract methods (that removes material from a starting block to obtain the desired shape) or using additive methods, used in the rapid prototyping, increasingly used in CAD/CAM oral technology.
Prosthetic abutments
Ideally, the abutment head should resemble a prepared tooth with good form, morphology and emergence profile. Proper implant positioning and appropiate preparation of hard and soft tissue are critical to creating optimal emergence profile, function, esthetics, and periodontal health.
The types available can be separated into three categories:
Stock (prefabricated). They are milled in different materials (titanium, zirconium) using CAD/CAM technology. These are available either straight or preangled.
UCLA (laboratory wax and cast). They are manufactured from a gold platform and a castable sleeve that allows to individualize the shape and height.
Computer-milled solid abutment (10). A solid block of titanium is milled using a computerized milling machine to the operator´s specifications.
CAD/CAM abutments in Implant Dentistry
Advantages of CAD/CAM abutments
Custom abutments created with CAD/CAM technology have the potential to provide the advantages of both stock and laboratory processed custom abutments without the disadvantages(2). First, like laboratory-made abutments, CAD/CAM abutments are specific for each patient (11), however the results are much more consistent. The technician´s learning curve is less steep than that for handmade components. The technician controls the abutment design using CAD software that incorporates parameters to assist him or her. The virtually designed abutment is electronically transferred to a CAM milling apparatus that creates the abutment from a block of the selected abutment material. Most of the inherent dimensional inaccuracies of waxing, investing and casting are eliminated. Unlike stock or cast custom abutments, the abutment surfaces of CAD/CAM abutments are not subjected to the above-mentioned manipulation processes after machining, so CAD/CAM abutments have the potential to provide the most accurate fit of any abutment type.
When compared with a stock and cast abutment, the cost of a CAD/CAM implant abutment presently lies somewhere between the two. This expense is likely to decrease over time as CAD/CAM systems for abutment fabrication become commonplace. Conversely, costs of manpower and labor-intensive laboratory processes are likely to escalate, thereby increasing the cost of prepared stock abutments or handmade cast custom abutments.

Materials used

CAD/CAM technology has used metals such as titanium and titanium alloys, and ceramics such as aluminum oxide or zirconium oxide for the fabrication of implant abutments (12). The higher strength of these materials, which can be shaped only with CAD/CAM systems, has increased the longevity of these restorations and the demand between dentists recently. Some of these products are: CEREC 3D® (Sirona Dental Systems) (CEREC 3D), Everest® (Everest) (13) and Lava® (LAVA) (14).
CAD/CAM Custom Implant Abutments
Most implant systems offer these kind of abutments (4). The sequence begins introducing the patient informa-

tion in the software that employs CAD/CAM technology. The laboratory technician waxes the prosthesis over the corresponding abutment and scans it. Then this structure is adapted to the antagonist arch and to the emergency profile. These data are transferred to the CAM center and the designed abutment is then milled, adding the ceramic later (4).

Nowadays, with the exception of the internal or external hex, the abutment structure is designed following this method. The current CAD softwares have databases that allow to choose the abutment, or another option is to scan and introduce it into the software to get the desired shape. Then the designed shape can be modified according to instructions sent with the case. The digital information is transferred to a computer-controlled milling machine and the abutment is milled from a solid block of titanium alloy. The milled abutment is turned to the cast to verify the fit and shape (10).

Commercially available CAD/CAM abutments systems Cerec® (Sirona, Patterson Dental Co., Milwaukee, WI) is an available system that allows the milling of ceramic restorations at the dental office. The dentist can scan the image from the patient mouth using an optical scanner, design the ceramic restorations and mill them at the dental office. If diagnosis is thorough and accurate, placing the implant and doing a definitive restoration in 1 appointment can be as predictable as the traditional 2 appointment technique (15). One of the most important disadvantages is that the dentist must purchase the scanner machine, the milling units and softwares.

Ortorp et al. (16) show that the precision of fit between cast and CNC-milled titanium implant frameworks for the edentulous mandible was better than structures made in a traditional process.

Atlantis® Abutments(Atlantis Components, Inc, Cambridge, MA), milled in titanium alloy, has been commercially available since the early the 1990s.

A single impresion or implant positioning index can be made at the time of implant surgery, or it can be made in a second stage, when a minor modification of the abutment will be necessary so that soft tissues will be healed. A transfer coping is attached to the implants and an index is fabricated orienting the transfer copings to the adjacent teeth. This is sent to the laboratory together with full-arch impressions. The laboratory incorporates the implant analogs into the master cast using the transfer coping and makes measurements directly on the cast. This determines what degree of emergence profile is needed and the length and shape of the abutments and the margins. The image generated can be modified according to instructions sent with the case. The file is transferred to a computer-controlled precision milling machine and the abutment is milled from a solid block of titanium. The milled abutments are returned to the treatment casts to verify proper shape, contour, and occlusal clearance (10).

Atlantis provides a second duplicate abutment to give dentists the option of placing a provisional crown on the first abutment and a definitive crown on the second. Ensuing tissue recession during soft tissue healing may necessitate hand modifications of the abutment margin before crown fabrication (2).

Procera® (Nobel Biocare, Yorba Linda, CA), initially developed for titanium and aluminum oxide copings for convencional crowns, has recently added implant abutments to their line of CAD/CAM components (5).The abutment made of commercially pure titanium eliminates concerns about the use of dissimilar metals and about interfases between machined and cast components. As for natural abutments, the luting agent, the height and convergence angle of the abutment influence the retention of metal doping luted on titanium CAD/CAM abutments. Specifically for CAD/CAM titanium Procera® abutment the most retentive cement was zinc-phosphate, followed by polyurethane, polyurethane plus vaseline, and zinc oxide-eugenol (17).

The Procera® system also allowed the production of sintered alumina and zirconia abutments, which have provided new opportunities for single-tooth esthetic restorations. With this system, the abutment is virtually designed by the local laboratory using a Procera digital scanning system and software purchased from Nobel Biocare. The information is ellectronically transmitted to a Procera facility where the virtual abutment is milled and returned to the local laboratory. The dentist has the option to receive both a CAD/CAM abutment and CAD/CAM titanium or ceramic coping using this same system (2).

Some advantages of this technique are the possibility of shorten the overall treatment time and the minimal manipulation of the soft tissue (18). Heydecke et al. (19) emphasizes the natural appearance using aluminum oxide ceramic implant abutments and the minimal necessity of postproduction adjustments if we compare with stock abutments. The accuracy of this system is reflected in the concept Teeth-in-an-hourTM (20) for immediate functional loading in maxilla using CAD/CAM fixed prostheses manufactured from a block of milled titanium through the protocol Procera Implant Bridge.

Procera abutment, after determining the precision of fit (21), could be considered for universal application for the most commonly used external-hexagon implant systems Branemark System (Nobel Biocare, Lifecore Restore (Lifecore Biomedical, Chaska, MN), Implant Innovations (3i) System, ImplaMed (Sterngold-IMplaMed, Attleboro, MA) y Paragon Taper-Lock (Encino, CA).

There are some in vitro studies (22,23) which purpose was to assess the precision at the implant interface of titanium, zirconia and alumina Procera abutments with a hexagonal connection for single tooth restorations, suggesting Procera abutments showed less than 3 degrees of rotational freedom, what shows a stable screw joint and may reduce the risk of screw loosening.

Encode® Restorative System (3i Implant Innovations Inc, Palm Beach Gardes, Fla). The system consists of a coded healing abutment and a CAD/CAM titanium abutment. The proprietary healing abutment has three notches that are codes that provide the information about the implant hex position, the platform diameter, and the soft tissue collar height, all of which are necessary to design the definitive abutment. A laser optical scanner interprets these codes, and a custom abutment is designed with special CAD software. The scanning process is a white light scanner that scans the definitive casts of the healing abutment and the opposing arch. The digital information is transformed to a solid model. The proprietary software recognizes the codes on the healing abutment and the designed abutment is then milled from a solid titanium alloy block. Finally, a cement-retained restoration is fabricated over the CAD/CAM abutment in the dental laboratory (24).

Advantages of this system are (24): 1) it provides an anatomical emergente profile for the definitive abutment; 2) it provides the ability to correct an implant angle of up to 30 degrees; 3) there is no need to wax or cast, so laboratory time and cost are decreased; 4) it is easy to use since there is an option not to make an implant-level impression, and there is no need for intraoral abutment preparation. However, this technique does have its disadvantages (24,25): 1) its use is limited to a specific implant system (3i Implant Innovtions, Inc); 2) an inter-arch space of at least 6 mm and minimal distance of 2 mm between the implants are required; 3) ceramic abutments are not available; 4) specific mounting plates are needed for mounting the final casts, 5) these abutments cannot be used when there is less than 1 mm of soft tissue surrounding an implant or if one implant deviates more than 30 degrees from other implants.

CAD/CAM surgical guides

Placement of dental implants requires precise planning that accounts for anatomic limitations and restorative goals. Diagnosis can be made with the assistance of computerized tomographic scanning, but transfer of planning to the surgical field is limited. Recently, novel CAD/CAM techniques such as stereolithographic rapid prototyping have been developed to build surgical guides in an attempt to improve precision of implant placement (26,27). As a result of this technology, the surgical guide permits accurate and consistent position and orientation of the implants (28). Sarment et al. (26) showed the advantage of this technique in a case-control study that compared the distances between planned implants and actual osteotomies using a conventional surgical guide or a stereolithographic surgical guide (SurgiGuide; Materialise Medical, Glen Burnie, MD).

Using the surgical template, minimally invasive surgery is performed without a flap, what is called transmucosal implant placement, that shows reduced patient morbidity (29,30).

Then, the transference of the surgical planification from the software to the patient using these guides facilitates the production of a prostheses that will be delivered after surgery, achieving immediate functional loading to the implants.

Conclusions

1 CAD/CAM technology applied to implant surgery allows the production of high resistance and high density crowns, and the manufacture of implant abutments and surgical guides.

2 A custom design, a perfect fit and a higher resistance are the main characteristics of CAD/CAM implant abutments.

3 CAD/CAM surgical templates allow to transfer the software planning to the surgical field.

References

1. Duret F, Blouin JL, Duret B. CAD-CAM in dentistry. J Am Dent Assoc. 1988;117:715-20.

2. Priest G. Virtual-designed and computer-milled implant abutments. J Oral Maxillofac Surg. 2005;63:22-32.

3. Mörmann WH. The origin of the Cerec method: a personal review of the first 5 years. Int J Comput Dent. 2004;7:11-24.

4. Raigrodski AJ. Contemporary materials and technologies for all-ceramic fixed partial dentures: a review of the literature. J Prosthet Dent. 2004;92:557-62.

5. Kucey BK, Fraser DC. The Procera abutment--the fifth generation abutment for dental implants. J Can Dent Assoc. 2000;66:445-9.

6. Voitik AJ. CT data and its CAD and CAM utility in implant planning: part I. J Oral Implantol. 2002;28:302-3.

7. Strub JR, Rekow ED, Witkowski S. Computer-aided design and fabrication of dental restorations: current systems and future possibilities. J Am Dent Assoc. 2006;137:1289-96.

8. Sirona [homepage on the Internet]. Germany: SIRONA Dental Systeme GmbH; 1997 [updated 2007 Jan 3; cited 2008 Jan7]. Available from: http://www.sirona.com/es.

9. D4D Technologies [homepage on the Internet]. Dallas: D4D Tecnologies, L.L.C.; 2007 [updated 2008 Jan 2 ;cited 2008 Jan7]; Available from: http://www.d4dtech.com.

10. Schneider A, Kurtzman GM. Computerized milled solid implant abutments utilized at second stage surgery. Gen Dent. 2001;49:416-20.

11. Petrungaro PS. Immediate one-stage implant placement and CAD/CAM abutments for posterior restorations. Pract Proced Aesthet Dent. 2003;15:595-9.

12. Sherry JS, Sims LO, Balshi SF. A simple technique for immediate placement of definitive engaging custom abutments using computerized tomography and flapless guided surgery. Quintessence Int. 2007;38:755-62.

13. Kavo [homepage on the Internet]. Germany: Kavo Dental GmbH; 2004 [updated 2007 Apr 9 ;cited 2008 Jan6]; Available from: http://www.kavo-everest.com.

14. 3M [homepage on the Internet]. Minnesota: 3M Company, 1902 [updated 2008 Feb 4 ;cited 2008 Jan6]; Available from: http://cms.3m.com/cms/US/en/2-21kzikuFW/view.jhtml.15. Griffin JD. Immediate definitive CAD/CAM restoration of a non-submerged implant. Compend Contin Educ Dent. 2005;26:115-6, 118, 120-2.

16. Ortorp A, Jemt T, Bäck T, Jälevik T. Comparisons of precision of fit between cast and CNC-milled titanium implant frameworks for the edentulous mandible. Int J Prosthodont. 2003;16:194-200.

17. Bresciano M, Schierano G, Manzella C, Screti A, Bignardi C, Preti G. Retention of luting agents on implant abutments of different height and taper. Clin Oral Implants Res. 2005;16:594-8.
18. Tselios N, Parel SM, Jones JD. Immediate placement and immediate provisional abutment modeling in anterior single-tooth implant restorations using a CAD/CAM application: a clinical report. J Prosthet Dent. 2006;95:181-5.
19. Heydecke G, Sierraalta M, Razzoog ME. Evolution and use of aluminum oxide single-tooth implant abutments: a short review and presentation of two cases. Int J Prosthodont. 2002;15:488-93.
20. Mitrani R, Vasilic M, Bruguera A. Fabrication of an implant-supported reconstruction utilizing CAD/CAM technology. Pract Proced Aesthet Dent. 2005;17:71-8.
21. Lang LA, Sierraalta M, Hoffensperger M, Wang RF. Evaluation of the precision of fit between the Procera custom abutment and various implant systems. Int J Oral Maxillofac Implants. 2003;18:652-8.
22. Takahashi T, Gunne J. Fit of implant frameworks: an in vitro comparison between two fabrication techniques. J Prosthet Dent. 2003;89:256-60.
23. Vigolo P, Fonzi F, Majzoub Z, Cordioli G. An in vitro evaluation of titanium, zirconia, and alumina procera abutments with hexagonal connection. Int J Oral Maxillofac Implants. 2006;21:575-80.
24. Grossmann Y, Pasciuta M, Finger IM. A novel technique using a coded healing abutment for the fabrication of a CAD/CAM titanium abutment for an implant-supported restoration. J Prosthet Dent. 2006;95:258-61.
25. Drago CJ. Two new clinical/laboratory protocols for CAD/CAM implant restorations. J Am Dent Assoc. 2006;137:794-800.
26. Sarment DP, Sukovic P, Clinthorne N. Accuracy of implant placement with a stereolithographic surgical guide. Int J Oral Maxillofac Implants. 2003;18:571-7.
27. Marchack CB. CAD/CAM-guided implant surgery and fabrication of an immediately loaded prosthesis for a partially edentulous patient. J Prosthet Dent. 2007;97:389-94.
28. Benjamin LS. The evolution of multiplanar diagnostic imaging: predictable transfer of preoperative analysis to the surgical site. J Oral Implantol. 2002;28:135-44.
29. Balshi SF, Wolfinger GJ, Balshi TJ. Surgical planning and prosthesis construction using computed tomography, CAD/CAM technology, and the Internet for immediate loading of dental implants. J Esthet Restor Dent. 2006;18:312-23.
30. Nkenke E, Eitner S, Radespiel-Tröger M, Vairaktaris E, Neukam FW, Fenner M. Patient-centred outcomes comparing transmucosal implant placement with an open approach in the maxilla: a prospective, non-randomized pilot study. Clin Oral Implants Res. 2007;18:197-203.