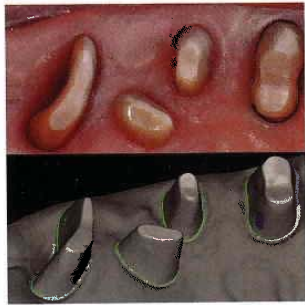
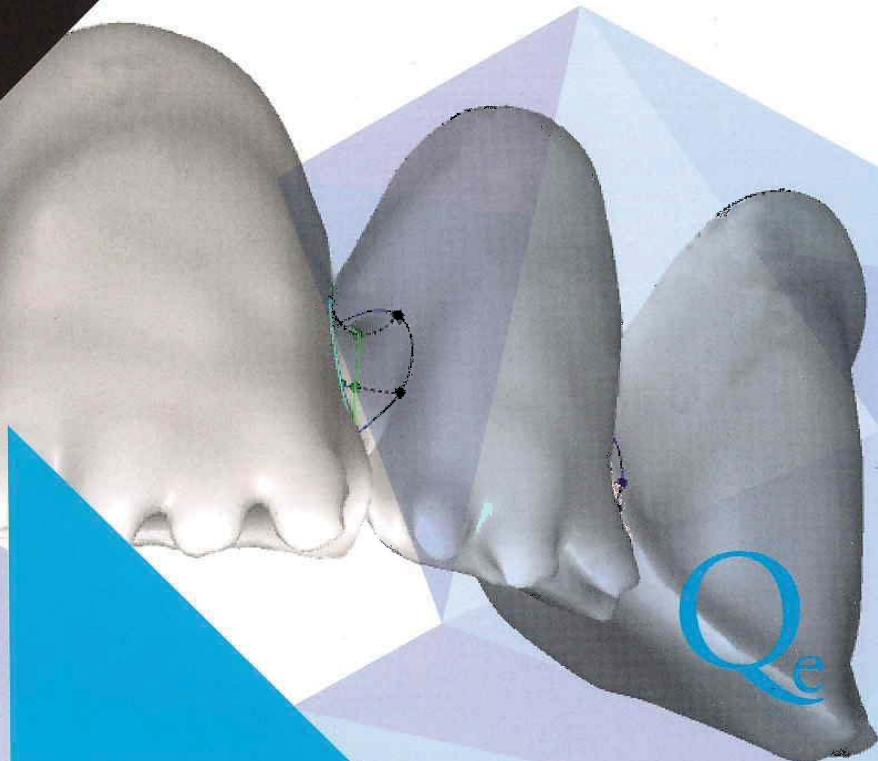
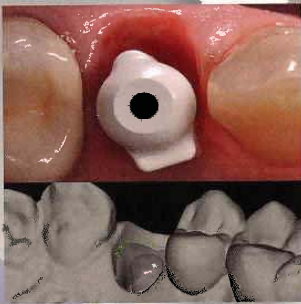


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# DIGITAL DENTAL REVOLUTION

## THE LEARNING CURVE

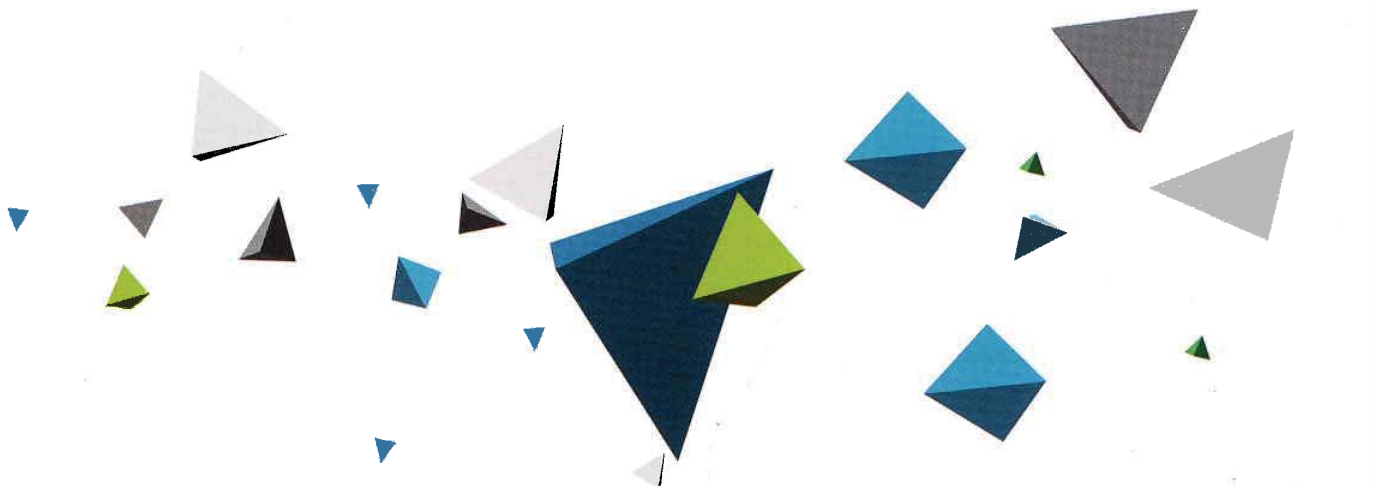


Align Ex. 1014  
U.S. Patent No. 9,962,244

alessandro**agnini**  
andrea**agnini**

# DIGITAL DENTAL REVOLUTION

## THE LEARNING CURVE



Milan, Berlin, Chicago, Tokyo, London,  
Paris, Barcelona, Beijing, Istanbul,  
Moscow, New Delhi, Prague,  
São Paulo, Seoul, and Warsaw





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# THE DIGITAL IMPRESSION

# CHAPTER 03

Every year in the US, 400,000 impressions are made: 90% did not have the margin recorded completely; therefore, there are 360,000 crowns with margin inaccuracies.

Gordon Christensen

A collection of various 3D geometric shapes, including pyramids and triangles, in shades of blue, green, and grey, scattered across the upper half of the page.

Digital dental technology (DDT) for fabrication of dental restorations, including computer-aided design/computer-assisted manufacture (CAD/CAM), has been in development since the 1980s.<sup>1</sup> Its rapid expansion and incorporation into the field of dentistry has been documented since the beginning of 1990s.<sup>1,2</sup>

Currently present on the market are several diagnostic digital software programs, for example, the Digital Smile Design (DSD) created and designed by Christian Coachman and Livio Yoshinaga, digital tools to check functional parameters and define tooth shades, which in this era of esthetics are becoming more important every day; digital articulators and digital customized abutments; and computer-guided surgery that can be combined with a three-dimensional (3D) computed tomography (CT) evaluation to provide a wealth of information to the surgeon before and after procedures. In the last few years, several software programs for digital impressions have been developed, playing an important role in the transition from conventional fixed prosthodontics to DDT

because they represent one of the very last steps toward fully digital prosthetic fabrication, which is the goal of modern dentistry. The intraoral impression, indeed, is the first means of communication between clinician and technician.<sup>3</sup>

Digital dental impression devices have been introduced to the profession, potentially eliminating the need for taking conventional impressions for crowns and fixed prostheses. The direct acquisition systems, which have been continually improved, are less invasive, quicker, and more precise than conventional methods. Moreover, traditional protocols require many critical steps that can be skipped when taking a digital impression.

In fact, this technique can reduce chair time for procedures such as tray selection, cast setting time, disinfection, and transportation to the laboratory. In addition, the digital images can be easily stored. These emerging new digital concepts are creating a growing interest among dentists, causing them to think about the possibility of changing their impression techniques.<sup>4,5</sup>

**Fig 1.** The digital dental revolution. The goal of modern dentistry is to create a completely digital work flow.

Some clinicians face the dilemma of wanting to keep up with the technologic advances in the profession while feeling unsure about embracing the digital impression technique and the related in-office milling of restorations (Fig 1).

Benefits of the digital impression have been presented as:

1. Improved patient acceptance
2. Reduced distortion of impression materials
3. 3D preview of the preparation
4. Potential cost reduction and time effectiveness<sup>4</sup>

Digital impressions for implant rehabilitations (Fig 2) would allow for:

1. Virtual assessment of the implant prosthetic space
2. Evaluation of depth of restorative margin
3. Configuration of the emergence profile before proceeding with laboratory steps<sup>6</sup>

Digital impressions have been used successfully for a number of years in orthodontics with software such as iOC/OrthoCAD (Cadent), OrthoPlex (Dentsply), SureSmile (Orametrix), and RapidForm (EMS). The introduction of the first digital intraoral scanner for restorative dentistry was in the 1980s by a Swiss dentist, Dr Werner Mörmann, and an Italian electrical engineer, Marco Brandestini, who developed the concept for what would be introduced

in 1987 as Cerec (Sirona), the first commercial CAD/CAM system for dental restorations.<sup>2,7</sup>

Since that time, research and development sectors at many companies have improved their technology and created in-office intraoral scanners that are increasingly user-friendly and produce precisely fitting dental restorations. These systems are capable of capturing 3D virtual images of tooth preparations; from such images, restorations may be directly fabricated (using CAD/CAM systems), or they can be used to create accurate master casts for fabrication of the restorations in a dental laboratory.<sup>1</sup> Today there are 11 intraoral scanning devices for restorative dentistry available worldwide; four are made in the United States; two in Israel; two in Germany; and one each in Italy; Switzerland; and Denmark. Generally speaking, such scanners try to overcome the problems and disadvantages of the traditional impression fabrication process, such as instability of the impression, pouring of plaster, laceration of the margins, and geometric and dimensional discrepancy between the cast and the impression.

The main benefits of the use of these devices are precise casts/models, creation of 3D archives and surgery simulation, and a simplified process. Existing devices are driven by several noncontact optical technologies, such as confocal microscopy, optical coherence tomography, photogrammetry, active and passive stereovision and triangulation, interferometry, and phase-shift principles. Basically, all of these devices combine some of the cited imaging techniques to minimize the sources of disturbance related to scanning inside an oral cavity, eg, optical features of the target surfaces (translucency and the different reflectivity of the target materials such as teeth, gingiva, preparations, and composites), moisture, and random movements. Also, several types of structured light sources and optical components are used.<sup>8</sup>

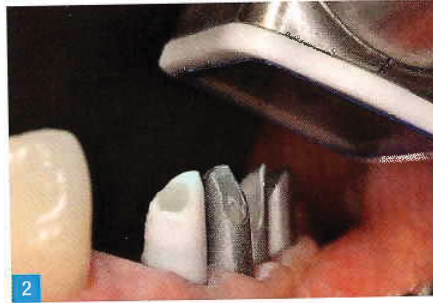
Commercially available digital systems for the dental office are commonly divided into two categories: digital impression systems and chairside CAD/CAM systems. Both types must be able to accurately record the intraoral condition on a computer data file with a scanner or camera.





It is what the system accomplishes after recording the data file that distinguishes them:

- Digital impression systems are designed to electronically transmit the recorded data file to the dental laboratory for restoration fabrication. Once dental laboratories have downloaded the file, they can have casts processed from it. Any conventional laboratory process can be used to fabricate the restoration once the laboratory receives the processed casts. Alternatively, the dental laboratory can use the transmitted data file in a CAD program to create a full-contour restoration or coping that can be refined on the processed casts. Some of the most common examples of digital impression systems are the Lava Chairside Oral Scanner (C.O.S.; 3M Espe), the iTero system (Cadent), the Zfx system (Zfx), and TRIOS (3Shape). This expedites the overall work flow, resulting in delivery of the definitive restoration in a shorter time span compared with the traditional approach (Figs 3 to 5).
- The Cerec Acquisition Center (AC; Sirona) and E4D Dentist system (E4D Technologies) are the



**Fig 2.** Detail of the position of the lens of the intraoral scanner during scanning for a provisional restoration.<sup>9</sup>

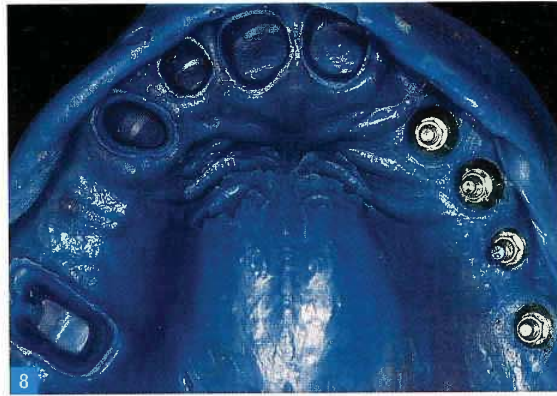
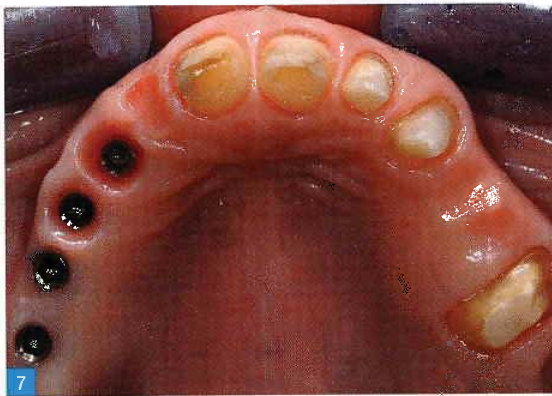
**Figs 3 to 5.** Lava, iTero, and TRIOS are some of the most common examples of digital impression systems.

**Fig 6.** Cerec AC is one of the two available chairside CAD/CAM systems.

two available chairside CAD/CAM systems. They can complete all three steps of the imaging, design, and milling process in the dental office to fabricate full-contour restorations within the time span of a single appointment. Both of them have manufacturer-specific software programs that permit the production of single-tooth ceramic or composite inlays, onlays, veneers, and crowns. They also offer the option to be used as purely digital impression systems. The choice to adopt one method or the other depends on the organization of the dental office and the type of initial investment that is intended.







**Figs 7 and 8.** Taking a good impression is one of the most crucial steps of the clinical work flow.

In fixed prosthodontics, an accurate and precise impression is one of the main requirements for obtaining a proper and long-lasting restoration.<sup>10</sup> When discussing digital impression taking compared with the conventional approach, an argument is always made that the latter is more precise and that there is a mandatory and time-consuming learning curve involved in learning to use the new digital tools.

However, it is important to note that the conventional technique also presents many difficulties and involves a learning curve to avoid all the pitfalls.<sup>11</sup> In fact, a recent literature survey conducted in the UK showed that many impressions judged to be "acceptable" by dental laboratory technicians are not; according to Storey and Coward, 44.2% of the intraoral recordings would not be satisfactory due to the presence of imperfections at the level of the prosthetic preparations.<sup>12</sup> Careful evaluation of the traditional impression work flow reveals that the many steps involved are sources of possible inaccuracies and how it is, once again, critical to have a protocol to follow step by step in order to help the operator reduce mistakes<sup>13</sup> (Figs 7 and 8): The clinician should ensure that the impression includes all the necessary information, is clearly

readable, provides details of the preparation, is free of bubbles and tears, and covers all of the elements involved.

In a study by Samet et al,<sup>14</sup> an assessment was made of 193 impressions sent to 11 different laboratories. Factors such as the material, the technique, the type of impression tray, and the number of elements prepared were recorded, and then the quality of the impression technique for the construction of fixed prostheses was assessed, describing the frequency of clinical errors and analyzing the correlations between the factors involved (Tables 1 and 2).

The results can be summarized as follows:

- Lack of precision
- Removal of material from the tray
- Putty exposure in two-stage impressions

Taking an impression is, in fact, probably the most critical step in the process of creating restorations that fit.

A perfect impression should:

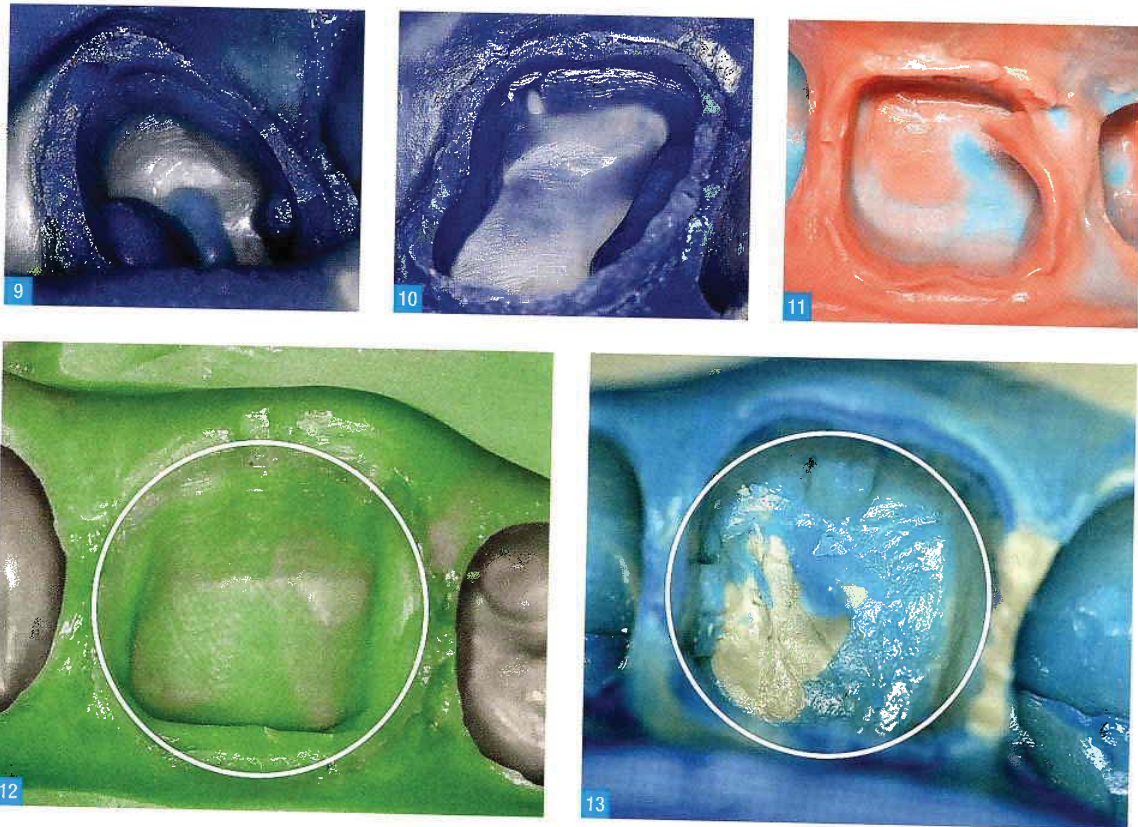
- Provide an exact duplication of the clinical situation
- Include a complete, void-free, and accurate reproduction of the margins
- Be correct on the first attempt

Type of void	Causes	Solutions
Localized on the lingual and buccal surfaces	Underuse of light-body material and appearance of a gap. High environment temperature and premature light curing.	Place an adequate quantity of material in critical areas. Store the product at the indicated temperatures to preserve the viscosity and hardening characteristics.
Localized on the mesial and distal surfaces	Low hydraulic pressure for the flow and adaptation of the material to the proximal surfaces.	Use an individual tray. Use a combination putty/light-body technique or a two-phase technique.
Multiple, randomly distributed	Incorrect manual mixing of the material with air trapping. Incorrect automatic dispensing (tip not in the material).	Repeat manual mixing. Maintenance of the dispenser tips or syringes dispensed in.
Localized in the sulcular area	Contamination by moisture, chemicals, or crevicular fluids. Inadequate hemostasis.	Use the double-cord technique to improve the displacement and absorption of moisture. Rinse thoroughly and dry.
Localized on the preparation margins	Incorrect technical delivery of the light-body material: the start and end points of the material do not meet. Error in setting times: lack of integration of light-body material in some areas.	Complete delivery of the light-body material 360 degrees around the abutment. Use slow-setting materials in complex cases; cool impression materials to increase the working time.

**Table 1.** Causes and solutions for common defects (voids) that could be found during conventional impression taking

Issue	Causes	Solutions
Protrusion/projection of material (from the surface of the impression to the hollow areas) contact between the impression tray and dental elements/preparations.	Movement/sliding of the tray before complete hardening of the material. Incorrect repositioning of the tray during relining in the putty wash of the two-phase technique or inappropriate size or shape of the selected tray. Inaccurate insertion of or excessive thrust on the tray. Patient grinding with the tray between the arches.	Prevent movement of the tray during the impression. Increase the separation of the material before relining the impression. Use an custom tray or carefully select a standard tray. Try in the tray and determine how to correctly insert it before proceeding with the impression. Ask the patient to keep the mouth open during the impression.
Lacerations/tears	Removal of the material before complete hardening. Accentuated undercuts. Inadequate displacement of the gingival margin (intrasulcular area too tight). Contamination. Use of a material with low tear resistance.	Use a custom tray. Use a combination putty/light-body or two-phase technique. With silicone impressions, do not directly touch the material with the gloves. Use a high-tear-strength material. Correctly displace the soft tissue.
Delaminations	Lack of coordination of the curing time between the high- and low-viscosity materials. Contamination between the delaminated layers. High ambient temperature.	Follow the recommendations of the manufacturer regarding processing times. Perform maneuvers for control of hemostasis and retraction; prevent contamination between heavy- and light-body layers. Cool the impression material.

**Table 2.** Causes and solutions for other common defects found in conventional impressions



**Figs 9 to 11.** Problems can occur and sometimes cannot be resolved, such as incomplete hardening of the material, exposure of the tray, an improper mixture of light- and heavy-body material, or absolute inaccuracy of details.

**Figs 12 to 14.** Poor bond between the tray and wash material, lack of impression details, and inappropriate methods of storing and transporting are causes of lack of accuracy in the final conventional impression.

The various clinical decisions made during the protocol are essential for the accuracy of the impression, such as:

- The choice of tray and adhesive in relation to the material used helps to prevent detachment of the material from the tray; in fact, even removal from the oral cavity may cause problems of deformation.
- The quality of the impression material chosen can greatly affect the surface of the hardened plaster.
- Prior to casting, it is necessary to eliminate the anatomical undercuts, allowing easy detachment of the cast without deformation of the impression.<sup>15</sup>

The most common clinical errors can be identified as incomplete reproduction of the intraoral situation, voids and tearing at the preparation margins, wash material displaced or washed

away from the preparation area, distortions, defects caused by blood or saliva, exposure of the tray, incomplete setting of impression material, poor bond between the tray and wash material, and discrepancies on the cast (Figs 9 to 11).

Also, what is done after a conventional impression is taken might be a cause of inaccuracies; inadequate disinfection may affect surface quality, detail reproduction, and dimensional stability. In fact, before casting and/or providing the impression to the dental technician, the office must have specific protocols for disinfection. The manufacturer's instructions should be consulted to determine which disinfection products will not damage the impression. Unfortunately, studies have found that the percentage of clinicians who perform this procedure with care is low. In some countries, this figure is as low as 57%, but the factors that prevent compliance with guidelines are not understood.<sup>16</sup>



Storing the impression at room temperature avoids deformations. A low storage temperature, for example, prolongs the setting reactions and changes the viscosity of the material, affecting the surface quality (detail reproduction) and dimensional stability.

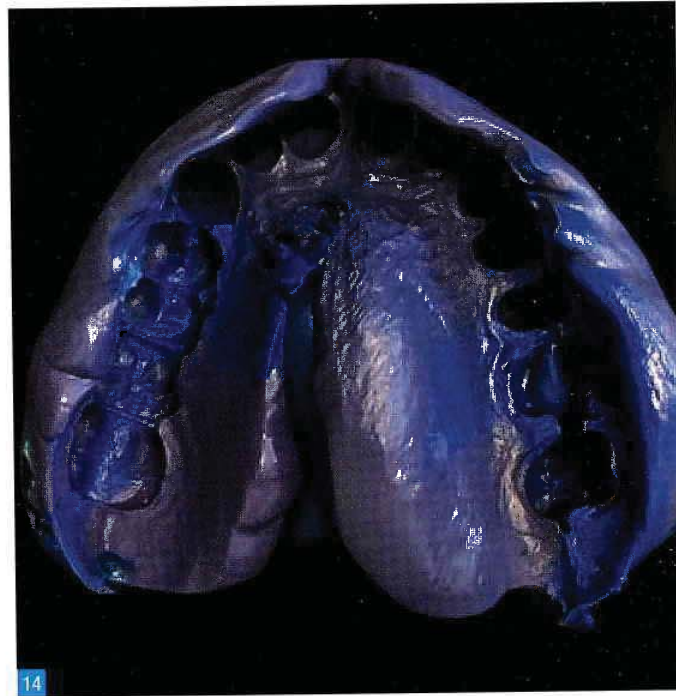
It is always recommended to rinse the polyether impressions with water and dry them before sending them to the laboratory, avoid putting them in a bag along with alginate impressions, and store them away from direct sunlight to prevent a reduction in the impression quality.

Transporting the impression to a commercial dental laboratory subjects an impression to significant variations in temperature. A temperature variation from 4°C to 40°C has been shown to result in a 1- to 18-mm dimensional change.<sup>17</sup> Moreover, during the time between securing an impression and the pouring stone cast, the ambient temperature, the surface wettability, and disinfection procedures may result in additional distortion.<sup>18,19</sup>

Cast production is another step that might lead to uncontrolled expansion of the cast, bubbles, and fractures. It is obvious that if these imperfections were located on critical areas, such as the preparation margins and the axial and occlusal surfaces of the abutments, the restoration would not fit properly. There are, in the traditional approach, different impression techniques

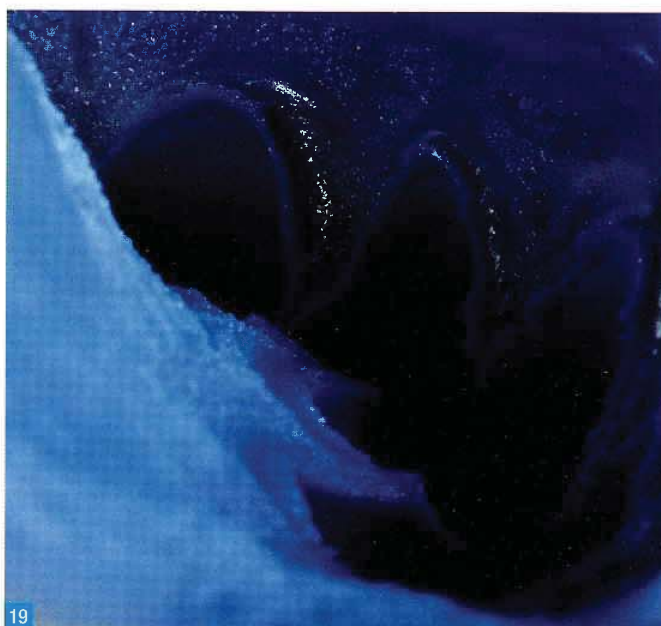
classified according to the timing with which the materials are used and the consistency of the materials themselves.

It is important that the dentist has an in-depth and detailed knowledge of the various techniques order to move toward the most suitable one for the clinical situation at hand (Figs 16 and 17).



**Figs 15 and 16.** Examples of inaccuracies in the production of the plaster cast include voids in the plaster cast, giving the appearance of a golf ball, and voids at the finish line and on the incisal edges of the abutment.



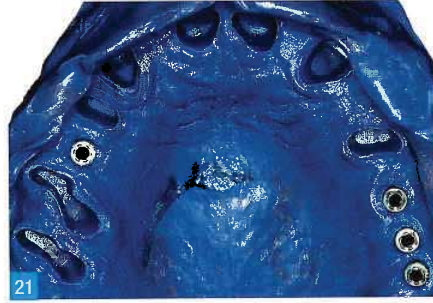


**Figs 17 to 19.** Final polyether impression to restore a case with ceramic veneers.

One of the main roles of the impression is to record the details of the preparations and neighboring structures in their entirety, eg, over-preparation in case of shoulder finish lines and to record the architecture of the gingival tissues (Figs 17 to 21). That is why taking an accurate and detailed final impression is a crucial step in creating a successful prosthetic rehabilitation. Having a protocol for taking impressions is mandatory and should consider the following:

1. Ensure healthy soft tissue at the level of the prosthetic abutment.
2. Ensure adequate retraction of the marginal soft tissue with mechanical and/or chemical procedures. If chemical agents are used, rinse and dry thoroughly.
3. Choose an appropriate tray and viscosity of wash materials as well as proper working times (regular or quick) according to the impression technique and indications.
4. Use a properly fitting, rigid, and sturdy impression tray.
5. Thoroughly apply tray adhesive and let it dry appropriately (for at least 15 minutes) before taking the impression.
6. Ensure uniform and homogenous mixing of material (ie, using automatic mixers).
7. Fill tray sufficiently with impression material without trapping air bubbles.
8. Use gloves that do not inhibit the setting of the impression material.
9. Have separate timers to check the working time (2 to 2.5 minutes) and the hardening time (5 to 6 minutes).
10. Avoid air entrapment during intraoral syringing of the wash material by immersing the tip in the material.
11. Apply controlled vertical pressure upon seating the tray to avoid contact between teeth/tissue and the bottom of the tray with a vertical movement.
12. Move the light-body material into the gingival sulcus with a puff of air and cover all of the abutments with the light-body material, starting with the nonvital tooth preparations and implant abutments.
13. Avoid any movements that could shift the position of the tray and lead to distortions.
14. Stay within the working time of the tray and wash materials.





**Figs 20 and 21.** Final polyether impression for a complex periodontal case involving prepared teeth and implants.

**Fig 22.** Digital impressions are as sensitive to blood and moisture as traditional impressions; therefore, soft tissues must be healthy.

15. Use the correct protocol to remove the tray from the mouth, depending on where the abutments are located.
  16. When removing the tray from the mouth, avoid unilateral rotation.
  17. Verify that, on all surfaces, the tray does not show through the impression material, which would indicate that the tray came in contact with the hard or soft tissues and there will be an inaccuracy in that area.
  18. Make sure that the tray is not exposed, which would mean that the tray is in contact with the tooth structures or soft tissues and the information recorded would not be accurate.
  19. Check for proper blending between the tray and wash materials as well as a proper bond to the tray.
  20. Disinfect the impression according to the manufacturer's instructions for use.
  21. After disinfection, rinse the impression with water and dry it before sending it to the lab.
  22. Exact brand of impression material and disinfection protocol must be communicated to the dental laboratory.
- materials. Blood and saliva obscure the surface of the tooth and dentogingival margins from the camera and prevent an accurate recording. At best, the camera records the moisture as a false surface contour; at worst, no data is recorded where moisture has collected. In either situation, an accurate restoration cannot be fabricated.
2. A second principle is that inadequate management and retraction of soft tissues may prevent visualization of the marginal areas, resulting in an inaccurate recording with the camera. As desirable as it may be to scan through soft tissues, this is not possible with current systems. Digital cameras can only record data that is directly visible to the camera lens<sup>10,20</sup> (Fig 22).

### Digital impressions in the literature

All digital impression systems and chairside CAD/CAM systems rely on the ability to accurately record the intraoral data file, and there are a couple of principles that are common to all the cameras that significantly influence the outcome:

1. Digital impressions are as sensitive to moisture contamination as traditional impression





**Fig 23.** Clinical situation of central and lateral incisor preparations immediately before digital impression taking. Note the presence of fine powder on the scan area to bring uniformity to the differing reflectivity of the surfaces.

**Figs 24 and 25.** Scannable impression coping in place on the study cast (Fig 24) and virtual model (Fig 25) from a digital impression (iTero). Reprinted from Lee and Gallucci<sup>24</sup> with permission.

Several studies investigated the efficiency and accuracy of the digital impression in tooth-supported fixed prostheses.<sup>21,22</sup> Recently more standardized and randomized studies have been published, for example, one by Syrek et al<sup>23</sup> evaluating ceramic crowns produced from a totally digital process, which revealed that the crowns from intraoral scans featured significantly improved marginal fit and interproximal contact area compared with crowns fabricated from a silicone impression, while both groups performed equally well with regard to occlusion.

In 2011, Monaco and colleagues at Bologna University<sup>25</sup> performed clinical trials to test the accuracy of single all-ceramic zirconia crowns resulting from a digital intraoral impression with active wavefront sampling technology by measuring the marginal and internal fits of the crowns and found that the single crowns obtained from the digital work flow presented enough accuracy to be used as an alternative to the traditional one.

In 2013, Almeida e Silva et al<sup>26</sup> published a comparative analysis of four-unit zirconia fixed dental prostheses based on digital and conventional techniques, revealing that while both groups showed clinically acceptable marginal fit, frameworks fabricated from

a digital impression demonstrated better internal fit compared with those fabricated from a conventional impression.

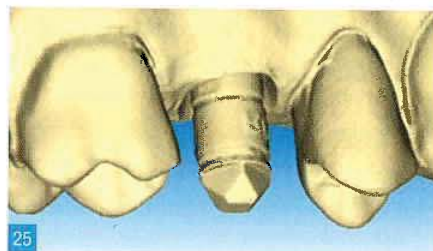
More specifically, reviewing each retainer face, the digital impression showed better marginal and internal fit at the premolar mesial and molar distal faces. As for the efficiency, accuracy, and clinical viability of digital impressions for implant restorations, there have not been any standardized and randomized clinical studies. In this specific context, validation of DDT is paramount to understanding the impact of this new technology in terms of modifying well-established traditional protocols.

During the last decades, implant dentistry has become fully integrated into prosthetic patient treatment and dental reconstruction. The dental implant industry has started to develop tools that facilitate the use of intraoral scanners to make digital impressions of dental implants.

Despite the deformation of impression materials<sup>13</sup> and the cast,<sup>27,28</sup> the work flow for conventional impression taking for implant restorations has proven itself in clinical practice.<sup>29</sup>

The introduction of scannable impression copings, however, now enables the use of intraoral scanners as an alternative to conventional impression taking. Del Corso et al<sup>30</sup> showed in an in vitro study that intraoral scans could be a valid alternative to analogue impression taking. A recent clinical study by Karl et al<sup>31</sup> showed that the intraoral digitization of dental implants appears to be at least as precise as conventional impression taking and master cast fabrication using prefabricated transfer components and laboratory analogs.

In their 2013 publication, Lee and Gallucci<sup>24</sup> evaluated the efficiency, difficulty, and operator's preference

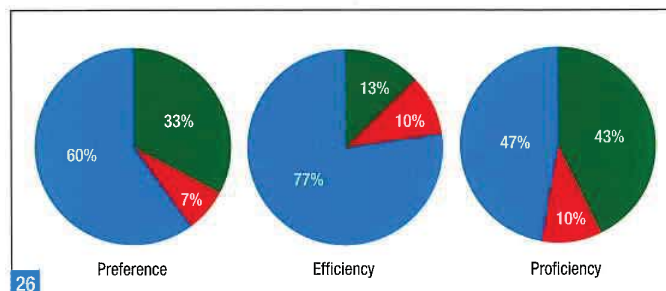




of digital impressions compared with conventional impressions for single implant restorations. An interesting aspect of this study was that participants were dental students with no previous exposure to conventional or digital implant impression taking. This homogenous group allowed investigation of the efficiency of these impression techniques in an objective and nonbiased manner.

This is of particular importance since results from a different study population including experienced clinicians may have been difficult to interpret. Moreover, a conventional (closed tray impression) protocol was used, which is less accurate but easier to learn than the open-tray impression (Figs 24 and 25). The conclusions of this study were that digital impressions resulted in a more efficient technique than conventional impressions when assessed by total treatment time; more time was needed for preparation, working, and retaking to complete an acceptable conventional impression compared with a digital one.

Digital impressions allowed for additional rescans without the need to entirely repeat the impression



Blue = digital; red = conventional; green = either.

technique, resulting in a shorter treatment time. The level of difficulty was lower for the digital impression compared with the conventional one when performed by inexperienced second-year dental students.

Digital impressions were deemed the most preferred and effective technique according to the participants' perception (Fig 26). Conventional impression protocols would require more experience to achieve the same level of proficiency compared with digital impression protocols (Tables 3 and 4).

**Fig 26.** Representation of percentage of students' preference, efficacy, and competence regarding the two impression protocols.<sup>24</sup>

	Conventional	Digital	Either
Number of participants (%)	3 (10%)	23 (77%)	4 (13%)
Working time for conventional method	21:54 ± 1:52	26:17 ± 7:32	17:38 ± 1:57
Retake time for conventional method	2:59 ± 5:10	8:42 ± 6:50	0:00 ± 0:00
Working time for digital method	16:33 ± 7:06	12:10 ± 3:18	11:19 ± 2:05
Rescan time for digital method	1:03 ± 1:25	1:38 ± 1:06	2:17 ± 0:36

**Table 3.** Time consumed (in minutes:seconds; mean ± SD) for each impression technique based on participants' efficiency outcomes (measured in time and level of difficulty)<sup>24</sup>

	Conventional	Digital	P value
<b>Efficiency</b>			
Preparation time	4:42 ± 1:25 (2:50 to 8:06)	3:35 ± 0:58 (2:24 to 6:42)	< .001*
Working time	20:00 ± 6:37 (11:18 to 34:50)	8:54 ± 3:12 (5:34 to 19:44)	< .001*
Retake/rescan time	6:58 ± 6:56 (0 to 21:37)	1:40 ± 1:05 (0 to 5:20)	.003*
Total treatment time	24:42 ± 7:18 (14:28 to 41:24)	12:29 ± 3:46 (8:16 to 24:23)	< .001*
Total number of retakes/rescans	21	67	< .001*
Participants needing retakes/rescans	17/30 (56%)	29/30 (96%)	—
<b>Difficulty</b>			
VAS (0 to 100)	43.12 ± 18.46 (0 to 73.68)	30.63 ± 17.57 (0 to 77.89)	< .001*

**Table 4.** Overall time (in minutes:seconds) consumed, number of retakes/rescans, and difficulty for each impression technique<sup>24</sup>

VAS = visual analog scale. Time and VAS data are presented as mean ± SD with range in parentheses. \*Statistical significance  $P \leq .05$ .

P	AU1	IOSU1	P	AU2	IOSU2	P	AL1	IOSL1	P	AL2	IOSL2
1	12	12	10	12	25	13	12	25	22	12	24
2	14	25	11	15	40	14	14	20	23	12	35
3	10	15	12	12	20	15	12	15	24	15	40
4	10	40				16	15	25	25	12	35
5	14	25				17	15	20	26	10	40
6	12	18				18	18	10	27	12	18
7	12	20				19	12	18			
8	10	20				20	12	17			
9	10	15				21	10	16			

**Table 5.** Time comparison (minutes) between the conventional impression and the intraoral scan in the Wismeijer et al<sup>32</sup> study

P = patient number; A = analogue impression; IOS = intraoral scan; U = maxilla; L = mandible; 1/2 = number of implants.

In 2013, Wismeijer et al<sup>32</sup> pointed out another important aspect of this new digital solution: patient perception. More specifically, it is interesting to evaluate whether patients perceive the conventional impression-taking technique as more cumbersome than the digital technique or not. In conclusion, they stated that although their research was based on a relatively small cohort of patients, the preference of patients for the intraoral scan was statistically significant. This was mainly because of the perception of the unpleasant taste associated with the conventional impression procedures and the preparatory activities involved. However, patients did perceive the duration of the intraoral scan more negatively than that of the analog procedure (Table 5).

### The digital work flow

The CAD/CAM systems basically are formed by three main elements:

1. Data acquisition unit that registers the preparation design and the surrounding structures
2. Data processing software that designs an anatomical virtual restoration or framework and establishes all the milling parameters
3. Automated production machine that manufactures the restoration<sup>4</sup>

The first two elements comprise the CAD phase, while the third element is responsible for the CAM phase. The precision of these three elements combined will dictate the success of the system.

The CAD/CAM systems currently can be classified into two different groups according to the ability to share CAD data: open CAD/CAM systems and closed CAD/CAM systems.<sup>2</sup> The closed systems integrate all the steps, with no interchangeability between different systems. With this closed system, the professional relies on one specific producer for all the software updates. The open systems, on the other hand, allow the professional to choose between different CAD and CAM combinations.<sup>33,34</sup>

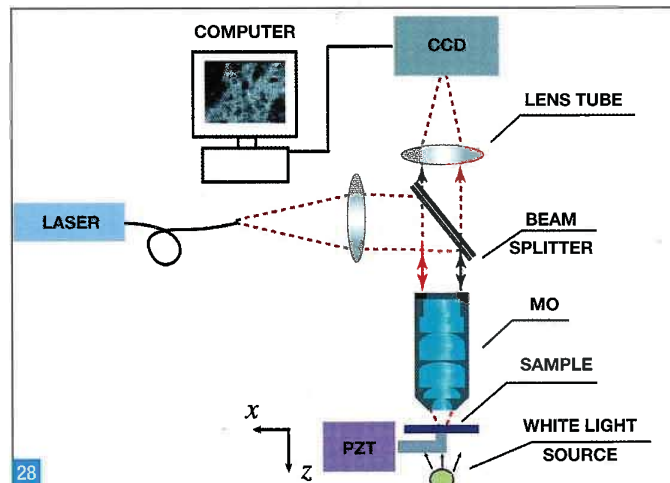
**The transfer of digital information does not require disinfection, land transportation, or fabrication of a gypsum cast for articulation. Thus, the potential for dimensional inaccuracies is eliminated or at least reduced.**



### The Zfx intraoral scanner

Zfx IntraScan is a lightweight handpiece that is connected to a laptop by means of a cable and weighs only 600 g. All of the scanning technology is incorporated into the handpiece, obviating the need for a complex workstation (Fig 27). The one component common to all digital systems is the intraoral camera (scanner) used to record data files of the intraoral condition. Recording the digital files negates the need for a conventional impression to fabricate a restoration and is a significant paradigm shift in the clinical work flow.

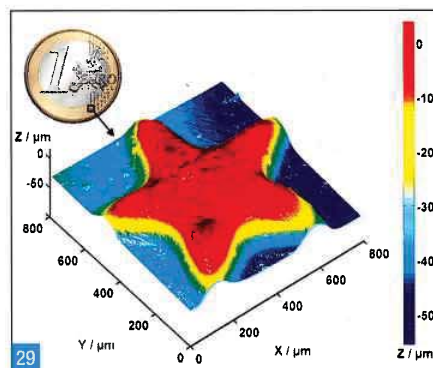
Confocal microscopy is the technology behind the system, permitting the intraoral scanner to acquire 3D digital data from inside the mouth and read hard and soft tissue morphology directly, thanks to a series of single overlapping photographic shots that are linked together in real time. Confocal microscopy is an optical imaging technique used to increase the optical resolution and contrast of a micrograph using point illumination and a spatial pinhole to eliminate out-of-focus light in specimens that are thicker than the focal plane. It enables the reconstruction of 3D structures from the obtained images. The principle of confocal imaging was patented in 1957 by Marvin Minsky<sup>35</sup> and aims to overcome some limitations of traditional wide-field fluorescence microscopes. In a conventional (ie, wide-field) fluorescence microscope, the entire specimen is evenly flooded by light from a light source. All parts of the specimen in the optical path are excited at the same time, and the resulting fluorescence is detected by the microscope's photodetector or camera, including a large, unfocused background area. In contrast, a confocal microscope uses a single illumination point and a pinhole in an optically conjugate plane in front of the detector to eliminate the out-of-focus signal. The name confocal stems from this configuration (Fig 28). As only light produced by fluorescence very close to the focal plane can be detected, the image's optical resolution, particularly in the sample depth direction, is much better than that of wide-field microscopes.



**Fig 27.** Computer-aided impression taking (CAI).<sup>16</sup> Zfx intraoral scanner.

**Fig 28.** Schematic showing how confocal microscopy works.

**Fig 29.** Partial surface profile of a 1 euro coin, measured with a confocal microscope.

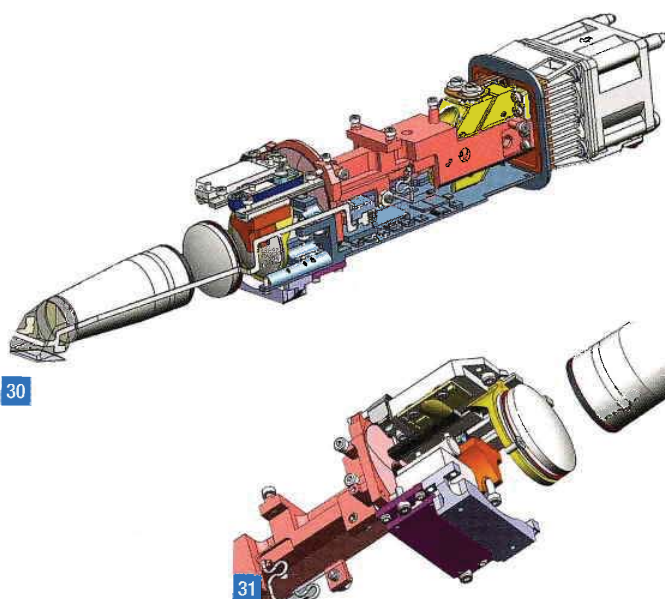


**Figs 30 and 31.**  
Confocal microscopy  
technology the inside the  
Zfx handpiece.

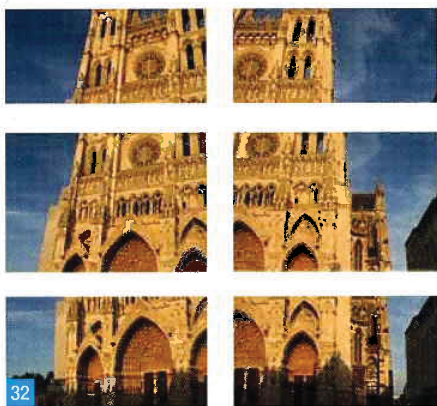
### Highlights of the system

The system has several characteristics that make it very interesting from various perspectives:

- It produces an STL (standard triangulation language) file compatible with all major dental CAD devices on the market, making it an open system and consequently appealing to a wider range of clinicians using different systems. At the beginning of the digital era, the data files were designed with a closed architecture concept, ie, the digital files could only be read and used by equipment from the same manufacturer, whose systems were also used for processing the restoration. This led to several problems for dental laboratories, who were faced with having to acquire systems from each manufacturer in order to manage all the data files they received from their various dentist clients.
- Use of the additional plant-based powder is not mandatory. It is only required when the clinician wants the scanning process to proceed more quickly.
- The start/stop button provides the clinician the ability to stop at any time during the digital impression protocol, check it, and then move forward with the impression or start again from the beginning if needed.
- The presence of a gravity sensor holds the orientation while scanning.
- The time for a single scan takes less than 0.1 seconds, and up to 28 scans can be captured per second, depending on the hardware. The scanning speed range is from 18 to 28 individual 3D scans per second. This very fast acquisition rate allows real-time 3D video acquisition, with a scanner seeming more similar to a video camera than a traditional dental scanner.
- The handpiece is relatively light, approximately 1.3 lbs, which makes the system easy to carry between offices.
- Pixels on sensor (X × Y): 144 × 90 μm; pixel dimension: 50 × 86 μm; on the object (X × Y): 66 × 120 μm.
- Scan field (on the object; X × Y × Z): 10.4 × 9.6 × 1.8 mm, which is exactly the scanning field dimension of three-dimensional space data for a single-tooth abutment.
- Most importantly, the system makes use of patented real-time stitching technology, which enables controlled overlapping of every individual scan to create a real-time, three-dimensional animated movie on the screen; in other words, the camera captures a series of individual digital images that overlap one another and are then stitched together by the computer software program to process a single 3D virtual model. The number of overlapping digital images recorded will determine the size of the virtual model on the computer; therefore, the more teeth desired in the working model, the more images are necessary to record it. The number of images recorded is not as important as the time for efficiency in recording the images for the case; the longer the time required, the longer the operating field must be well isolated and free of moisture for the images to be accurate.
- The system takes advantage of the smart pixel sensor, which is an image sensor consisting of an integrated circuit containing an array of pixel sensors, with each pixel containing a photodetector and an active amplifier.
- While scanning, the software is easy to







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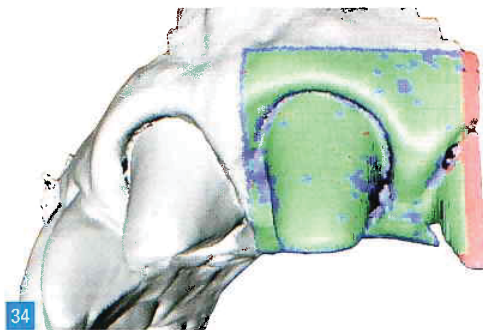
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understand since everything is associated with a color, guiding the clinician during the impression taking.

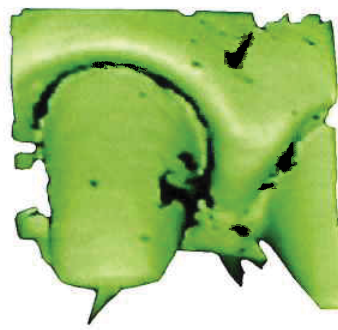
- Accelerometers inside the scanner allow full control of the functions used during the scanning procedure, directly moving the handpiece itself. In this way, the operator does not need to move to the computer or the display to input commands or review the acquired data.
- The handpiece can be disinfected using a soft cloth moistened with and ethanol-propanol

disinfectant. It is also recommended to use the disposable covers supplied.

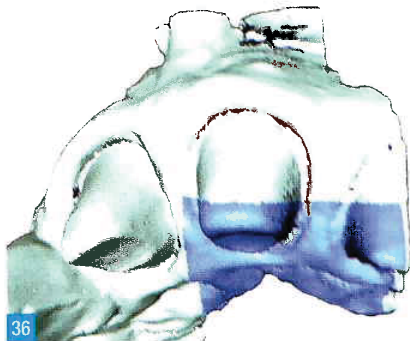
- Once the scan has been acquired, the clinician has the ability to remove the unnecessary areas to decrease the size of the file (Figs 41 to 44).
- The file that is sent to the lab provides the patient's personal information, the prosthetic plan, and the various processed scans. Because of the accuracy of the points acquired, the STL file of the surface can be used by the dental technician for the CAD and CAM procedures.



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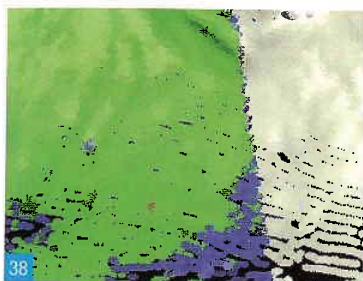


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**Figs 32 and 33.** The different scans are put together in real time to create the final image.

**Figs 34 and 35.** In the central part of the computer screen, the 3D model (in grey) is built up as the operator moves the scanner along the jaws with the guidance of the system's color coding: orange = the most recently added points; black = points still not acquired, missing information; green = points already acquired in the model and actually shown by the camera; blue = points already present in the model and not fixed by the camera even though they are within the field of view of the camera; usually indicates the most recent part of the model recorded by the camera before losing the stitching; gray = points already acquired in the model. While scanning, on the top right of the screen, the clinician can see precisely what the scanner is seeing at that specific moment with this green icon.

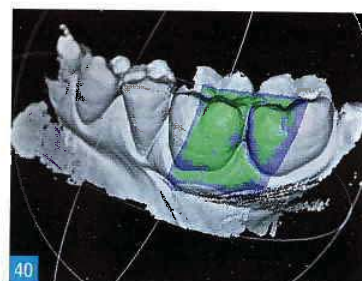
**Figs 36 and 37.** If the scanner should lose a signal, the clinician will see this view on the screen. After the loss of the signal, a blue area will appear in the 3D model, showing the last scanned photo shot acquired, and the image on the right side will immediately become red. In order to recommence the scan, the most recent area should be highlighted to allow the system to reattach the scans. At this point, the scanner will resume recording the 3D data, the blue area will return to green, and the red icon at the top right of the screen will change to green. It is not strictly necessary to select the blue area with the same orientation as it appears on the screen, but the angle should be not greater than 90 degrees to allow the software to recognize the scanned area.



**Fig 38.** Lower density (in scanning).



**Fig 39.** Higher density (perpendicular scan).

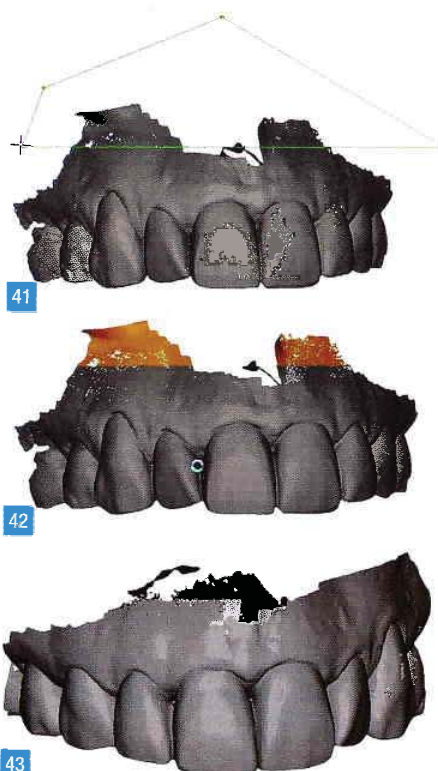


**Fig 40.** When the scanner has stopped, it is possible to view the results in 3D by moving the mouse; rotating, moving, and zooming the view can easily be done in real time in the three spatial axes to quickly check the quality of the scan. The scan must be analyzed from different angles to avoid defects.

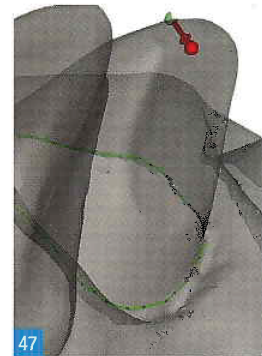
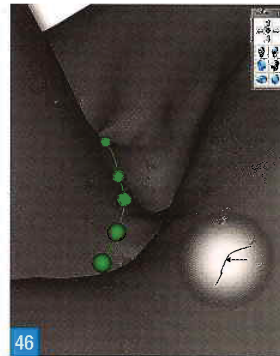
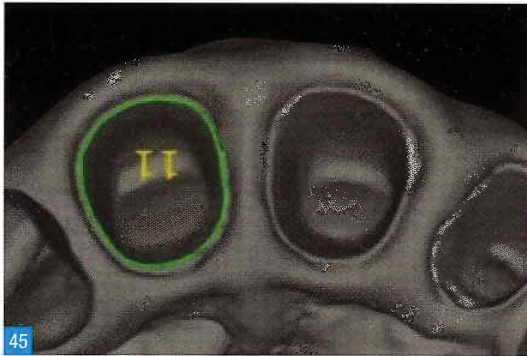
**Figs 41 to 44.** Decreasing the file size by removing needless data is important to speeding up the process. The wizard guides the operator at every step.

- Some areas may need to be filled in, as illustrated in Figs 38 and 39, when the device is scanning an inclined area from above, and consequently the density of the data points is reduced. If more data points are needed, the scanner needs to be rotated perpendicularly to the inclined plane, and the missing points will be filled.
- Checking the scans (Figs 40 to 44) is a very important process, analogous to examining

silicone or polyether materials for defects when taking a conventional impression of the mouth to avoid problems during the rehabilitative process. In the same way, it is necessary to analyze the scan before proceeding to the next phase. There are several crucial things that must be checked, such as the abutment preparation margins, the teeth adjacent to each preparation (to determine the interproximal contact points), and the







- occlusal surface of antagonist teeth (to provide information for correct function of the definitive crown).
- One of the great advantages of the digital impression is that it enables the clinician to immediately define the finish line of the abutment (automatically for the shoulder finish line, manually for the knife-edge finish line) prior to sending the files to the technician. This process is simplified and made more accurate by the software's onscreen wizard and by the 2D position guide. In addition, the system allows the operator to check the incisal thickness and taper of the preparation to obtain the correct milling strategy and produce a precise framework and restoration, without any voids (Figs 47 and 48).
- An obvious concern of many clinicians is the size of the camera, which is much larger than a dental handpiece or a curing light, broaching the issue of how much space is needed for the camera to fit in the mouth and record, for example, the distobuccal aspect of the maxillary molar and the distolingual aspect of the inferior molar. The Zfx system overcomes this issue with its 45-degree laser beam. The body of the camera, which contains all the technology, is comfortable to handle and facilitates all translation or rotation movements during the scan (Fig 49).
- The Zfx digital system also works without the need for additional powder.



**Figs 45 and 46.** The prosthodontist has the ability to mark the finish line of the abutment preparation, at high magnification, before sending the file to the laboratory. In this image, it is interesting to note the two-dimensional guide (inside the bubble), which represents the sagittal section of the abutment (black line) and, with the blue arrow, helps the clinician to identify the final preparation.

**Figs 47 and 48.** The CAM milling strategy involves the use of different drill diameters for performing subtraction from the block of raw material, depending on the area of the abutment. It is therefore important to know the abutment size in order to give the correct thickness and taper to preparations. In this way, the laboratory can produce restorations that are precise and free of voids that can affect their durability. Courtesy of Federico Boni.

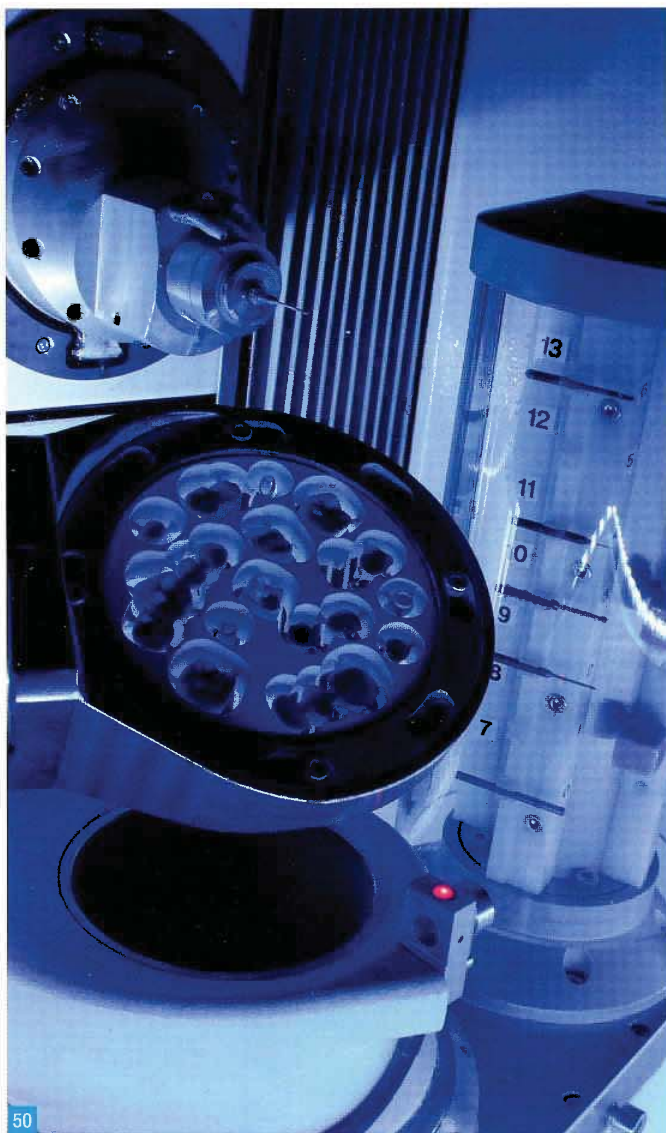
**Fig 49.** The technician can choose, depending on the prosthetic treatment plan, the most suitable milling strategy. Modern burs have a minimum diameter of 0.5 mm.

- The Zfx digital system offers a unique alternative technique for clinical dentistry based on the application of computer technology. This represents a significant change in the dental clinical work flow. Each digital system company has developed unique software programs to manage the digital impression as well as the design and milling of restorations. The Zfx software permits the user to record basic patient identification information, serves as a guide for the scanning process, and then provides an online prescription form to electronically transmit the recorded digital file to the dental laboratory for restoration fabrication.



**Fig 50.** Milling machine with five axes that guarantees the milling of all materials in a dry or wet environment.

The learning curve for the software is short because there is little variation in the process of recording a digital impression, and data input is straightforward. The CAD program provides a variety of very intuitive tools as aids to virtually design and customize the restoration to the specific needs of the clinical case at hand on the computer monitor. The main tool of the ZFX system, referred to as the wizard, guides the operator in every step of the process.



In addition to the potential inherent errors when clinical impressions are taken, including the exchange of information with the laboratory, several drawbacks might occur, which are necessary to remedy with standardized procedures for the submission and management of the impression itself, eg, paying attention to the time required for elastic recovery, the appropriate disinfection procedures, and the time limits dictated by the materials and manufacturers.<sup>36</sup>

- To avoid these issues, Zfx Dental-Net is an exclusive online platform for milling centers, labs, and dentists, giving them the chance to control and secure data exchange during every treatment process.
- Each scan is not subject to additional laboratory fees.
- The five axes of the Zfx Mill InHouse (Fig 50) enables accelerated and consistently accurate in-house milling of resins, composites, waxes, and other soft materials; zirconia; and lithium disilicate. This tool can be economically viable for producing small zirconia and lithium disilicate frameworks as well as long-term polymethyl methacrylate provisional restorations and wax structures in-house while producing more complex restorations in a milling center.

For the chairside digital systems, the in-office milling of restorations for simple cases can provide several benefits to the clinician since these can be delivered in one appointment, which many patients regard as a significant advantage. In addition, the elimination of a second appointment means they receive fewer anesthetic injections.<sup>37</sup>

However, not every aspect of the digital in-house work flow is positive; learning to use the device and fit it into the office routine requires time and extra effort. To become and remain proficient in using the software and hardware, the clinician and staff members must use the devices frequently considering the economic investment that is made.

As for implant restoration, the Zfx system provides a scannable implant impression coping with specific characteristics:

1. Indicates the apicocoronal position and implant head inclination.
2. Fits perfectly without any prosthetic allowance.
3. Has a titanium base that is available in two depths, 4- or 7-mm depth, to guarantee a better adaptation to different morphologies of the gingival sulcus.
4. In screw-retained implant prosthesis cases that involve several implants, it is important that the scannable impression coping is screwed to the implant with a dynamometric key, which allows consistent torque screwing force and detection of the correct position of the implants, guaranteeing a passive fit of the final screw-retained prostheses.

During their learning curve with the system, the authors have developed a specific scanning protocol that consists of three steps and defines important and unimportant areas (Figs 51 and 52).

### Important areas

It is always important to include the area to be treated by scanning the surface and margin of the preparation, the contact points of the restoration, and the occlusal morphology of the adjacent and antagonist teeth. There should not be gaps in these areas of the 3D digital model because it would affect the final quality of the impression.

### Areas of less importance

Cervical areas distant from the preparation and interproximal areas distant from the target zone are areas that are not important to be included in the scan. Gaps in the scan in these areas will not influence the final quality.

### STEP 1. Target area definition

Before starting, it helps to mentally define the limits of the acquisition area around the preparation and implants. It is important to be sure to include all areas and information the laboratory may need.

### STEP 2. General scan

Start the acquisition from the distal areas, then

incline the scanner at a 45-degree angle and with a fluid and slow movement capture together the occlusal and lingual surfaces of the target teeth, and then go back to the starting point, focusing on the occlusal and vestibular surfaces. In this phase, the clinician does not have to worry about the gaps, which will be filled in next step.

### STEP 3. Checking and finishing phase

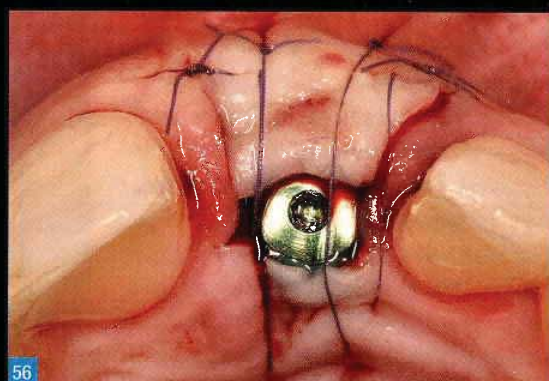
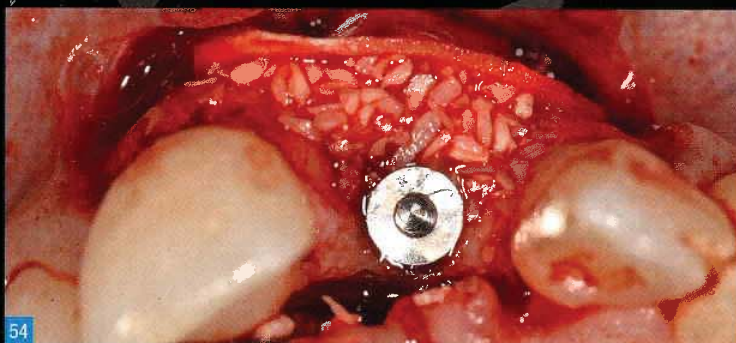
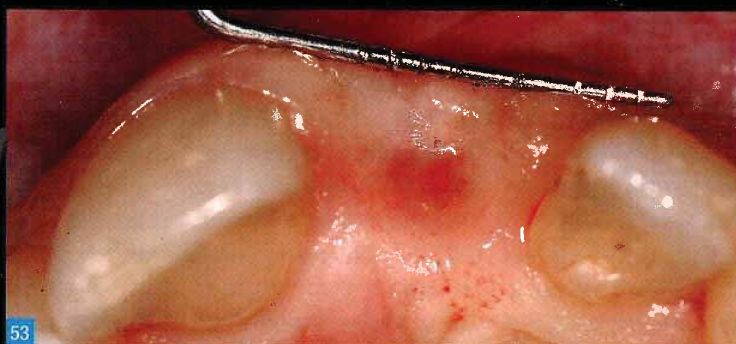
Before finishing the acquisition, it is critical to confirm the data. Check if there are any overlapping objects, such as the tongue or cheeks, modifying the data. It is now possible to fill the areas left empty in the second phase. Once this is completed, the acquisition is done.

If the surface to be scanned has been obstructed (eg, if the patient placed their tongue between the scanner and the target teeth), it is possible to repeat the scan by simply clicking the back button. The image on the screen and the scan will revert back according to how many times the back button on the scanner is pressed.

**Figs 51 and 52.** In 2008, a 29-year-old patient presented with a removable prosthesis to replace the maxillary left central incisor, which had been extracted 4 months earlier because of a root fracture. She requested a more comfortable fixed prostheses. At the intraoral examination, a low smile line with a thin upper lip was evident; at the edentulous ridge level, soft tissue loss of about 2 mm horizontally and 3 mm vertically compared with the contralateral tooth was found. The adjacent lateral incisor was chipped incisally and labially inclined. The gingival margin of the right central incisor was more coronal than that of the left central and lateral incisors, while the periodontal attachment of the adjacent teeth was normal.



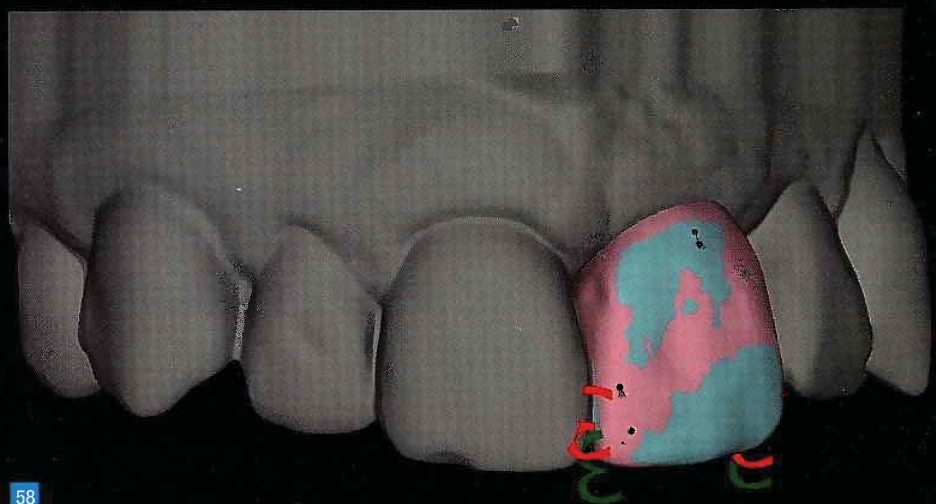




**Figs 53 to 56.** After further diagnostic examination (cone beam CT scan, intraoral periapical radiographs, and study cast mounted in the articulator), it was decided to place a provisional adhesive Maryland partial denture to immediately improve the patient's comfort and allow for easy removal during the treatment plan phases; despite the clinical difficulties presented, there were only two surgical steps planned, one for implant placement with simultaneous guided bone regeneration (GBR) and the second stage after 6 months. The first surgery provided flap elevation with two "hockey stick" (J-shaped) incisions distal to the maxillary right central incisor and left lateral incisor with a palatal paramedian incision at the edentulous ridge level at full thickness to access the underlying bone. Implant placement was aided by a prosthetic-surgical guide, and the GBR was done by placing homologous bone and a collagen membrane, stabilized with two titanium tacks, to overcorrect the bone defect, which was a two-wall dehiscence with exposure of six vestibular implant threads. The flap was then released, with deep and superficial periosteal incisions to dissect the muscular fibers, to achieve primary closure with internal horizontal mattress Gore-Tex (W. L. Gore) sutures and some single superficial sutures. At the 6-month follow-up, no soft tissue dehiscence or infection was observed, a modified roll flap technique with a papilla-sparing incision was performed to augment the thickness of the vestibular soft tissue profile, and a healing abutment was screwed onto the implant.



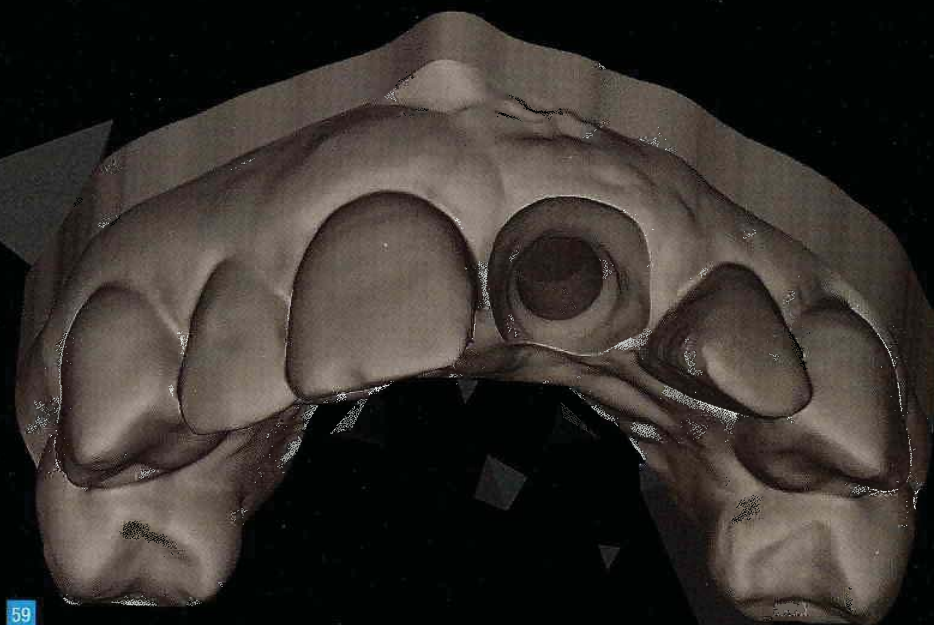
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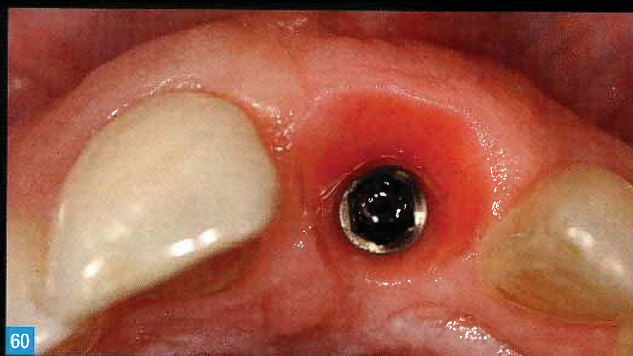
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**Figs 57 and 58.** After 3 weeks of healing, the screw-retained provisional restoration of the maxillary left central incisor has been placed. After its emergence profile conditioned the peri-implant tissues, the final digital impression was taken.

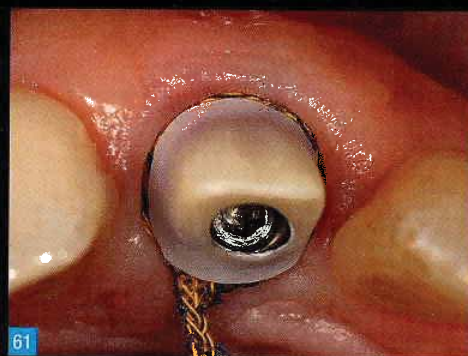




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**Figs 59 to 61.** This case was the first done with a prototype of a digital intraoral scanner with which it was possible to transfer crucial data to the technician, such as the morphology of the gingival sulcus, the correct shape of the functionalized provisional restoration, and the implant position and diameter. The technician, using the CAD system, was able to manage the proper design of the abutment with a shoulder finish line and the zirconia framework with a 0.3-mm thickness, facilitated by a video representation of the final shape of the tooth, which was derived from the functionalized provisional restoration. The detailed view of the morphology of the gingival sulcus highlights the correct emergence profile of maxillary left central incisor compared with the contralateral incisor. The closeup view of the abutment in the mouth prior to cementation shows the retraction cord in the undercut apical to the finish line, which will facilitate the precise removal of excess cement.

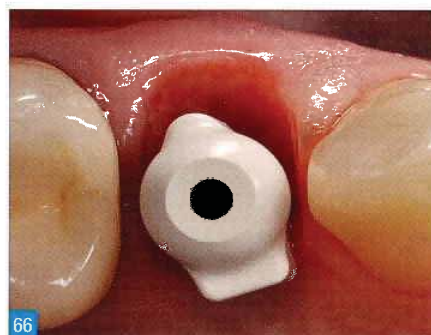
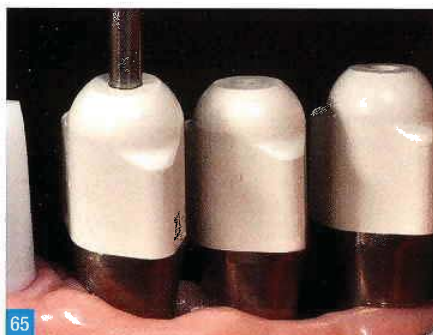


**Figs 62 to 64.** On the day of cementation, a self-adhesive dual resin cement was used after conditioning the different substrates. Note how the prosthesis blends in well with the surrounding teeth and tissues due to the correct position and shape of the peri-implant soft tissues. The 6-year clinical and radiographic follow-up confirms the stability of the hard and the soft tissues and the excellent accuracy of the prosthetic components between them. The digital impression, although in this case only a prototype, together with the whole dental digital work flow, has guaranteed excellent reliability.



**Figs 65 and 66.** Scannable impression coping tightened with the dynamometric torque screwdriver. Detailed view of the shape of the scannable impression coping, which is recognized by the software and provides the diameter and position of the implant.

**Fig 67.** Detail of the position of the scannable impression copings for the digital impression. The scanner is positioned at 45 degrees and must simultaneously capture the copings and peri-implant tissues during scanning.



Today, the major issue with intraoral scanning systems is gaining more accuracy, especially for larger scan areas, and simplifying clinical handling. In 2013, Ender and Mehl<sup>38</sup> published a study with the aim to investigate the accuracy of different scanning strategies for full-arch scans in an in vitro study design. A reference master model was used for the digital impression with the Lava C.O.S., the Cerec Bluecam, and a powder-free intraoral scanning system such as iTero.

They concluded that, with the current intraoral scanning systems, good accuracy of full-arch dental impressions are possible if adequate scan strategies are used (Figs 65 to 67) and that the powder-free scanning system provides the same level of accuracy compared with scanning systems with surface pretreatment.

As has already been discussed, the impression accuracy is critical to obtaining a passive fit between prostheses and implant and in preventing mechanical and biologic failures in implant dentistry since

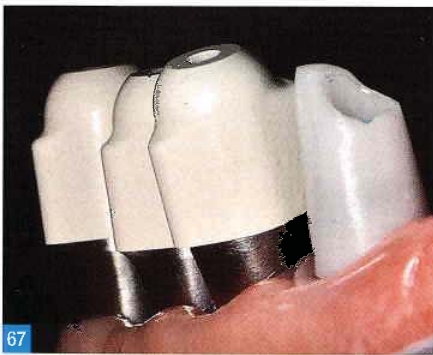
the presence of misfit in the interface between different implant components may decrease assembly stability.<sup>39–41</sup>

The long-term survival capacity of the restoration depends directly on the accuracy of the fit between the restoration and the abutment; in rehabilitations on natural dentition, marginal discrepancies and voids also increase plaque retention and change the distribution of the microflora, reducing the prosthetic strength. Marginal and internal fits in implant- and tooth-retained restorations have been evaluated with different materials, margin designs, and fabrication techniques.

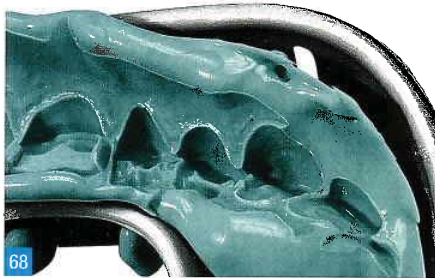
Although implants may not be subject to problems such as recurrent caries or dentinal hypersensitivity, poorly fitting implant restorations may have long-term implications that affect the overall bio-integration of the implant restoration complex with the hard and soft tissues. Poor marginal adaptation leads to an increase in bacterial colonization and changes the composition of the subgingival microflora. The maximum accuracy possible should be the goal until threshold values defining a biologically acceptable misfit and reliable fit assessment methods are determined.<sup>42</sup>

In general, errors can be caused by each clinical and laboratory step necessary for the fabrication of the prosthetic rehabilitation, such as impression taking and master cast production<sup>43,44</sup> (Figs 68 and 69).

Each of these inaccuracies is typically additive, with the final degree of misfit being a function of the combined errors in the system. Swain, in a review on fabrication methods for implant-supported







**Figs 68 and 69.**

Inaccuracies in impression taking master cast generation could cause errors in the prosthetic rehabilitation.

**Fig 70.** A scanning protocol is needed to increase the accuracy of the scan data.

**Figs 71 and 72.** Digital impression permits a faithful replica of the intraoral situation with several benefits both to the clinician and the patient.

fixed restorations, concluded that CAD/CAM technology would be the most consistent and least technique-sensitive method for achieving implant frameworks with an excellent fit.<sup>45</sup>

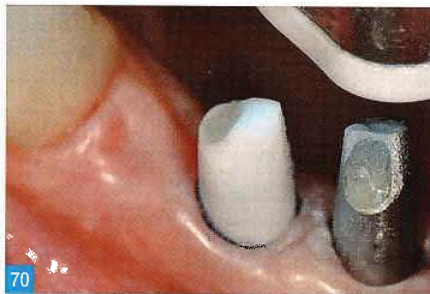
Although CAD/CAM fabrication may have the potential for providing passively fitting restorations, conventional impression taking and master cast fabrication with all the associated imperfections are still a prerequisite for laboratory-based CAD/CAM Systems.<sup>46</sup>

In addition to good accuracy, intraoral scanning, as discussed previously, is said to provide more comfort for the patient and a more efficient work flow for the practitioners, which reduces treatment costs<sup>47,48</sup> (Figs 65 and 66).

Some data is available on the accuracy of data acquisition by intraoral scanning.

In 2010, Syrek et al<sup>23</sup> compared the fit of all-ceramic single crowns fabricated from intraoral digital impressions and conventional silicone impressions and showed that intraoral digitalization resulted in a significantly better marginal fit.

In addition, Henkel,<sup>11</sup> in a similar publication, stated that, in a blind study, single crowns developed using intraoral scanner technology were preferred over the ones generated using conventional impressions.



In 2012, Karl and Taylor<sup>41,47</sup> published an investigation finding that implant-supported fixed restorations with an absolute passive fit (ie, zero microstrains recorded at any sensor) cannot be fabricated with currently available technology. However, he found that, given the limited capabilities of detecting misfit and assuming a certain biologic tolerance for misfit, it appeared that all of the digital restorations evaluated in the study could have been classified as excellent. He also stated that the intraoral digitalization of dental implants was at least as precise as conventional impression taking and master cast fabrication using prefabricated transfer components and laboratory analogs (Figs 71 and 72).





**Figs 73 to 75.** While designing the abutment and the definitive implant crown, the CAD software allows the technician to keep control over all the major variables of the case, such as the inclination of the prosthetic screw access hole, the morphology of the gingival sulcus, and the prosthetic freeway space.

**Figs 76 to 79.** Digital intraoral impression of a periodontal and prosthetic case.

The same author, in a recent investigation on the effect of material selection on the passivity of fit of implant-supported restorations, revealed only a minor influence of the core material used.

Summarizing, the general practitioner today can be assured that current systems for intraoral digitization are at least as precise as conventional impression techniques for fabricating fixed restorations on teeth and implants (Figs 73 to 75).

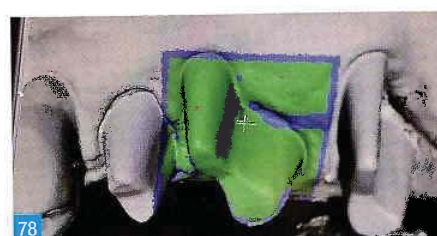
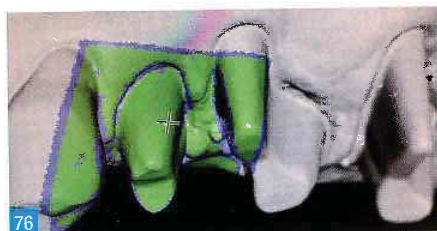
### Conclusion

In light of the considerations made so far, it is possible to say that digital impressions on teeth and implants represent a new technology that is likely to be increasingly used in dental practice due to its high accuracy, so far in short-span fixed partial prostheses, that increases clinical outcomes and reduces the need to make modifications to the

definitive prosthesis. It avoids the imperfections of the traditional impression, such as bubbles, and eliminates the need to repeat the impression taking procedures because the real-time display on the screen allows the operator to check for errors during the acquisition.

Other benefits are the expedited production time and reduction in the cost of materials and shipping. There are obvious benefits both for the operator and patients. Patients have a brief and convenient digital impression appointment, and the need to have unpleasant materials in the oral cavity for a long period of time and the resulting gag reflex are eliminated.

Among other benefits, there is the reduction in the number of appointments otherwise necessary for repeating the impression procedures in cases of inaccuracies; the high precision and adaptation of the prosthetic restoration; and the greater

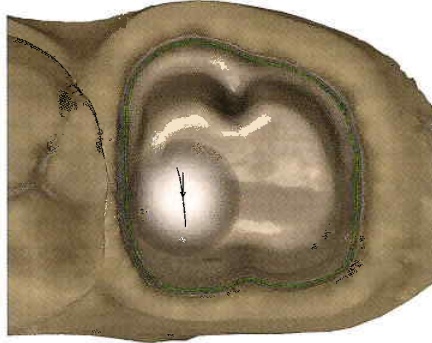




involvement of the patient, who can directly view his or her intraoral situation on the screen during the scanning process (Figs 76 to 79).

The definitive prosthesis, the ultimate objective of the whole process, is manufactured with the latest-generation materials through high-performance milling processes or laser sintering procedures, avoiding the typical risks associated with the traditional processes of metal casting.

The digital intraoral impression also has numerous advantages for the clinician, including a faster and less operator-dependent procedure than the traditional method, allowing improved precision and optimal clinical results while reducing the possibility of errors by the technician during the processing steps. Finally, it minimizes the cost of

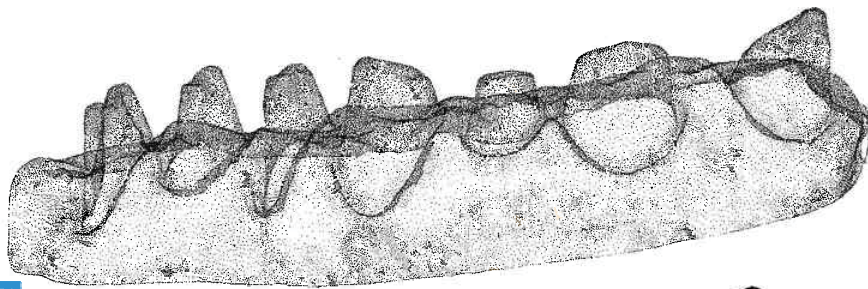


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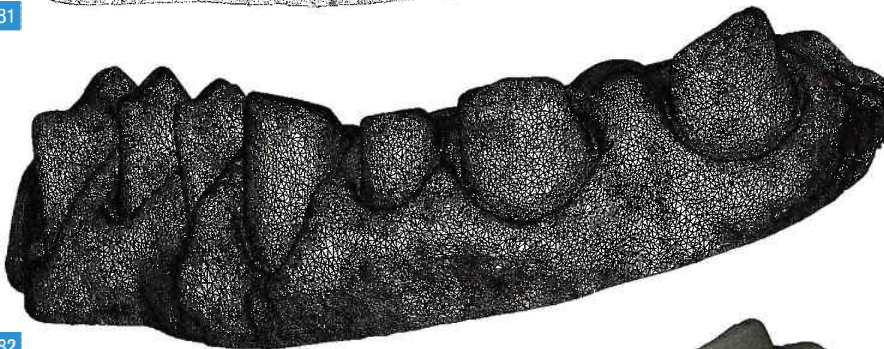
materials and shipping: everything is transmitted online, with files able to travel from one side of the planet to the other in real time, facilitating collaboration between dental offices regardless of the geographic location.

**Fig 80.** One of the significant advantages of the intraoral scanner is the ability to define the margin of the preparation immediately after the scan is complete. In this case the operator is working with a knife-edge finish line and, with the help of the software, can draw the finish line manually.

**Figs 81 to 83.** The CAD software also gives the operator the ability to display the same file in several different views; from the group of points, to the triangulation of those points, to the flat and shaded view of the final STL file.



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For many years systematized and well-established conventional protocols have been used in prosthetic rehabilitations, yielding results that met clinicians' expectations and often exceeded those of patients. Over time the advent of new technologies and new materials has enabled the dental team to create prosthetic rehabilitations with an accuracy and precision that were previously difficult to obtain. Today, intraoral scanning technology is one of the most exciting new areas in dentistry, with three-dimensional digital reconstruction of the oral structures facilitating a wide range of procedures in fields such as prosthodontics, implant dentistry, and orthodontics. Currently available intraoral scanners overcome many of the limitations and disadvantages of traditional impression procedures while maintaining a high level of accuracy, making them an efficacious alternative to conventional impression techniques. In this book, the authors introduce the protocol they have used in their own practice, integrating new digital technologies and advanced materials with experience gained from using traditional techniques to provide restorations with optimal strength, esthetics, and function while reducing treatment times and improving patient comfort. Many cases are presented, highlighting the modified protocols the authors have developed over time with their increasing knowledge of new materials and the ongoing development of new technology and demonstrating a level of quality in the results that is on par with if not superior to that achieved using conventional methods.

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# DIGITAL DENTAL REVOLUTION

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