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Next generation digital implant restorations
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Digital implant restorations

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This article briefly reviews the advances in CAD/CAM (computer-aided design/computer-aided manufacturing) and digital dentistry with special emphasis placed on virtual-model implant restorations. The indications/contraindications and benefits/limitations of these technologies are critically assessed, and a series of new workflows are recommended. The workflows have been successfully applied in clinical situations. This fully digital approach to implant restorative dentistry has proven to achieve efficient and predictable treatment outcomes, as compared to other digital options and conventional implant restorative modalities.

Key Words: digital restorations, digital dentistry, CAD/CAM, implant restorations, intraoral scanning

Introduction

Computer-aided design and computer-aided manufacturing (CAD/CAM) generally consists of two steps: scan/design and milling/manufacturing. However, unlike industrial applications, CAD/CAM in dentistry has consisted of three steps.¹ ²

Currently, most CAD/CAM dentistry worldwide is at least partially analog-based, meaning that gypsum casts are scanned in dental laboratories, and based upon the digital data acquired in that process, the restorations are designed and milled. This process includes what has been defined as “digital islands,” meaning certain steps in the process are digital with at least one transfer of data (casts) from the analog world to the digital world and then back again.

Dentistry as a profession has been moving towards full digitalization, with intraoral scanning replacing impressions.³ This can now be accomplished by the synergy of software/milling advances and increased knowledge of material sciences. A full digital approach may be defined as a process in which intraoral dental components (preparations, coded healing abutments) are scanned using an intraoral scanner. The data acquired during the scanning process is then sent electronically to dental designers, and then on to dental manufacturers for fabrication of the restorations. Certain types of dental restorations may now be fabricated completely in the digital world, without the need for any type of impressions, casts, articulator mountings, castings, and labor-intensive porcelain applications.

For the purposes of this article, intraoral scans will be synonymous with digital impressions.
Digital Workflow

1. SCANNING OR DATA ACQUISITION:
   A scanner (camera) captures an image of the preparation or coded healing abutment and transforms the geometry into digital data to be processed by a computer. This can be accomplished in one of two locations:
   a) In a dental laboratory where a desktop scanner scans the master cast.
   b) In a dental office where an intraoral scan can be made with a chairside intraoral scanner.

   One of the key concepts in CAD/CAM terminology is the difference between closed and open architecture systems. Closed-architecture systems have been defined as specific lab-based scanners linked to one manufacturing or milling center. Open-architecture systems have been defined as systems in which scanners are linked to multiple manufacturing/milling centers. These scanners not only scan dental components; but they also represent the gateway to multiple manufacturing facilities.

2. DESIGN:
   This step entails designing dental restorations/abutments using computer programs. These virtual designs are generated by dental laboratory technicians or designers in accordance with the parameters established by the clinicians treating the patients. They are virtual representations of the dental restorations. Abutment design follows principles established in the fixed prosthodontic literature.

3. MANUFACTURING/MILLING:
   This step involves transmitting the digital data to machines that mill the restorations as specified by the designs. Clinicians/technicians have pre-selected the material that is milled (titanium, titanium alloy, zirconia, or other ceramic materials).

   Dental CAD/CAM processes are considered to be a subtractive manufacturing process, and depending on the complexity of the specific restorations, production may occur in one of three possible locations:
   1. Chairside in the dental office,
   2. In a commercial dental laboratory,
   3. In a commercial milling center.

   Regardless of the location, dental CAD/CAM protocols always include the same three steps – scanning, designing, and milling – as each restoration is created for an individual patient. The above steps define the digital workflow. Biomet 3i has termed implant components manufactured with this workflow Patient Specific Restorations®.

   Are CAD/CAM protocols better than conventional protocols? If so, how? Will new CAD/CAM protocols lead to improved patient outcomes? CAD/CAM
protocols have multiple clinical applications in implant dentistry. This article focuses on a CAD/CAM protocol to fabricate cement-retained restorations (with different restorative materials) supported by BellaTek Abutments generated from intraoral scans.

Digital Intraoral Scan/Digital Implant-Level Impressions with the BellaTek® Encode® Impression System

Digital implant-level impressions in dentistry represent a considerable advancement when compared to conventional protocols. It eliminates several steps:

1. Impression trays are no longer needed. Along with this, impression materials, adhesives, gypsum products, articulators, and dental laboratory expenses associated with fabrication of conventional crowns are also eliminated.

2. Decreased clinician chairtime and auxiliary preparation time as compared to the time needed for conventional impression steps, including packing cord, waiting for hemostasis, and waiting for impression material to set.

3. Patients have reported that the dental experience associated with intraoral scanning is better than those associated with intraoral impressions. In addition, problems with gagging and unpleasant taste are eliminated.

The authors believe that, overall, the digital workflow presented above provides a more efficient process for dentists and laboratories and makes the patient experience more comfortable.

BellaTek Encode Impression System

The foundation for intraoral scanning/abutment design and milling is the BellaTek Encode Impression System with its unique characteristics. BellaTek Encode Healing Abutments have been manufactured with a combination of four codes machined into their occlusal and axial surfaces. The two-piece healing abutments must be seated correctly into the implant/abutment connection. In order to be successfully scanned, the occlusal codes on the healing abutments must be supragingival. The occlusal codes enable a computer software program to recognize the specific three-dimensional location of the implant hex position, implant orientation, implant restorative platform diameter, emergence profile diameter, and height of the healing abutment. The scan also identifies the location of the peri-implant soft-tissue margins. With one of three validated chairside intraoral scanners ((CEREC® Omnicam (Sirona Dental, Charlotte, NC), Itero® (Align Technology, Inc., San Jose, CA), 3M™ True Definition Scanner (3M ESPE, St. Paul, MN)) and a process called reverse engineering, the three-dimensional positions of implants can be determined. Once established, the design and manufacturing processes follow.

Several implant companies and commercial dental laboratories have recently introduced intraoral scan bodies that may be scanned to procure digital implant-level impressions. The BellaTek Encode Impression System differs from these in several significant ways:

1. With intraoral scan bodies, healing abutments must be removed from the implants and replaced with the scan bodies. The correct scan body must be chosen (necessitating a large component inventory), and then radiographs are required to confirm that the scan bodies are seated optimally. With the BellaTek Encode Impression System, BellaTek Encode Healing Abutments are uniquely designed with proprietary features that provide a combination of traditional healing abutments and intraoral scan bodies. No removal of the healing abutments is necessary. There also is no need for an additional radiograph, as the restorative dentist can
use the postoperative radiograph typically taken by
the surgeon prior to discharge of the patient from
the surgical office. This greatly simplifies the intraoral
scanning portion of the procedure.
2. BellaTek Encode Healing Abutments are part of a
closed architecture system, meaning that the process of
intraoral scanning, abutment design, and manufacturing
is seamless. This also provides clinicians the opportunity
to use company-specific components, achieve an ideal
preload seal, minimize microgaps between implant
components, and obtain optimal screw-joint stability.
3. BellaTek Encode Healing Abutments are versatile. They
may be used to obtain implant-level impressions with
conventional implant techniques, while avoiding the
need to remove the healing abutment. A cast can be
poured from an impression of the healing abutments;
the resulting gypsum die can then be scanned. With this
same digital technology, a conventional implant analog
can be accurately placed into the gypsum cast with
robotic technology. The design and milling process can
be accomplished as described above.

Digital Versus Conventional Impressions
Digital implant-level impressions currently are indicated
for either single-tooth implant restorations or short-
span fixed partial dentures. Currently, digital implant-
level impressions are contraindicated for full-arch implant
prostheses or complex screw-retained prostheses. Digital
implant-level impressions have proven to be ideal for
quadrant dentistry; it is the authors’ conjecture that
this will eventually evolve to full-arch applications. The
limitation to this change is not in the scanning process
but rather challenges associated with the accuracy of
3D implant modeling. In a well-designed laboratory
study that compared the accuracy of digital impressions
made with BellaTek Encode Healing Abutments and scan
bodies, the researchers concluded that:
1. None of the three tested intraoral scanners were more
accurate than the others.
2. BellaTek Encode Healing Abutments and the scan bodies
yielded impressions that were equivalent in terms of
overall accuracy.
3. Digital intraoral scans may be used for fabricating accurate,
short span, screw-retained implant fixed dental prostheses.

Partial Digitization for CAD/CAM BellaTek Abutments
and Cement-Retained Crowns
The original protocol and workflow includes the
following steps:
1. Chairside intraoral scans of BellaTek Encode Healing
Abutments produce scan data. Depending on the
type of chairside scanner, these data are converted to
surface tessellation language (STL) files. STL files are
composed of raw unstructured triangular surface data,
the information required for 3D modeling or printing.
An STL file is an open-architecture universal file type and
a critical element of the CAD/CAM process. STL files are
imported into a lab-based 3Shape® scanner, and this data
can then be used by abutment-design software.
2. Once the abutment design is complete (it may or may
not need approval from the clinician), this digitized
information is transferred to a 3D model manufacturer
such as Align Technology, Inc. (San Jose, CA) for milled
models or InTech Industries (Ramsey, MN) for SLA
models. A 3D cast is either printed or milled. It is
important to note that this 3D working cast represents
an analog of the abutment and not an analog of the
implant. At the same time, with the same digitized
information, the definitive abutment is milled from
titanium blanks at the BellaTek Production Center.
Both the implant abutment and the working cast are forwarded to the commercial dental laboratory for fabrication of the crown restoration.

**BellaTek Abutments Offer the Following Advantages:**
1. A predictable level of reproducible precision fit. Multiple references in the literature have concluded that CAD/CAM abutments yielded higher degrees of precision between abutments and implants, with small microgaps, as compared to a conventional implant impression/cast protocol.\(^{15-19}\)
2. Decreased costs/improved efficiencies. Clinicians and dental laboratories eliminate the need to purchase implant restorative components associated with impressions, casts, castings, and feldspathic porcelain. Labor costs associated with the above procedures are also greatly reduced or eliminated, as is the cost for alloy.\(^{20}\)
3. Contemporary implant designs may require a higher degree of customization. Custom abutment designs may be associated with more physiologic implant restorative designs by varying abutment margin heights for ease of cement removal after crown cementation.\(^ {21-25}\)

Custom abutment designs may aid in crestal bone preservation especially when coupled with platform switching.\(^ {21-25}\)

The prevalence of peri-implant mucositis and peri-implantitis have been shown to be increasing; these pathologies have been associated with retained dental luting agents. Ideal margin location is critical for ease of cement removal and can be obtained with proper designs.\(^ {26-28}\)

From a restorative point of view, platform switching has the potential to increase the difficulties associated with the fabrication process, since the abutment restorative platforms are narrower in diameter than the implant restorative platforms, necessitating a higher degree of abutment customization.

Custom CAD/CAM abutments also allow clinicians and dental laboratory technicians to manage embrasure spaces relative to using stock, non-custom abutments.\(^ {29}\)

Loss of interproximal contacts adjacent to implants have been reported as a potential implant restorative/biologic complication. Customized, optimal abutment design is important for developing optimal retention and resistance form. Optimal taper can also offer clinicians the potential to utilize provisional or temporary luting agents for cement-retained crowns so that implant restorations may be removed and modified to close open interproximal contacts if they develop, depending on the choice of restorative materials.\(^ {30-33}\)

**Potential Disadvantages of BellaTek Abutments:**
1. Lab designer learning curve. It takes time and experience for dental designers to learn and understand the virtual design process. There are multiple challenges associated with implant restorative dentistry; one of the more challenging is the design of anatomic abutments that must, by definition, differ from the circular shapes of stock healing abutments.

Clinicians and dental laboratory technicians should be aware that third-party implant restorative components cannot be milled as accurately as the original manufacturer’s products. Third-party components also typically void the warranty of implant manufacturers. No studies have evaluated the long-term prosthetic aftercare considerations such as screw loosening when using third party abutments and screws.
The authors of this article have come to the realization that restorations fabricated from digital intraoral scans are considerably more time-efficient than similar restorations made with conventional impression protocols. Clinical outcomes for both processes appear to be similar. However, the first author has noted a series of distortions or inaccuracies with the 3D modeling process. Clinically, small discrepancies have been noted regarding crowns made with this type of three-dimensional models. The dies made from the 3D modeling process were slightly smaller than the custom BellaTek Abutments fabricated from the same digitized data. Other potential 3D model inaccuracies to consider include shrinkage of the resin used in the SLA process, milling errors, margin identification, and die trimming issues. Model fabrication has been recommended for iTero and True Definition scans but not for scans with Omnicam.3

**Complete Digitization and the BellaTek Encode Impression System**

Is a 3D working model absolutely necessary for implant restorations, especially in light of the numerous benefits associated with CAD/CAM materials i.e., IPS e.max® CAD, (Ivoclar Vivadent, Inc., Amherst, NY) or full zirconia34 including durability and increased fracture resistance? Benefits of fabricating implant abutments and restorations without casts or models include:

- Fewer remakes may be necessary.35
- Profitability is likely to increase.
- Fewer harmful environmental impacts should result.

**For Clinicians**

- Decreased chairtime.
- Turn-around time for fabrication of abutments and restorations decreases. 3D working models are not needed for this fabrication process but can be used to maintain control by approving crown designs on working casts (shape of crown, contacts).
- Pouring casts, trimming dies, and articulator mountings are eliminated.
- Costs decrease due to elimination of material costs associated with impressions, casts, and articulators.

Limitations of a complete digital approach include that abutments cannot be modified after crowns have been fabricated. This may be considerably more challenging with highly anatomic abutments where CAD/CAM custom abutments may impinge on the peri-implant soft-tissue dimensions associated with circular healing abutments. Also, with monolithic CAD/CAM materials, it is extremely difficult or impossible to modify milled components with additive changes (adding to the occlusion or interproximal contacts; shades may be changed with the use of surface staining). Due to the monolithic nature of milled ceramic materials, these restorations are generally not prescribed for challenging cases in the anterior aesthetic zones. In such cases, clinicians may still use digital impressions, but 3D working casts will be needed for conventional ceramic applications.

Because of the learning curve and small margin for error associated with a complete digital approach, the authors propose a new type of digital communication between designers, dental laboratory technicians, and dentists.
Physical or analog models have been eliminated, however working casts will still be used, but they are digital. Designers, laboratory technicians, and dentists need to understand how to utilize, read, and modify restorations in the digital world. This proposed fully digital workflow requires the highest level of understanding and integration of technologies. Dental laboratories and clinicians should not initiate this process until the processes and materials have been validated with laboratory and clinical studies.

After evaluating the fully digital approach and comparing it to the original digital protocol, the first author has found that this method is not only more cost-effective, but also results in the easiest and fastest seating times for abutments and crowns. The assumption of decreasing the number of “touches in and out” of the digital world and eliminating physical models has proven to be favorable. However, it should not be applied to every patient and all laboratories as a universal technique.

The results of a private laboratory report on the type of digital work flow that has been described in this article was recently presented at the European Academy of Osseointegration (September 2014). Prestipino and Fischer reported on 1007 restorations that were fabricated for 1114 implants in 839 patients. The results included 564 restorations fabricated from impressions of BellaTek Encode Healing Abutments, 132 restorations digital intraoral scans of BellaTek Encode Healing Abutments and 311 restorations fabricated from conventional implant-level impressions. The authors reported that all three impression techniques produced similarly high rates of clinically acceptable restorations, with minimal adjustments. Prestipino and Fischer reinforced the principles expressed in this article that the intraoral scanning process offered dental laboratory owners a protocol that was considered to be the preferred restorative protocol for single-unit implant restorations.

**Recommended Clinical Workflow for the Fully Digital Option**

1. Select the proposed shade and assess all of the subtleties of tooth color for the intended restoration. Determine if customized feldspathic ceramics will be needed. If this is the case, clinicians may still proceed with intraoral scanning but will need a 3D model for manual application of ceramics.

2. Select the material for the crown restoration (monolithic...
zirconia or e.max press or other CAD options).

3. Determine the abutment material—titanium or titanium gold-nitride-coated. The major benefit of ordering titanium gold-nitride-coated abutments is in the aesthetic zone, where the gold color tends to decrease the gray color of metallic components as viewed through thin peri-implant soft tissues.36

4. Evaluate/approve the abutment designs according to principles associated with optimal crown preparations regarding axial taper, interocclusal clearances, and margin location/type.4 Have the abutment milled at Biomet 3i.

5. Evaluate/approve the crown design according to the principles of fixed prosthodontics and implant restorative dentistry regarding contours, occlusal/interproximal contacts, and materials/shades as needed.4

6. After milling the abutment, Biomet 3i will send the abutment to the designated commercial dental laboratory. The dental laboratory will fabricate the crown. Biomet 3i is a milling center for abutments, bars and frameworks; it is not a commercial dental laboratory.

Careful case selection is important, and clinicians should be aware of the following considerations:
• Posterior restorations are generally considered to be relatively simple to design, fabricate, and use clinically. Aesthetics are generally not paramount; peri-implant soft-tissue changes will generally be minimal and more easily tolerated by patients as they adapt to definitive anatomic abutments instead of circular healing abutments.
• Achieving aesthetically pleasing anterior restorations will likely be more challenging and difficult. Scalloped soft-tissue contours generated by custom provisional crowns can be managed by replacing the provisional restoration with a BellaTek Encode Healing Abutment and then immediately scanning it and the surrounding tissue.

Restorative dentists, surgeons, laboratory technicians, and dental designers should optimize communications and quality control with electronic checkpoints.

Alternative Treatment Options for Fully Digital Approaches to Implant Restorative Dentistry
Screw-retained options for single implant restorations are generally indicated where there is minimal inter-arch space (5 mm or less).37 Biomet 3i recently introduced specific titanium bases (FlexLink™ TiBase Abutments®) designed to provide a metal connection between implants and ceramic/zirconia abutments. The inserts are available in multiple heights to fit differing clinical situations. Screw-
retained implant crowns have proven to be useful, easy to use, and eliminate the need to remove cement.\textsuperscript{38}

The following clinical cases illustrate fabrication of custom CAD/CAM abutments and crowns. The first utilizes a stereolithographic model. The second uses only digital technology for fabrication of the abutment and crown.

Case Presentation 1 (Figs. 1-12 Pages 8-9)
The patient is a 73-year-old male who presented reporting pain in the mandibular left quadrant. Clinical and radiographic examination revealed that the left mandibular second molar, which was the distal abutment for a three-unit fixed partial denture (FPD), had a purulent perio-endodontic lesion (Fig. 1). The tooth was considered to be non-restorable. A treatment plan was developed and included sectioning the FPD between the retainer on the left mandibular second premolar extracting the second molar, followed by immediate bone grafting of the extraction socket to preserve ridge volume. Implants would be placed after the site healed in the first and second molar positions.

Three months later, two 5 mm diameter by 10 mm long Certain\textsuperscript{R} Tapered Implants (Biomet 3i) were placed in the mandibular left first and second molar positions. BellaTek Encode Healing Abutments (4 mm platform, 5 mm taper, 3 mm height) were attached to the implants (Fig. 2).

After three months of healing (Fig. 3), a digital scan of the two BellaTek Encode Healing Abutments was obtained with a chairside digital scanner (Fig. 4). Using the scan data, custom abutments were designed at the BellaTek Production Center (Biomet 3i, Palm Beach Gardens, Florida, USA) (Fig. 5). The design files were then transmitted to milling machines for fabrication of BellaTek Abutments with titanium gold-nitride coatings (Fig. 6) and simultaneously, to a rapid prototyping facility in Minnesota where analogs of the abutments were fabricated stereolithographically. Die spacers were applied to dies of the abutments (Fig. 7). This creates approximately 50 microns of added thickness to the dies to accommodate the cement used to secure the crowns to the abutments clinically, and also to correct for discrepancies between the titanium abutment dimensions and the smaller dimensions of the prototype abutments.

Two single porcelain-fused-to-metal (PFM) crowns were
fabricated on the three-dimensional stereolithographic model and then tried-in on the actual abutments in the commercial dental laboratory after they were received from Biomet 3i (Fig. 8). The abutments, crowns, and 3D model were then sent to the restorative dentist. The BellaTek Encode Healing Abutments were removed from the implants for the first time since the implant-placement surgery (Fig. 9), and the definitive abutments were seated (Fig. 10). The cement-retained PFM definitive crowns were tried in, adjusted, polished, and cemented to the abutments (Fig. 11). A periapical radiograph confirmed that the abutments were seated on the implants and the crowns fit the abutments (Fig. 12).

**Case Presentation 2** (Figs. 13-24, Pages 10-11)

This patient is a 68-year-old male who presented with pain around his right maxillary second molar. Clinical and radiographic examination resulted in a diagnosis of pulpal necrosis due to dental caries (Fig. 13). A treatment plan was developed that called for flapless extraction of the non-restorable molar. Initially the patient declined to replace the tooth. After extraction, the entire buccal plate remained intact.

Approximately eight months later, the patient returned, having changed his mind; he wanted to pursue some type of tooth replacement. A treatment plan was developed that included a trans-crestal sinus augmentation at the edentulous site using a xenograft (Endobon® Xenograft Granules, Biomet 3i), along with simultaneous placement of a 5/6 mm by 10 mm Certain PREVAIL® Tapered Implant. Implant placement was to follow a two-stage protocol because of the minimal amount of residual bone.

The implant was allowed to osseointegrate undisturbed for six months. Stage II surgery was then performed and a 5 mm wide x 4 mm high BellaTek Encode Healing Abutment with a 6 mm flare was placed (Fig. 14). Four weeks later, the site was digitally scanned chairside using a LAVA™ Chairside Oral Scanner C.O.S. (3M ESPE, St. Paul, MN) intraoral scanner (Figs. 15 and 16). The scan data were sent to the commercial dental laboratory and imported into 3Shape software that enabled importation of third-party impression scan data. The abutment was designed within the software (Fig. 17). Once the abutment design was approved, a virtual crown was then designed on the virtual abutment.

The abutment design was sent electronically to Biomet 3i where a BellaTek Titanium Abutment
(Fig. 18) was milled. Concurrently, a monolithic zirconia crown (Fig. 19) was milled at the dental laboratory using the data that corresponded to the virtual abutment dimensions. Because proper virtual spacing was incorporated into the design of both, the crown fit the abutment (Fig. 20) when both were received at the restorative dentist’s office.

At the next restorative appointment, the BellaTek Encode Healing Abutment was removed (Fig 21), and the definitive abutment was seated and secured with a GoldTite® Abutment Screw tightened to 20 Ncm (Fig. 22). (Note the precise location of the abutment margins relative to the gingival margins). Cement removal was easily facilitated because the abutment margins were designed to be at or just below the peri-implant soft-tissue margins.

The definitive crown was then cemented in position (Figs. 23 and 24). Due to the accuracy of the fully digital process, the entire amount of chairtime from removal of the healing abutment to insertion of the definitive abutment and crown was only a few minutes.

Clinical Relevance

Preliminary evidence has demonstrated the efficacy of technologies regarding digital intraoral scanning and CAD/CAM abutments. At this time, intraoral scanning with the BellaTek Encode Impression System for implant-level impressions represents a new, improved, and validated concept for certain applications in implant restorative dentistry. At present, this new process should be considered as a technique that supplements conventional implant restorative procedures. The authors believe that this new process will eventually replace existing conventional restorative options. Digital scans will become an essential part of CAD/CAM techniques and the first point of access or entry into the digital world of implant restorative dentistry.

The complete digital approach is ideal for single-tooth replacements or short-span fixed partial dentures but requires careful case selection. Ideal implant 3D positioning will avoid the need to fabricate highly anatomic abutments with anatomies significantly different from circular healing abutments. Clinicians should proceed with caution in areas with anatomies significantly different from circular healing abutments. Clinicians should proceed with caution in areas with anatomies significantly different from circular healing abutments.

To date, the complete digital approach (with elimination of 3D physical casts) represents an accurate and cost-effective clinical modality. In the future, continued change should be expected, including the increased likelihood of additive procedures regarding ceramic restorations.

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In support of their research or for preparation of their work, one or more of the authors of the publications cited in the references may have received financial remuneration from Biomet 3i LLC.
Why Was This Research Done?
Different intraoral scanners use different technologies for data acquisition and processing. This study was conducted to assess the accuracy of digital intraoral scanners (IOS) for fabrication of computer-aided designed and manufactured (CAD/CAM) implant-supported prostheses.

How Was It Done?
A stereolithographic replica of a human mandible with edentulous posterior segments was fabricated. Four Full OSSEOTITE® Certain Implants (Biomet 3i, Palm Beach Gardens, FL, USA) were placed in the posterior segments, two on each side. The implants on one side were vertical and parallel to each other; the implants on the other side diverged by 30°.

Two different types of scannable abutments were sequentially connected to the four implants: BellaTek Encode Healing Abutments (Biomet 3i) and Zirkonzahn scan markers (Zirkonzahn. Modellier, Gais, Italy). A series of scans were then taken. First the model was scanned (once for each set of abutments) using a high-definition laboratory scanner (Sirona in EosX5, Salzburg, Austria). This was considered to be the baseline scan. Three types of intraoral scanners were then used to obtain three sets of scans of each of the two abutment sets (18 scans total). The intraoral scanners tested were the 3M™ True Definition Scanner (3M ESPE, St. Paul, MN), the iTero (Align Technologies, San Jose, CA), and 3Shape Trios (3Shape Dental, Copenhagen, Denmark).

The data obtained with the laboratory scanner was imported into 3Shape Design software; it was used to design the control and test bars. Similar bars were designed using the data obtained from the intraoral scanners. A total of 36 test CAD bars were compared with four control bars. 3D evaluation software (Geomagic DesignX™ 2013, Morrisville, USA) was then used to assess the fit of the bars to the abutments. Virtual one-screw tests were performed to assess the fit of the bars to the implant restorative platforms. The planar angle difference was also measured; the final volume measurement was derived from the gap height and angular differences.

The calculated differences were analyzed using a repeated-measures multifactorial ANOVA and Tukey-test, with an alpha level equal to 0.05 and a non-directional alpha risk of 0.05. Post-hoc comparisons were done showing all the possible combinations of the variable types. Four actual CAD bars were milled through the CAM process and compared to the digital analysis.

What Were the Results?
Misfit of the CAD/CAM bars fabricated from the intraoral scans ranged from 12.40 to 90.20 microns, all of which were in the clinically acceptable range. None of the three intraoral scanners tested was significantly more accurate than the others (p=0.0781). No significant differences in the accuracy of the two scannable abutments (BellaTek Encode and Zirkonzahn) were noted either (p=0.5363). Neither the parallel nor the angled implants allowed for more accurate scans (p=0.3173). The actual bars milled from the CAD files showed a similar degree of misfit to the virtual data.

Clinical Relevance
The study suggests that digital intraoral scans (impressions) and scannable abutments can be used for fabricating accurate short-span screw-retained implant-supported fixed dental prostheses.
Clinical efficacy of the BellaTek Encode Impression System: A prospective laboratory study of three impression techniques

Prestipino T,1† Fischer K.2† Clinical efficacy of the BellaTek Encode impression system – a case-control study of three impression techniques. Poster session presented at the 23rd annual scientific meeting of the European Association for Osseointegration; 2014 Sep 15-17; Rome, Italy.

Why Was This Research Done?
Fabrication of master casts with implant analogs using conventional impression copings can be a cumbersome process, as it requires multiple component swaps, during which errors can accumulate. The BellaTek Encode Impression System simplifies the process of identifying implant restorative platform information required for designing and fabricating patient-specific definitive abutments. The objective was to compare the success rates of patient-specific abutments and restorations fabricated using the BellaTek Encode Impression System (both traditional impression- and intraoral scan-based) with those fabricated from conventional implant-level impressions.

How Was It Done?
A commercial dental laboratory in Virginia collected information from cases submitted between June 2012 and December 2013. Three techniques were used to register the positions of implants placed in partially edentulous patients to support implant restorations. Test-A implant restorations were made from casts developed from conventional impressions of BellaTek Encode Healing Abutments (Biomet 3i, Palm Beach Gardens, FL, USA). Test-B implant restorations were fabricated from intraoral scans of BellaTek Encode Healing Abutments. Unique codes on the surfaces of these abutments identify the abutment emergence profile, implant/abutment connection, and implant platform positions needed to design and mill patient-specific abutments. Control group restorations were fabricated from conventional implant-level impression copings and master casts. All fabrication steps were carried out in the dental laboratory with conventional components and materials. Upon delivery, the abutments, crowns, and fixed prostheses were checked for occlusion, marginal fit, and contacts (occlusal and interproximal). Restorations were deemed clinically acceptable if they were not returned to the laboratory for adjustment and/or remake.

What Were the Results?
Eight-hundred thirty-nine patients received 1,007 restorations supported by 1,114 implants. The Test-A group included 564 restorations, 132 were in the Test-B group, and 311 were in the control group. A total of 41 restorations required correction in the laboratory. A restoration could receive more than one type of adjustment. Interproximal adjustments were the most common modification (23), followed by occlusal adjustments (10). Frameworks did not fit properly in five cases, and margin adjustments were required for three cases. In one case, incorrect components were used. No significant difference could be detected among the groups. The control and two test groups showed comparably high clinical acceptability (Test-A 95.6%, Test-B 97.0%, control 96.1%; p > 0.05).

Clinical Relevance
All three impression techniques produced similarly high rates of clinically acceptable restorations and thus required only minimal adjustments. Within the limitations of this prospective laboratory study, the BellaTek Encode Impression System required fewer components and process steps and therefore simplified the process of obtaining the information required to design and fabricate patient-specific definitive abutments. Using these specific coded healing abutments for implant-level impressions eliminated the need for multiple intraoral component swaps, which reduced errors associated with implant-level impressions and master casts. Reducing component swaps has been shown to preserve peri-implant soft tissues and crestal bone levels better than conventional impression protocols.
Education Through Innovation.

The Institute for Implant and Reconstructive Dentistry (IIRD®) located in Palm Beach Gardens, Florida is the global training and education department of Biomet 3i. Based on the principles developed by Dr. Richard Lazzara,† the IIRD seeks to apply evidence-based research, advanced techniques, and practical methods into educational content that allows clinicians to develop meaningful clinical expertise.

The IIRD delivers a world of innovation to help clinicians progressively grow their knowledge and capabilities in all areas of their practice. In addition to learning about the latest technologies and techniques from the world-class faculty, the IIRD provides educational programs on topics from identifying candidates for implant and reconstructive therapy, to treatment planning and team development.

Programs and educational information can be found at: www.iird.com.