Original article

Intra-oral scanning and CAD/CAM prosthesis fabrication

Enrico Moglioni[1]
Luca dal Carlo[2]
Mike Shulman[2]
Marco Pasqualini[2]
Franco Rossi[2]
Carlo Cosma[2]
Flavio Lico[2]
Paolo Diotallevi[3]

[1] Presidente ARASS (Associazione per la Ricerca e le Attività Sociali in Stomatologia)
Association for Research and Social Activity in Stomatology Rome Italy
[2] Medico odontoiatra
[3] Medico radiologo

Corresponding author:
Enrico Moglioni
Presidente ARASS (Associazione per la Ricerca e le Attività Sociali in Stomatologia)
Association for Research and Social Activity in Stomatology Rome Italy
3388752989
enrico.moglioni@fastwebnet.it

Abstract

The acronym Cad-Cam stands for Computer-Aided Design and Computer-Aided Manufacturing. In 1970, Dr. Francois Duret and his colleagues were the first to develop a Cad-Cam dental system, later named the Sopha system (Sopha BioConcept, Inc. Los Angeles). In the early 80s, a Swiss dentist, Dr. Werner Mörmann, and an Italian electronic engineer, Eng. Marco Brandestini developed the first Cad-Cam chairside system for dental use, known as the Cerec system (Chairside Economical Restoration of Esthetic Ceramics). Anderson and his colleagues attempted to create titanium caps using Cad-Cam technology. In 1983, they introduced a Cad- Cam technology to mill implant restorations in titanium and cover it with ceramic or composite. This system later became known as the Procera system. Computer-Aided Design (CAD) technology of computerized systems to create, modify, analyze and enhance the design process. Computer-Assisted Manufacturing (CAM) is an automated system that organizes manages, and controls manufacturing process.

Together Cad-Cam process has three cycles:
1. The data acquisition.
2. Data elaboration and design processing.
3. Manufacturing of the appliance.

An intraoral scanner can capture the optical impression of soft and hard tissue intraorally. Alternatively, models fabricated from analog (traditional) impressions can be scanned and digitalized with a scanner. Doctors will transfer accumulated data to the dental laboratory, where dental technicians design and manufacture the prosthesis.

Especially in electro-welded immediate load implantology (characteristic of the Italian school of implantology) the digital flow optimized the entire rehabilitation process.

The Benefits of Using a CAD-CAM technology.
- **Effective communication with the patient.**
- **Greater patient comfort.**
- **Better diagnosis.**
- **Easy storage of data.**
- **A scanner is far less invasive compared to traditional dental impressions.**
- **The possibility of creating and reproducing high quantities dental models.**
- **The fast transfer of files via the internet to a laboratory situated far away.**
- **The reduction of corrections and remakes, high production workflow.**
- **Saving time and costs of the entire restoration process.**
- **The decrease in non-recyclable materials.**
- **The possibility of planning and simulating implant surgery using designated software, merging the intraoral scanning data is 3D CAT radiography (DICOM).**

Limitations of Using a CAD-CAM technology:
- **Initial Investment.**
- **Learning Curve.**
- **Continuous software updating.**

Computer-aided design (CAD) and computer-aided manufacturing (CAM) are innovative digital systems capable of scanning prepared teeth intended for receiving crowns, bridges, inlays, and other restorations. With the advent of technologies and potential applications, dentistry is one application area that has gained the highest market share in the last few years. CAD/CAM systems offer a better, faster, and more convenient method for fabricating dental restorations.

Many dental schools adopted CAD/CAM technology intended for education and clinical patient care. CAD/CAM technology improves the experience of both the professional and patient by reducing patient visits, increasing efficiency, and contributing to a positive practice environment and clinical productivity. Such factors ultimately contribute to the overall market growth and revenue during the forecast period.

Keywords: CAD/CAM, Intraoral Scanner, One-piece, Immediate loading, Intraorally welded, Implants Surgical Guides.

Introduction

The acronym Cad-Cam stands for Computer-Aided Design and Computer-Aided Manufacturing.
Computer-Aided Design (CAD) technology is applied to computerized systems to facilitate the creation, modification, analysis and enhancement of a design.
Computer-Assisted Manufacturing (CAM) is an automated system that organizes, manages and controls manufacturing operations (1).
In 1970, Dr. Francois Duret and his colleagues were the first to develop a Cad-Cam dental system, later named the Sopha system (Sopha BioConcept, Inc.Los Angeles) (2).
In the early 80s, a Swiss dentist, Dr. Werner Mörmann, and an Italian electronic engineer, Eng. Marco Brandestini developed the first Cad-Cam chairside system for dental use, known as the Cerec system (Chairside Economical Restoration ofEsthetic Ceramics) (3).
Anderson and his colleagues attempted to create titanium caps using Cad-Cam technology. In 1983, they introduced a Cad- Cam technology to mill implant restorations in titanium and cover it with ceramic or composite. This system later became known as the Procera system (4).
Computers are substitutes for regular hand-operated activity, and trained dental technicians, making the workflow more expeditious, cost-effective, and predictable.
Cad-Cam has three cycles (Fig. 1):

1. The data acquisition.
2. The data elaboration, design processing.
3. Manufacturing of the appliance.

The traditional method

The traditional method.
For a fixed metal-ceramic prosthesis manufacturing:
- Dental Impression
- Plaster Model
- Modeling of substructure in wax
- Casting
- Metal preparation
- Ceramic application

All these stages are 100% manual operations. All work depends on technicians and all of them can potentially flaw the final product. With different quality control levels, these defects could be detected relatively late; this might prolong the production times.
when detected and corrected (Fig. 2).
Collateral damage or side-effects of inappropriately produced laboratory work:
- open margins cause secondary decay and gingival inflammation, decreasing the teeth and prosthesis's lifespan, ultimately bone loss;
- the nonpassive fit of the prosthesis can move teeth to compensate for the deficiency.

However, overloaded implants will react differently than the teeth, active lateral forces will cause bone loss and ultimately even implant loss.
Natural teeth can move axially by 25-100μ and 56-108μ laterally (5). Prostheses on implants move more than

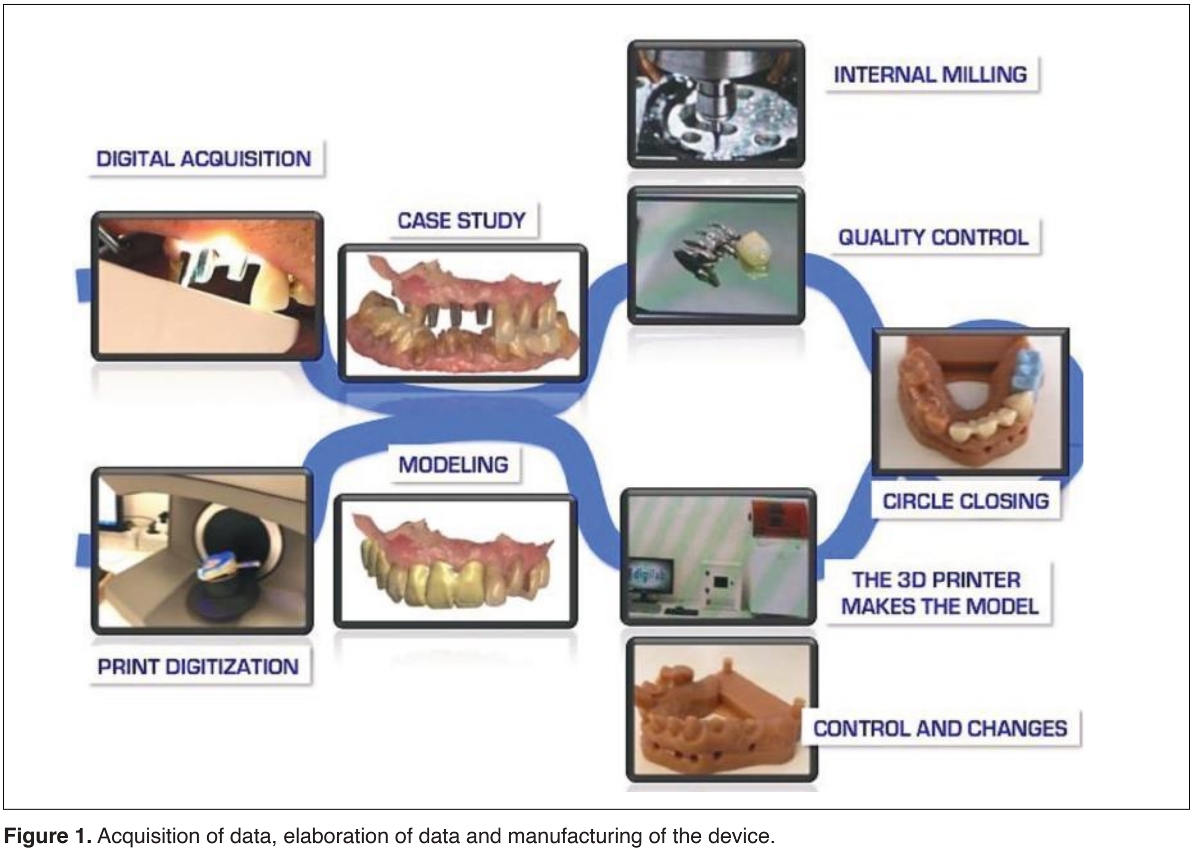

Figure 1. Acquisition of data, elaboration of data and manufacturing of the device.

Figure 2. Dimensional changes in elastomer impression material can be duplicated as plaster modeling errors, ultimately producing prostheses with defects.

3-5μ in an axial direction and 10-50μ in a lateral direction; implants will fail if moving further (6). An incorrect prosthesis fit generates stress that can negatively affect the bone-implant interface and, therefore, become the first step towards an implant's dis-integration (7). The most common prosthetic complications, the screw loosening or fracture, can be related to a nonpassive, forced prosthesis insertion (8).
If a titanium bar is seated with extra stress (nonpassive fitting) on welded abutments, it will cause an unbalanced forces distribution (9)

Analog, Traditional intraoral impressions

The dental impression material can inaccurately impress a titanium bar welded to the monolithic implants' abutments. This mono-block structure has undercuts (10). Elastomeric materials impressing the undercut, are deformed upon withdrawal, may not ideally resemble the contour, and when it is reproduced on the model, it will create inaccuracies.
The time between taking the impressions and casting the plaster model also can affect the accuracy because of the material's dimensional stability.
Small and thin abutments may give the technicians a hard timereproducing them on the model (11).
When comparing analog to digital impressions, the authors suggest that most of the challenges described above areeliminated (12)

Intraoral scanners

Intraoral scanners (IOS) are devices used for capturing direct optical impressions. The hard and soft tissues images, captured by imaging sensors and scanning software, generatea 3D model.
Taking dental impressions and the fabrication models can be done with an intraoral scanner and 3D printer (Fig. 3).
Digital dental impressions are the first step (Fig. 4).

Figure 3. Intraoral Scanner.

Figure 4. Scan of one-phase implant abutments level.

CHART 1. Compares manufacturing processes for a different type of restoration. Traditional workflow compared to CAD-CAM technology.
CAD-CAM technology eliminates some steps as well as 70% manual labor (Fig. 5).

Digital flow in implant prosthetics

Reverse Engineering

The term "reverse engineering" refers to the techniques and technologies which enable a virtual product to be created from a real one. Reverse-engineering can recreate the object or create a similar object with added enhancements to reconstruct an existing object's virtual or CAD model (13). In dentistry, these techniques are used to transfer a patient's anatomy into a calculator. Three general steps are common to all reverse-engineering efforts. They include:

- Information extraction. The reverse-engineered object is studied, information about its design is extracted and it is examined to determine how the pieces fit together.
- Modeling. The collected information is summarized into a model. Information is specific to the original and abstracts it into a general model that can design new objects.
- Review. Reviewing the model and testing it in various scenarios ensures a realistic abstraction of the original object or system. Once it is tested, the model can be implemented to reengineer the original object.

Computer-aided design (CAD) is a reverse-engineering technique used to recreate a manufactured part. It involves producing 3D images of the part so it can be remanufactured.A coordinate measuring machine measures the part, and as it is measured, a 3D wireframe image is generated using CAD software and displayed on a monitor. Reverse-engineering techniques eliminate some of the guesswork.

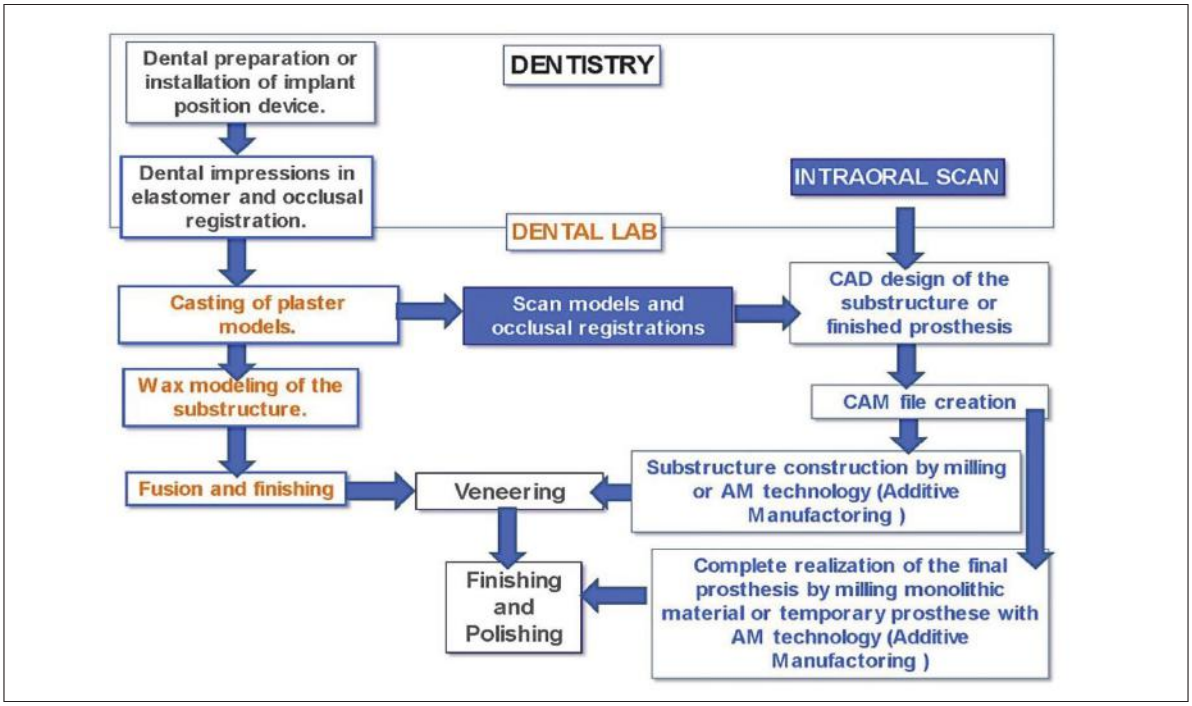

Figure 5 The main manufacturing processes for the creation of metal-ceramic ormetal-free crowns.

Digital dental workflow

- Digitalization done by the dentist; the digital impression of the patient's soft and hard tissue. Scanning of the preparation. Implant/abutment direct scan or a scanning body. Scanning by the dental technician a plaster model obtained from a traditional impression or scanning the impression also transferring articulated models into the virtual articulator in the laboratory.
- CAD designing of a prosthesis.
- The technician is milling the substructure or monolithic prosthesis.
- Application of the veneering material, finishing, and polishing.
- Dentist delivers the prosthesis to the patient.

3D Scanner

All 3D scanners are instruments to scan an object and uselight and specific sensors to convert optical data, the so-called "cloud of points" converting it into a 3D model. The basic principle is the emission of a light signal (Laser or structured light) by an emitter and the receiver's return signal's reception (14).
In dentistry, the most common scanners are the so-called "triangulation scanners."
Typically, a 3D scanner consists of a source of light, one or more video cameras. 3D scanners essentially create a digital copy of a real-world object. This digital copy of the 3D file can then be edited and 3D printed. Also, a 3D file can be used for further 3D modeling processes. Nowadays, in this 21st-century, Engineers are using this technology for reverse engineering processes. 3D scanner files are generally compatible with CADsoftware and 3D printing slicer software.

Dentists scan the dental/implant surfaces and/or of the scan-body implants and adjacent anatomical structures, the scanner reproduces the morphology of the dental arch with elements. Typically, hundreds of scans are necessary to capture all of the information from various sides and angles. These scans are then integrated through a common reference system known as alignment/registration.
Finally, the individual scans are merged to re-create the final model. This entire process of bringing together the individual scans and merging them is known as a 3D scanning pipeline. The dotted image reproduces the morphology of the scanned dental arch. At this point, it is necessary for the cloud of points to transform into a surface. To do this, the software undertakesthe joining of the single discrete points, according to a mathematical formula, measuring the distance between them and reconstructing a grid formed by a series of minuscule polygons (generally triangles) (Fig. 6).

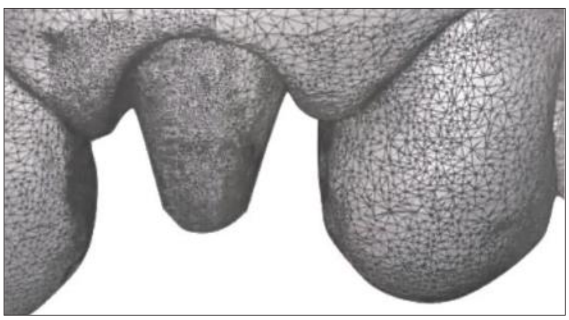

Figure 6. The software connects the points in the cloud, reconstructing a grid formed of triangles, calculating the area, and defining its filling in.

It is possible to calculate the three-dimensional position. The light is reflected through trigonometry, measuring the angleand distance between the video and the light source (which forms the scanner head). This principle of measurement is known as "triangulation." It is possible to obtain an in-depth image through scanning.
Having a series of polygons created by a wireframe, the software can calculate the single triangles' area and fill themin. The in-depth image is an image in which the 3D coordinatesof the object's surface are memorized.
A solid structure is recreated and forms the virtual model, and accuracy depends on the dimensions and number of triangles. Therefore, it is based on the number of reference points initially recorded by the scanner—the more detailed the scan, the more detailed reconstruction.
STL file formats encode information in order to store it on a computer. When it comes to 3D printing, the STL (Standard Triangulation Language) file format is the most commonly used.
The scanners that are available on the market are contactless optical technologies, such as:
- Confocal microscopy.
- Photogrammetry.
- Active and passive stereo display.
- Triangulation.

When the scanner recognizes a curved surface, such as the cylindrical bar welded to the implant abutments, it immediately increases the number of triangles. Although a large number of points, on one hand, better define the scanned area, on the other hand, this does not necessarily guarantee accuracy and precision.
Accuracy: represents the error/discrepancy between the recorded measurement and its true value (accepted as accurate). It is an error that supersedes the acquired data; where measurements of the same value are repeated, it canbe considered the distance between the average and truemeasurements.
Precision: is represented by the dispersion of the measurements around their average. It enables an estimation of the casual error component, considering several repeated measurements. Precision means the ability to repeat the same measurement several times. So, an already precise machine simply needs to be set accordingly to achieve maximum accuracy (Fig. 7).

Transfer of digital data to the laboratory

Once the optical impression is recorded and filed, the STL file is sent directly to the designated laboratory (Fig. 8).

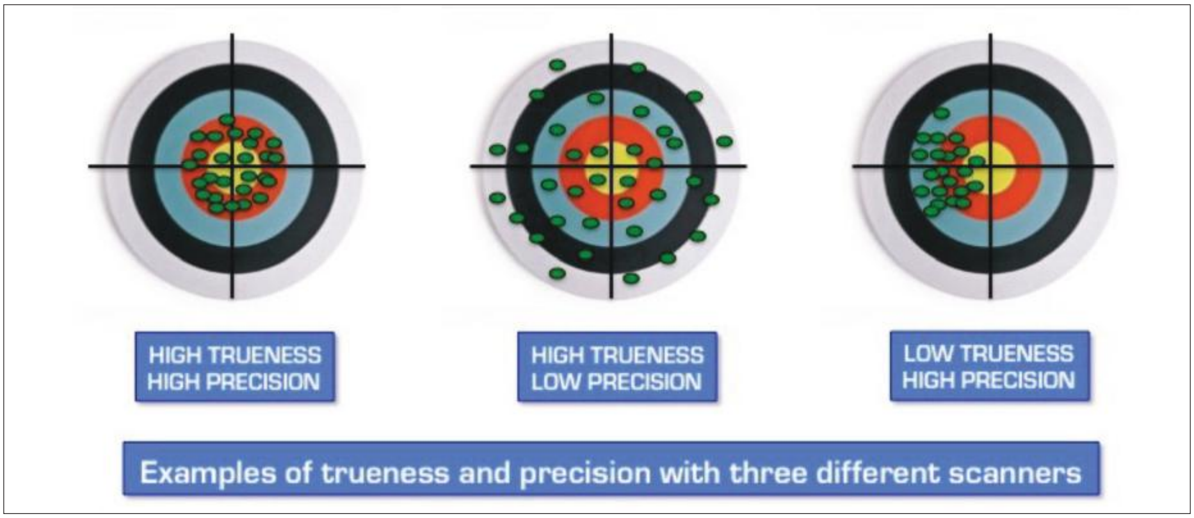

Figure 7. Examples of accuracy and precision (trueness and precision) with three different scanners.

Scanner precision

The international standards regarding the international regulations ISO 10360-1-9 2013 (15) Geometrical Product Specifications (GPS) (Quality control Test for coordination of the measuring machines (CMM); while for dentistry, the regulation is ISO 12836:2012 (16) (Dentistry - Digitizing devices for Cad-Cam systems for indirect dental restorations- test methods for assessing accuracy).
The parameters linked to three-dimensional measuring are resolution, accuracy, and precision; that is, measurement uncertainty. These can be defined in the following way:
(Maximum) Resolution: generally consists of the most minute variations in measurement possible to measure.
The cloud density of points is proportional to the resolution: it affects the distance between the recorded points and describes geometrical details of small dimensions.

Figure 8. Enhanced impression sent by internet to the laboratory.

The optical impression of welded/unwelded one phase immediate load implants

We are working with the one-piece implant/abutment (17).

Preparation of implant abutments

During the preparation, it is necessary to increase the interproximal space so that the cameras' light can stream freely and, therefore, precisely record the details. The one-piece implant/abutments, smaller than two-piece abutments, facilitates the camera capturing (Fig. 9-10).

Gingival retractions

Once the implants placements, preparation, and adjustments of the abutments are completed, the gingival margin needs to be verified and recorded; the gum needs to be repositioned or retracted. Gingival retraction can be accomplished using retraction cords; in some cases, a laser can be a helpful instrument.

Figures 11 and 12. Three implants, one submerged, and two one-piece implants were welded together in this clinical case. After integration, the welded bar was removed, and the three implants were prepared for impressions. Gingival cord/retractors were placed, and digital impressions were taken.

The upper jaw was scanned pre-operatively, where the abutments were positioned; this area was cropped from the image. The prepped abutments are scanned, and the software will re-impose the abutments into the previously cropped area (Fig. 13).

Figure 9. Intra-oral scanning of the abutment portion of the one- piece implants was prepared similar to natural teeth.

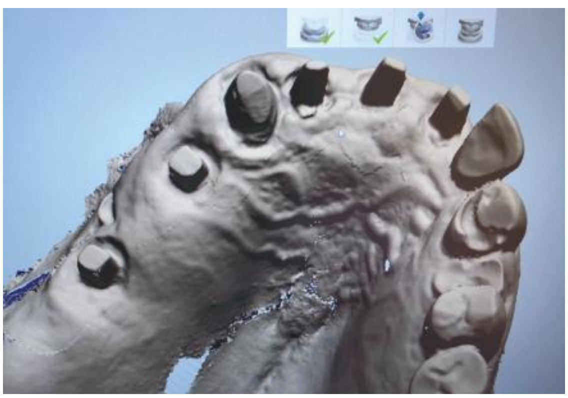

Figure 10. The structure of the one-piece implant abutment provides easier access for scanning.

Figure 11. Removing the welded bar, verifying the implant stability and the refining margins of the abutments.

Figure 12. The two gingival retractors/cords were left during the digital impression acquisition (clinical case of figure 11).

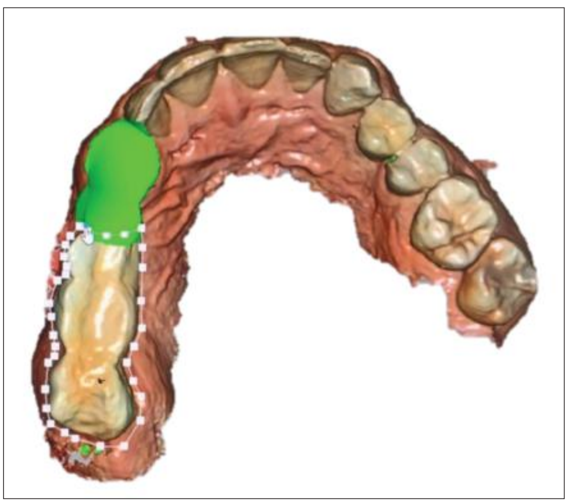

Figure 13. The eliminated area will be reproduced through the rescanning of the area with the placed abutments.

The acquired image part is cropped, and this area (cropped) is rescanned; It saves time because the second scan does not include the entire jaw. As this area is rescanned, the new partial second scan will re-impose the previously cropped part of the digital impression.
The full upper jaw impression, with the implant abutments and soft tissue, is reconstructed as a model. Once the second scan is complete, it can be articulated with the opposing jaw, the occlusion is scanned and sent (emailed) to the laboratory (Fig. 14).
Working with an intraoral scanner, taking digital records gives us:
The entire upper and lower jaw with the functional temporary prosthesis.
The recording confirmed occlusion.
The possibility for the second fragment impression to be re-imposed and to be taken any time later (a day or a week or longer).
The bite registration taken for the full mouth without the need to be retaken. Once the fragment is re-imposed, theocclusal record used is the one saved before.
The full-arch impression/model can be duplicated and saved.

Digital impressions of implants

The digital impression of the implants connected with a bar is a challenging procedure in the restorative stage (18).
Temporary PMMA prosthesis cemented on immediately inserted and connected implants. It will provide a temporary patient's function for the duration of the integration of the implant (19-21) (Fig. 15).
The digital impression of the temporary prosthesis is taken for record-keeping purposes. It can be used as a part of the permanent impression later on (Fig. 16).
This model will be used in the laboratory as a permanent prosthesis guideline. Occlusion, horizontal and vertical overjets are verified, and the technician can build the final prosthesis with the outline based on the provided data.
The temporary is removed and the implant abutments modifiedas needed to define the finishing line (Fig. 17).

Size control

The preoperative model, the temporary prosthesis model, will be used in the laboratory as a permanent prosthesis prototype.

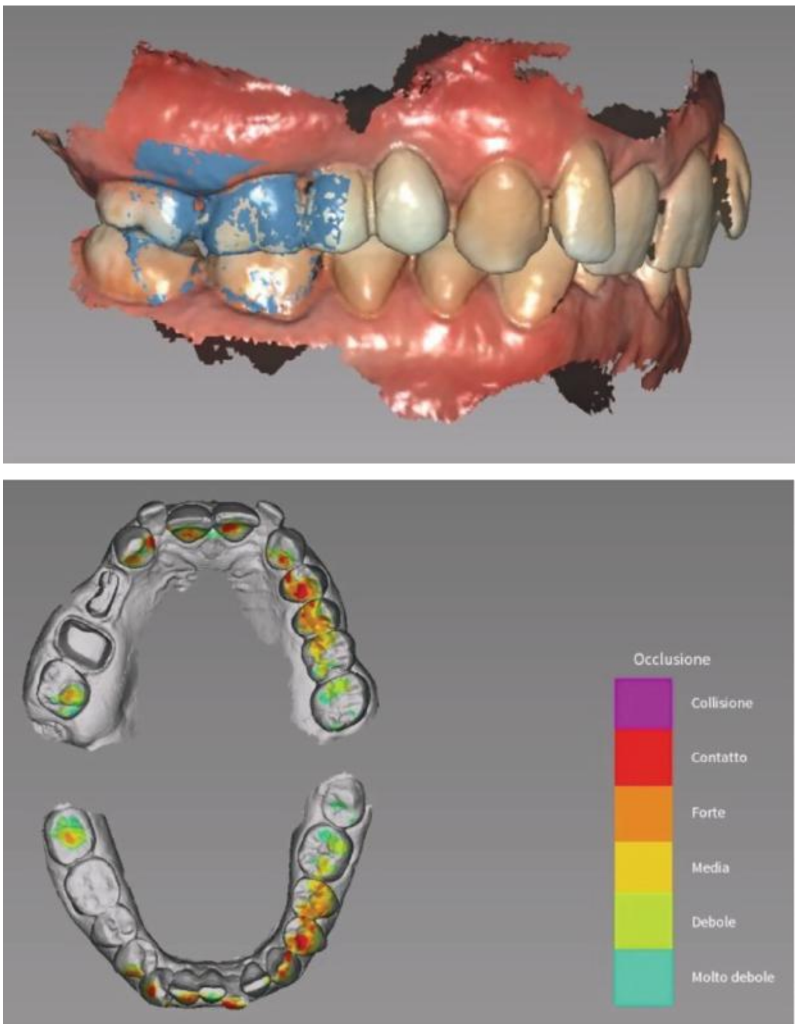

Figure 14. Bite registration record.

Figure 15.

Occlusion, horizontal and vertical overjects are verified, and the technician can create the final prosthesis outline based on provided data (Fig. 18).
We can verify that both abutments and the welded bar are within limits to maintain a proper prosthesis outline. If the bar position is compromised, the bar can be rewelded and the impression retaken. Intraoral scanning can verify the miss- angulated abutment, the compromised path of insertion and even the presence of an undercut; all these can be corrected and the impression retaken. This correction can be done with almost no time wasted, unlike using an analog, older technique (Fig. 19).
With a welded bar (22, 23) on the abutments, undercuts are frequent, especially junction points. With the digital impression, it can be detected and eliminated almost instantly.

Design of closing margins

Digital/optical impression reveals the finishing line immediately,and if it needs to be redefined, it can be done at that time (Fig. 20).
Another function of the software is to personally trace the prosthesis finishing line, the margins of the restoration.

Figure 16. The optical impression/ model of the temporary prosthesis after healing.

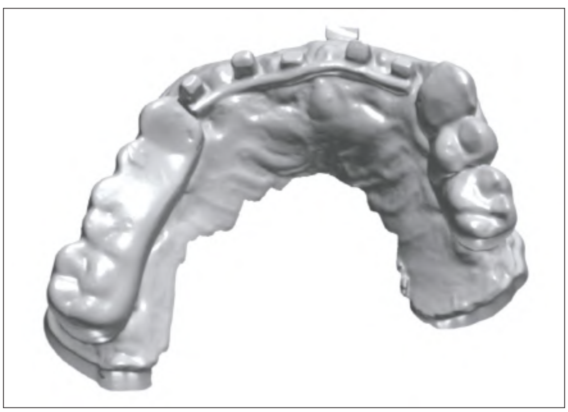

Figure 17. Illustration of the optical impression with welded one-phase implants at the laboratory, the workflow continues.

The margin is highlighted with a colored line, memorizing and saving it as a file. The welded bar is rested on the edentulous area, and we can draw the equatorial margin on the bar. The equator indicates the line which the prosthetic structure must not bypass.
Continuing with the digital flow, the software will visualize the acquired data in 3D; the technician will design a dental restoration in 3D (Fig. 21).

The Benefits of Using an Intra-Oral Scanner

- Effective communication with the patient.
- Greater patient comfort.
- Better diagnosis.
- Easy storage of data.
- A scanner is far less invasive compared to traditional dentalimpressions.

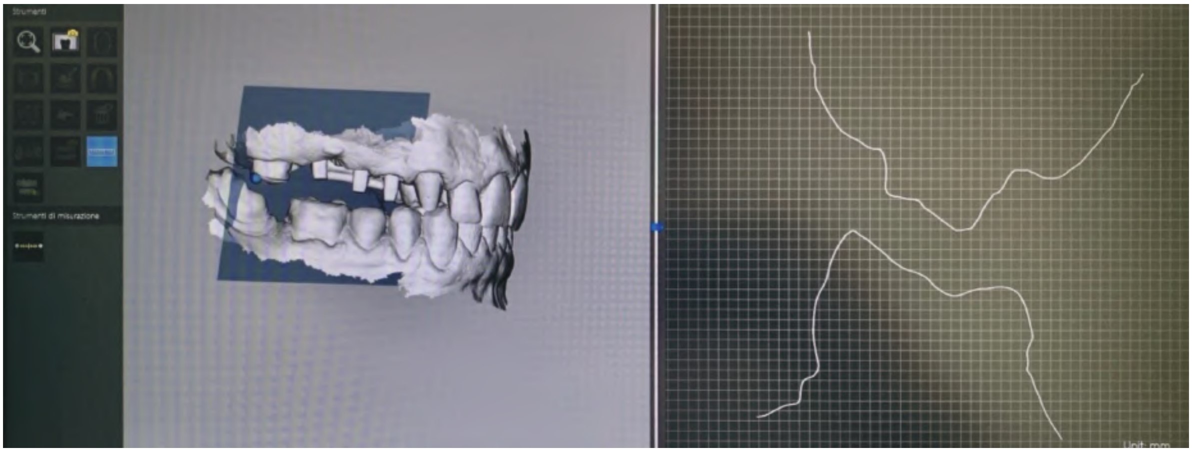

Figure 18. Control and immediate verification of the available sizes for the correct illustration of the prosthesis.

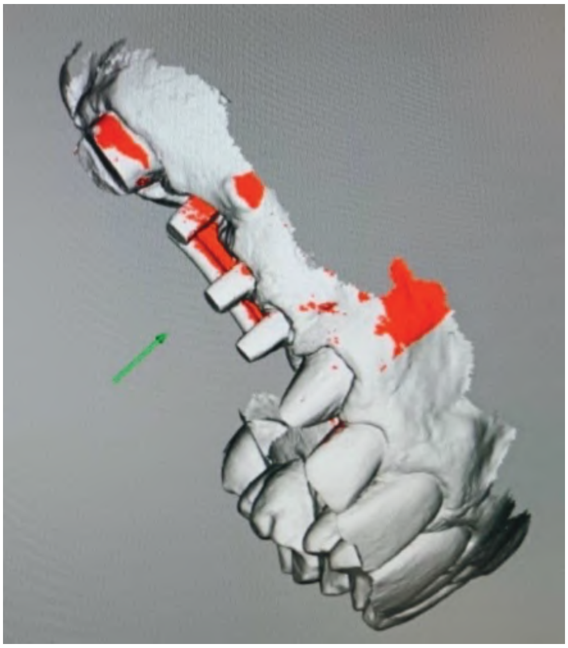

Figure 19. Assessing the presence of an undercut when it is determined can be immediately eliminated.

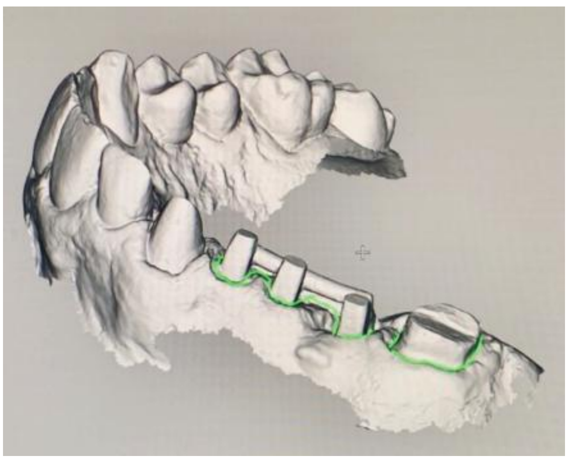

Figure 20. Outlining the finishing line or the restoration margins on the implant abutments.

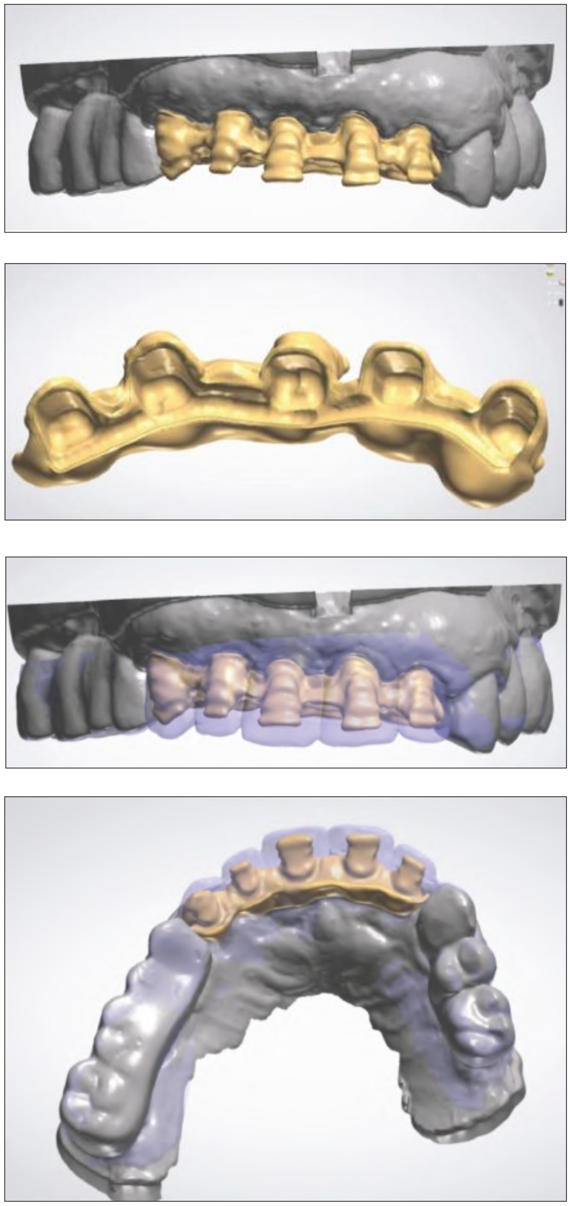

Figure 21. Design and illustration of the prosthetic restorations.

- The possibility to create and reproduce high quantitiesdental models.
- The fast transfer of files via the internet to a laboratorysituated many kilometers away.
- The reduction of corrections and remakes, high productionworkflow.
- Saving time and costs of the entire restoration process.
- The decrease in non-recyclable materials.
- The possibility of planning and simulating implant surgery using designated software, merging the intraoral scanning data is 3D CAT radiography (file DICOM).

There are some Limits:

- Initial Investment.
- Learning Curve.
- Continuous software updating.
- The camera's light may have limitations when a shiny object needs to be scanned. Oral fluids and gum covering the margin line have to be eliminated.

CAD technology, the different components of the prosthesis processing, two distinct working techniques:
The subtractive technique - CNC.
The milling machines are equipped with different drills for various materials. They can be used to cut solid disks. Alternatively, a soft disk (a green stage) will later besintered to become hard (24).
The additive technique - AM
The structure is built layer by layer, known as Additive Manufacturing (25).
Today, CAD/CAM technology has become irreplaceable, yet the last word is human intellect and the human hand.

Surgical guides

As Oral Implantology is becoming a standard treatment modality, more and more doctors are adding it to their treatment choices.
Artificial intelligence has also become part of our professional and social lifestyles. Bringing elements of artificial intelligence into our everyday lives changed it at different levels. As we are implying in oral implantology, one can say that 3D treatment planning and treatment performance has improved dramatically.
Treatment times, accuracy, and outcome benefited from artificial intelligence engagement.
As we move along with new technologies, one should understand the benefits and limitations, to guarantee the proper application.
Different synopses are as follow: computer-guided surgery, computer-assisted surgery.
It is up to an operator to decide who is what. Without prejudice we study the main principles to cover both options, and the operator will have to choose.
CBCT, initially used for diagnostic purposes, is the best for assessment, diagnosis, treatment planning and guiding the surgical and prosthodontic means.
The 3D reconstruction becomes more and more precise and predictable in education, fabricating surgical and prosthetic appliances.
Virtual treatment planning, implant placement, bone reduction, or bone augmentation can be guided or controlled with the surgical guide's utilization.
As artificial intelligence algorithms become more and more advanced, the increasing precision of the elements built with AI's help and its reliability make it irreplaceable in today's life.
Today, the practitioners are divided into a few groups, utilizing surgical guides, as computer-guided procedures and computer-assisted ones.
Once the CBCT acquisition was completed, the operator studied the radiographic images, checking for possible pathologies, examining vital structures.
To eliminate any possible misreading, it is recommended that the Maxillofacial radiologist evaluates the image.
The software used to design and illustrate the treatment planning, including implant placements and bone augmentations, usually comes with CBCT. Various third-party softwares offer comprehensive CBCT review, 3D reconstruction, treatment planning, and surgical guides design.
To transfer the data, build surgical guides or temporary restorations, we need to merge radiographic data. It generally comes in DICOM format files, with hard and soft tissue images obtained from the optical intraoral scan in STL format. To merge these files (generated from CBCT radiographic data, 3D anatomical model and soft and hard tissue scanned with optical scan) and fabricate patient-matched surgical guides, an additional software is needed. With software, one can merge the digital radiographic scan with the optical intraoral scan by choosing close matching points. The software will re- impose and merge the images.
Treatment planning is implemented in one of many methods. The suggested one includes placing the missing tooth or teeth on the virtual model, then placing an implant and abutment.
Once implants are placed into the desired position, an operatorcan build a surgical guide using different retention methods.
The guide can be teeth retained or bone retained dependingon the patient's condition. The bone retained surgical guardhas to be fixated with pins, slots, or pinholes; they are a part of the surgical guide design.
The operator builds a surgical guide over the implants, virtually placed on the reconstructed radiographic image and soft and hard tissue model obtained from the optical scan.
Surgical sleeves are incorporated into the surgical guide. Different companies offered their surgical kits with corresponding surgical sleeves and implant drivers for a fully guided procedure.
In a case, the operator chose computer-assisted techniques; the surgical guide is utilized for partial guidance: like osteotomy positioning.
The operator will be thoroughly guided from the first osteotomy to the final depth, width and implants (abutments optional) placement in the complete computer-guided surgery.
In the situation where bone augmentation is required, operator-guided techniques are preferred by the authors.
The tolerance of surgical instruments has advanced and the drills' lateral movements (vibrations) were significantly reduced. The software imaging devices and printing devices improved further, all ameliorating a lot the procedure's accuracy.
Prediction: soon most of the procedures will be fully computer- guided with high clinical success (Fig. 22-30).

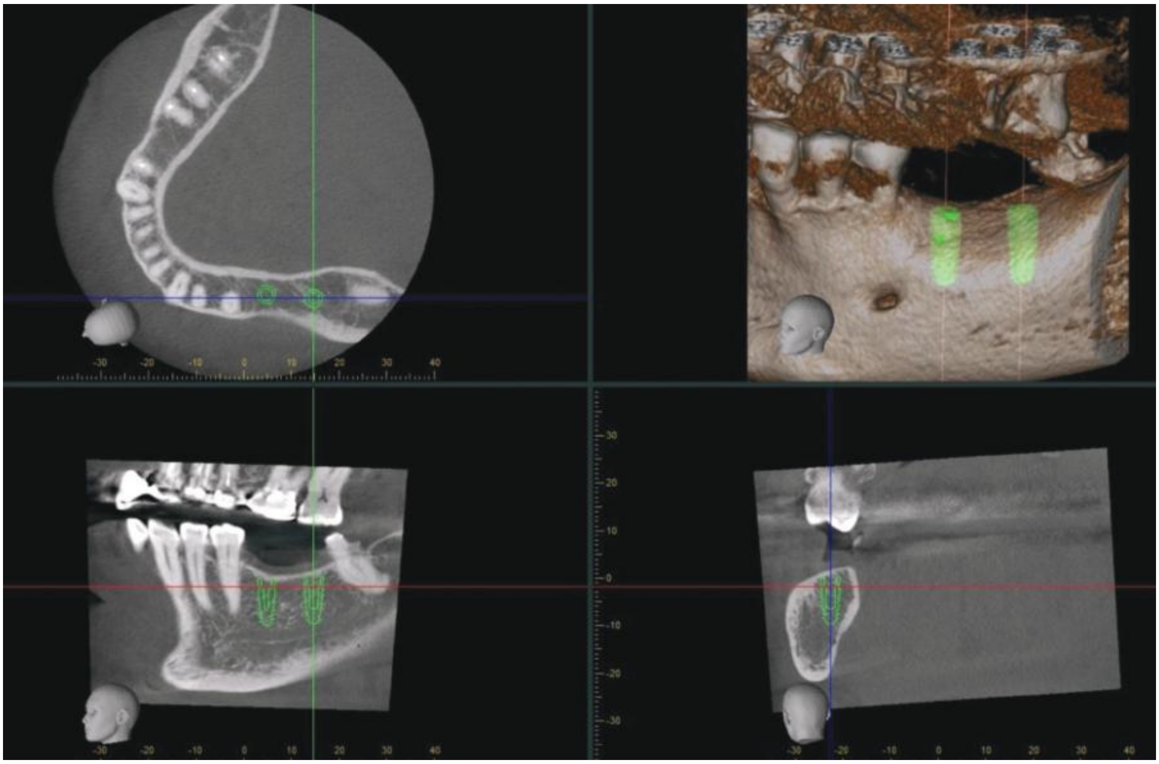

Figure 22. The software can evaluate and illustrate the treatment planning, implant placements and bone augmentations, usually included with CBCT.

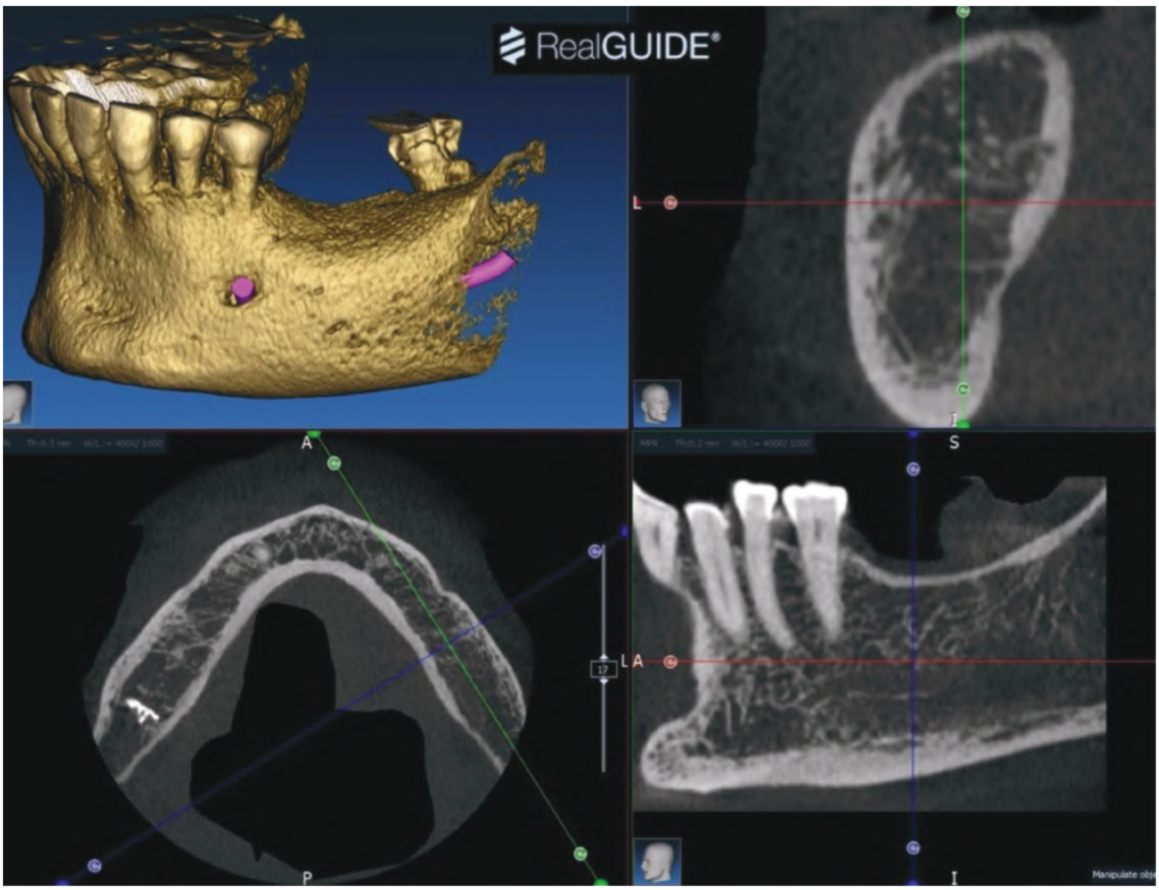

Figure 23. CBCT for diagnostic purposes.

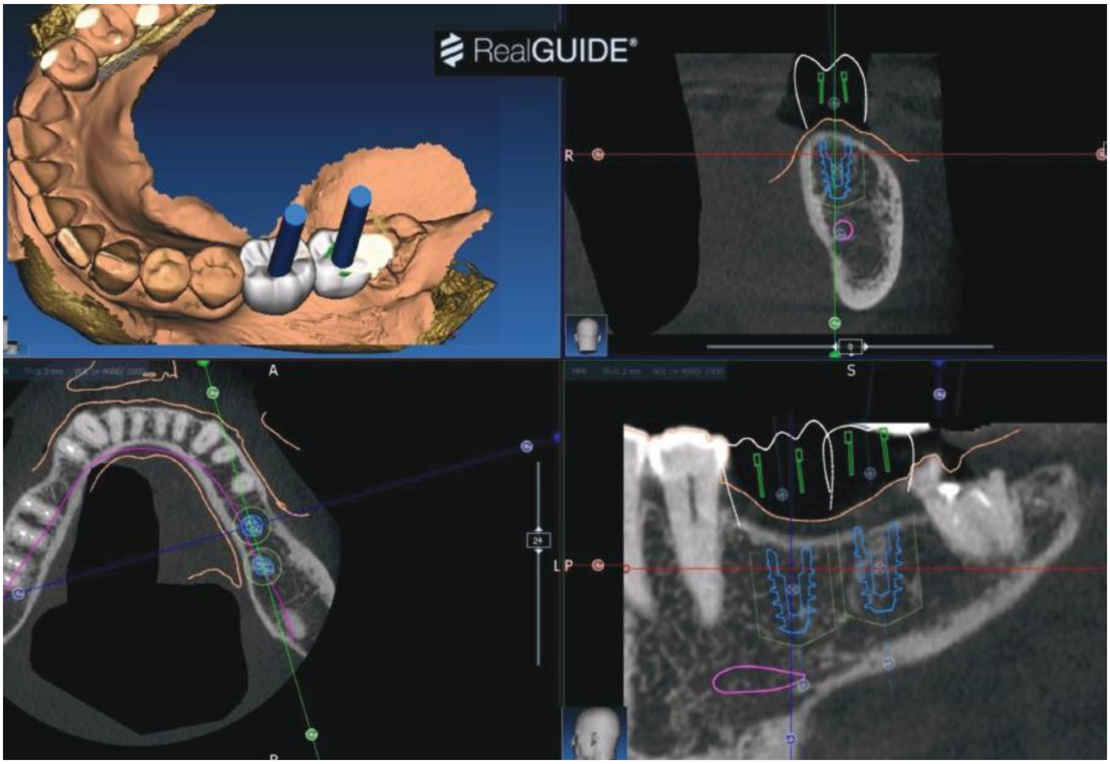

Figure 24. Virtual treatment planning on a generated model. Implants are placed into the desired position.

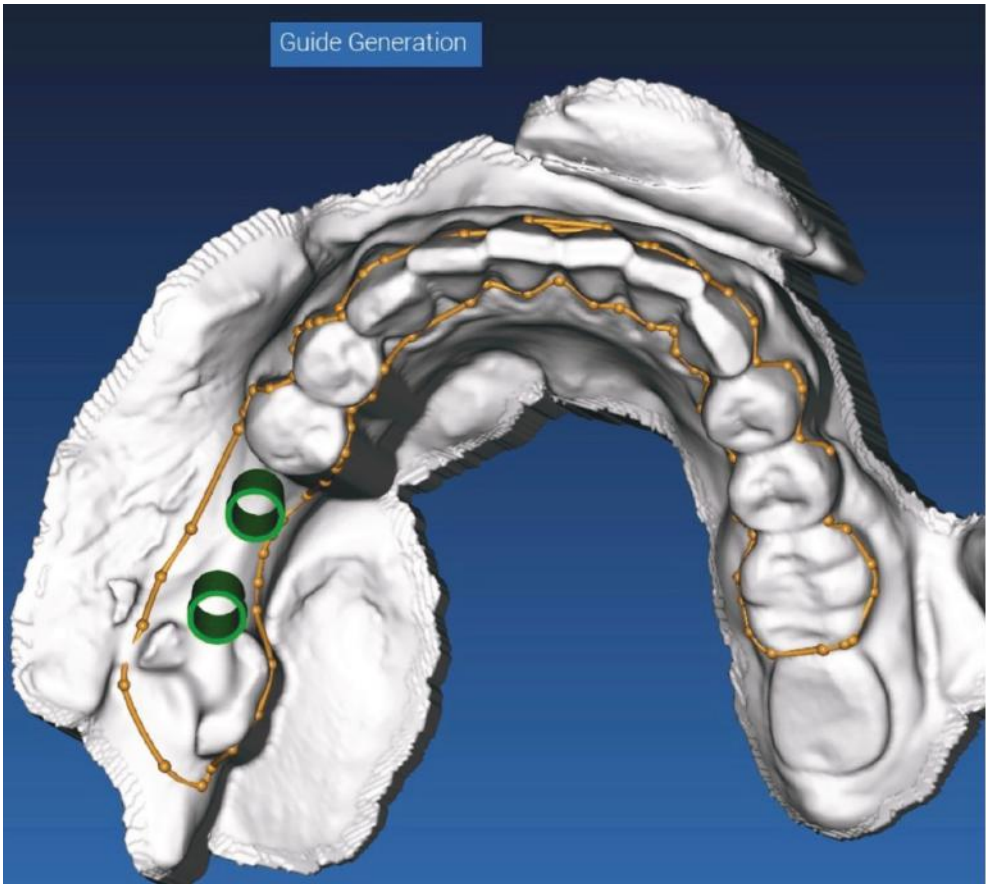

Figure 25. The operator builds a surgical guide.

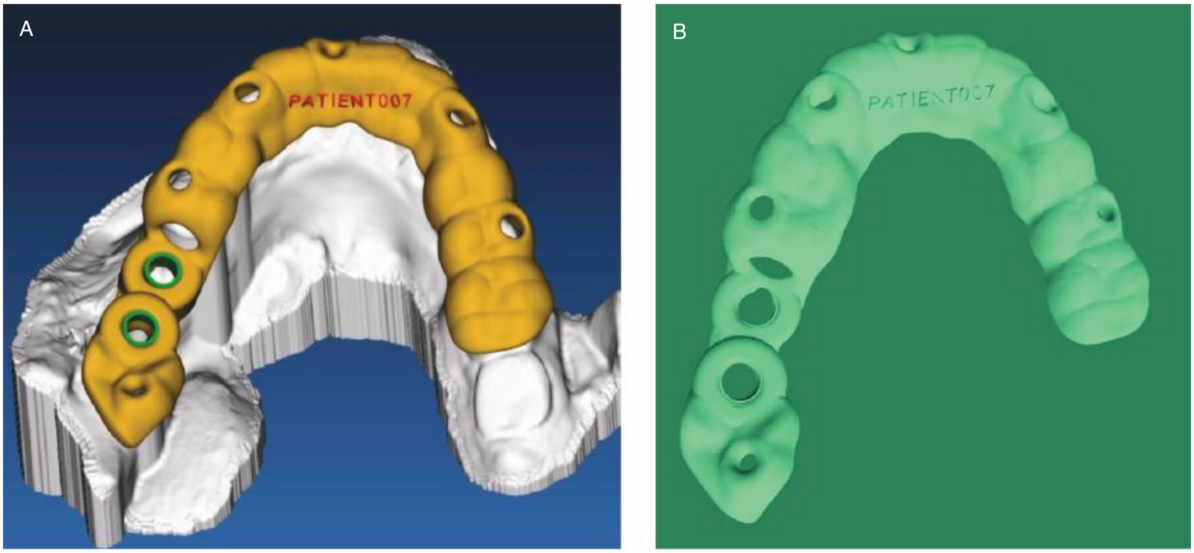

Figure 26. A. Designed surgical guide. B. Surgical guide

Figure 27. Surgical sleeve.
(RealGUIDE 5.0, 3DIEMME Srl, Italy)

Figure 28. Implant drivers (mount).
(RealGUIDE 5.0, 3DIEMME Srl, Italy)

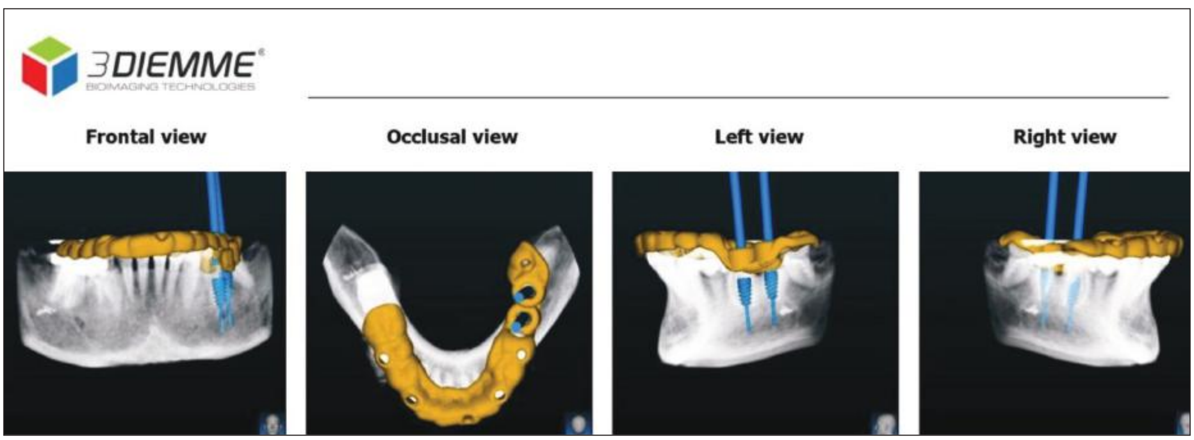

Figure 29. The report, the estimated bone quality and possible collision situations.

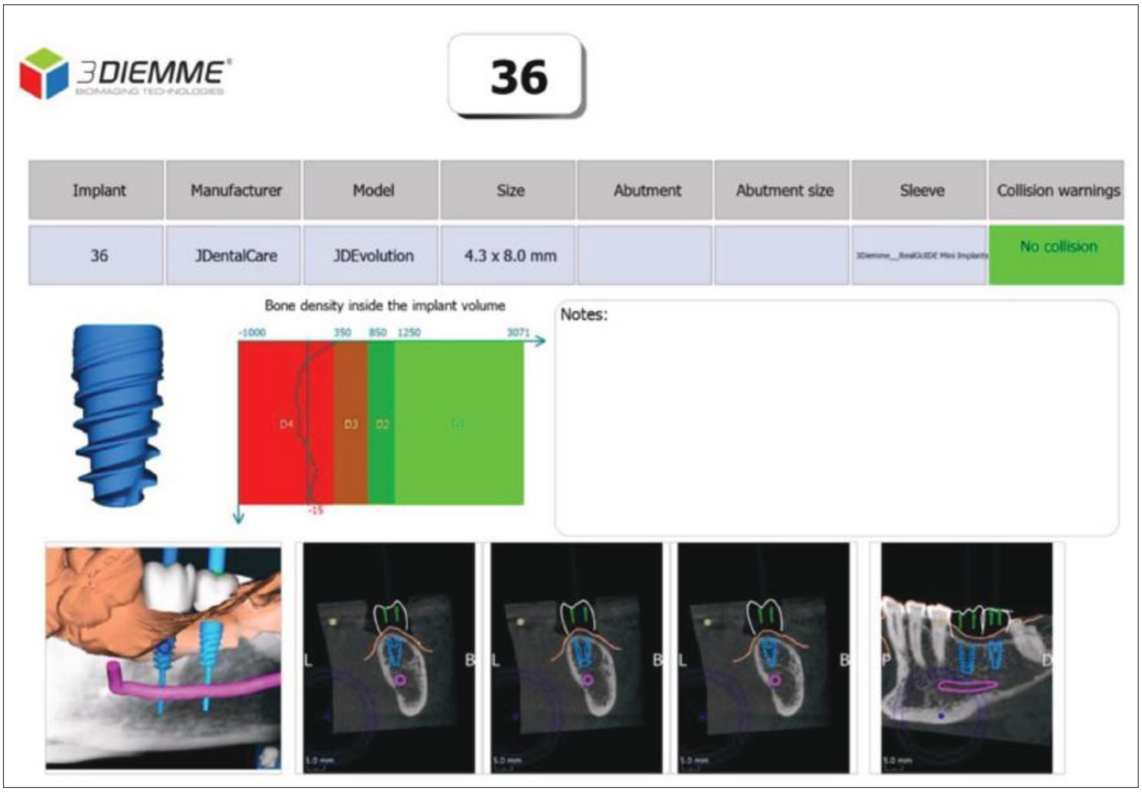

Figure 29. *Continua.*

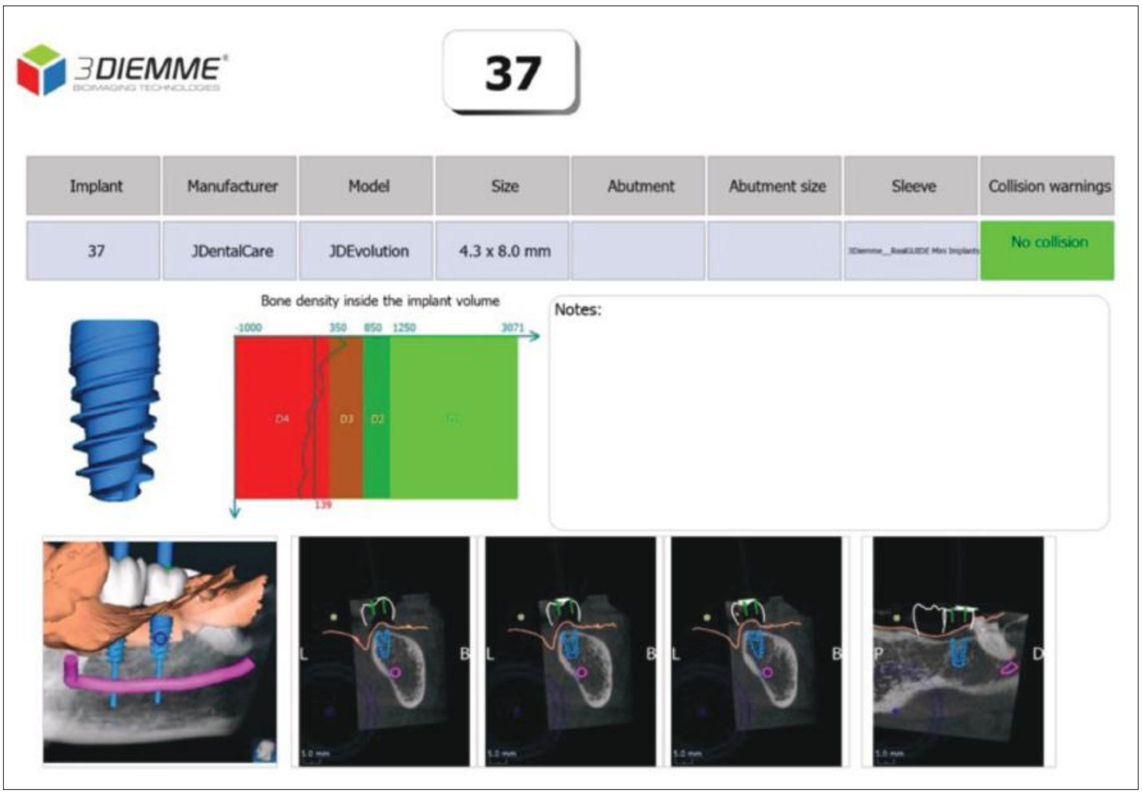

Figure 29. *Continua.*

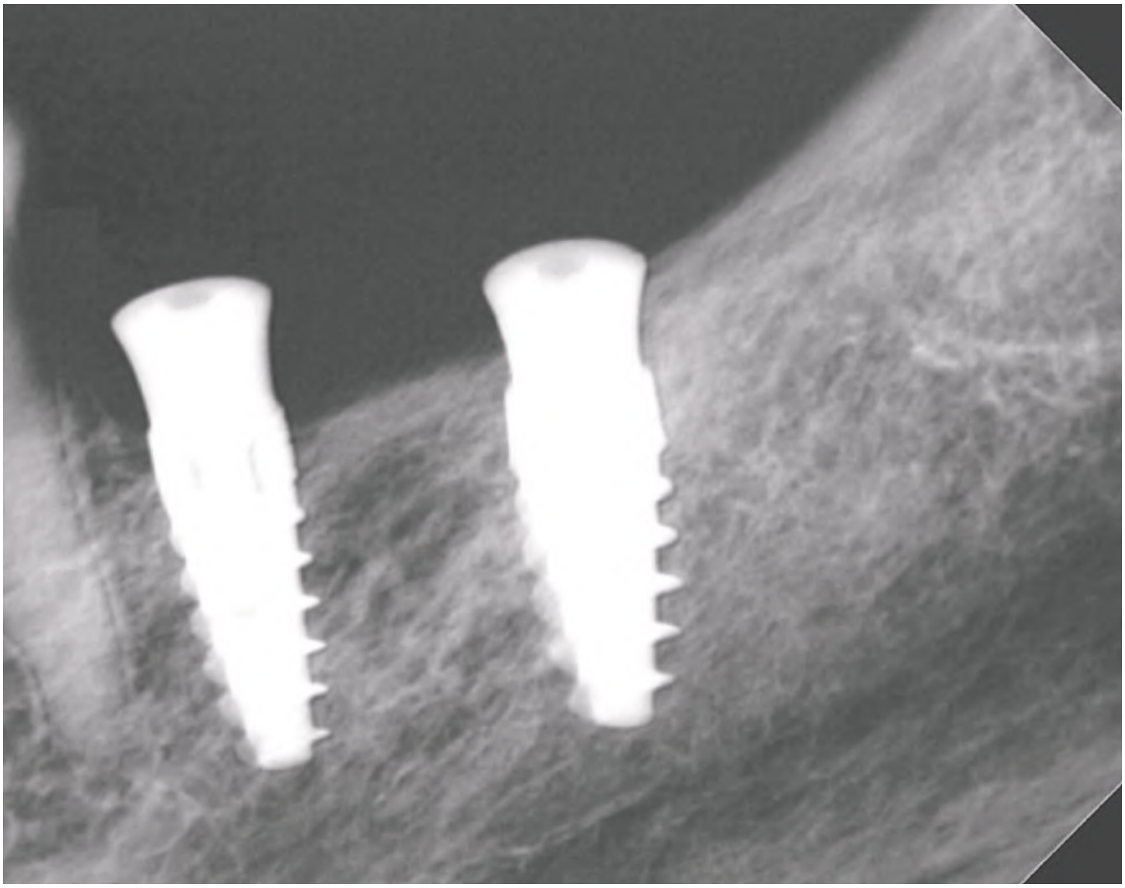

Figure 30. Completed surgical part

References

1. Carfagna G. CAD/CAM 3D. Studi di progettazione e produzione di un componente meccanico Edizioni Savine (2010).
2. Duret F.,Preston J.D. (1991). "CAD/CAM imaging in dentistry." Curr Opin Dent 1(2): 150-154.
3. Mormann W.H. (2004). "The origin of the Cerec method: a personal review of the first 5 years." Int J Comput Dent 7(1): 11-24.
4. Andersson M., Carlsson L., Persson M.,Bergman B. (1996). "Accuracy of machine milling and spark erosion with a CAD/CAM system." J Prosthet Dent 76(2): 187- 193.
5. Sahin S, Cehreli MC. The significance of passive framework fit in implant prosthodontics: current status. Implant Dent 200110: 85-92.
6. Kim Y, Oh TJ, Misch CE, Wang HL. Occlusal considerations in implant therapy: clinical guidlines with biomechanical rationale. Clinical Oral Implants Res 2005;16: 26-35.
7. Sahin S, Cehreli M, Yalcin E. The influence of functional forces on the biomechanics of implant-supported prostheses. A review J Dent 2002;30: 271-282.
8. Sones AD. Complications with osseointegrated implants. J Prosthet Dent 1989;62: 581-585.
9. Moglioni E, Diotallevi P, Pezzuti E, Pasqualini M, Ferrante G, Floris Pl. Success rates in subjects rehabilitated with immediate loading technique on according to AISI guidelines. Ann. Stom. 2008; LVII (1-2):19-23.
10. Moglioni E, Pezzuti E, Grotowski T, Dal Carlo L, Shulman M, Diotallevi
11. P. Oral Implantology today: Surgical protocol, Historical facts, Diagnostic imaging, Biomechanical notes. Implants n° 4 – 2016 44-51.
12. Picton DC, Creasey SJ Some causes of failure of crowns, bridges and dentures. J Oral Rehabil. 1989 Mar;16(2): 109-18.
13. Christensen GJ (2008) Will digital impressions eliminate the current problems with conventional impressions? J Am Dent Assoc 139(6): 761– 763.
14. Guidi G., Russo M., Beraldin JA. Acquisizione 3D e modellazione poligonale 2010 McGraw-Hill Companies srl Milano.
15. Persson A, Andersson M, Oden A, Sandborgh-Englund G A three- dimensional evaluation of a laser scanner and a touch-probe scanner. 2006, The Journal of Prosthetics Dentistry, Vol. 95, issue 3 p. 194-200.
16. ISO 10360-9:2013 Geometrical product specifications (GPS) -- Acceptance and reverification tests for coordinate measuring systems (CMS) -- Part 9: CMMs with multiple probing systems.
17. ISO 12836:2012 specifies test methods for the assessment of the accuracy of digitizing devices for computer-aided design/computer-aided manufacturing (CAD/CAM) systems for indirect dental restorations.
18. Moglioni E, Diotallevi P, Pierazzini A, Pezzuti E, Lagana' G. L'implantologia orale oggi: protocolli chirurgici, cenni storici, diagnostica per immagini e note di biomeccanica. 2005 Boll. SMO 25:4-9.
19. Dal Carlo L, Pasqualini Me, Mondani P.M, Rossi F, Moglioni E, Shulman M. Mondani intraoral welding: historical process

and main practical applications. Journal of Biological Regulators & Homeostatic Agents. Vol. 31,n°2 (S1), 233-239 (2017).
20. Rossi F, Pasqualini Me, Moglioni E, Meynardi F. Impianti postestrattivi one-piece a carico immediato nel settore frontale superiore con deficit osseo vestibolare. Doctor Os XIII (7) Sett. 2013:779-787.
21. Rossi F, Pasqualini Me, Carinci F, Meynardi F, Diotallevi P, Moglioni E, Fanali S. "One-piece" immediate-load post-extraction implants in labial bone deficient upper jaws. Annals of Oral &Maxillofacial Surgery 2013 Apr 01;1(2):14.
22. Meynardi F, Lauritano D, Pasqualini Me, Rossi F, Grivet-Brancot L, Comola G, Dal Carlo L, Moglioni E, Zampetti P. The importance of occlusal trauma in the primary etiology of periodontal disease. Journal of Biological Regulators & homeostatic Agents. Vol. 32, n°2 /S1), 27-34 (2018).
23. Dal Carlo L, Pasqualini Me, Rossi F, Meynardi F, Moglioni E, Riccardi L, Fanali S, Shulman M. Saldatrice endorale di Mondani. Principali applicazioni pratiche. Doctor Os 2017 XXVIII;05:36-47.
24. Dal Carlo L, Squillantini P. Shulman M, Winkler S, Moglioni E, Donati R, Pasqualini Me, Rossi F. Case Report: Immediate loading of intraorally welded implants. Implants n° 3 – 2016 – 8-13.
25. Van Noort R. "The future of dental devices is digital." Dent Mater 2012; 28(1): 3-12.
26. Beuer F., Schweiger J.,Edelhoff D.. "Digital dentistry: an overview of recent developments for CAD/CAM generated restorations." Br Dent J 2008 204(9): 505-51.