Streamlining orthodontic and restorative care with digital scanning technology

A Peer-Reviewed Publication Written by Dr. Perry Jones

Abstract
Optical/digital scanning technology now replaces conventional VPS impression taking. The tooth movement technology of Invisalign can now be used with digital data derived from the iTero scanning device, improving accuracy, patient communication, streamlining work flow and reducing aligner delivery time. This article will review the development of the iTero technology, describe the iTero unit, and outline the differences in current scanning technologies. New iTero v4.05 enhancements are described in this article. The benefits of the iTero scanning device are detailed for both patient and practitioner. As highly accurate iTero polyurethane plastic models may be used to eliminate the stone medium, the article details many practical uses for these models, for example, as a matrix for the use of various thermoplastic materials. Model and modeless restorative solutions as well as the use of STL files will be discussed.

Learning Objectives:
The overall objective of this article is to provide information on the iTero optical/digital scanning device. Its development, physical features, scanning technology differences, model/ modeless restorative solutions, use of STL files, and iTero v4.05 software features/tools. After reading this article the reader should be able to:
1. Briefly describe the development of the iTero optical/digital scanning device.
2. Describe the physical features of the iTero scanner.
3. Discuss the difference in scan technology.
4. Describe the uses of polyurethane models.
5. Describe the features of model and modeless restorative solutions.
6. Discuss the use of iTero STL files.

Author Profile
Dr. Perry E. Jones is the Director of Continuing Education and Faculty Development at Virginia Commonwealth University, School of Dentistry where he is also Adjunct Faculty, Department of Oral and Maxillofacial Surgery. He is a Fellow of the Academy of General Dentistry and Director of the Virginia VCU/AGD MasterTrack program. He has been a member of the Align Technology Speaker TEAM since 2002 presenting more than 250 Invisalign presentations. Dr Jones has been involved with Cadent/iTero optical scanning technology since its first release and was a beta tester for the iTero v4.05 software. Dr Jones belongs to numerous dental organizations and maintains a private practice in Richmond, VA.

Author Disclosure
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Abstract
Optical/digital scanning technology now replaces conventional VPS impression taking. The tooth movement technology of Invisalign can now be used with digital data derived from the iTero scanning device, improving accuracy, patient communication, streamlining workflow and reducing aligner delivery time. This article will review the development of the iTero technology, describe the iTero unit, and outline the differences in current scanning technologies. New iTero v4.05 enhancements and software are described in this article. The benefits of the iTero scanning device are detailed for both patient and practitioner. As highly accurate iTero polyurethane plastic models may be used to eliminate the stone medium, the article details many practical uses for these models, for example, as a matrix for the use of various thermoplastic materials. Model and modeless restorative solutions as well as the use of STL files will be discussed.

Introduction
Align Technology has delivered significant technological advances to the field of tooth movement as evidenced by the Invisalign clear aligner products. Recently released innovations termed G3 and G4 deliver Invisalign providers sophisticated movement systems derived from laboratory testing. The FMA or Force Measurement Apparatus helps Align’s R&D engineers, develop and test planned movements, to produce more predictable attachments and clinical movements. These solutions have produced tremendous benefits to patients and practices, both in terms of clinical application and profitability.

Until recently, achieving highly accurate impressions for optimizing aligner benefits has been challenging. Various impression materials have their drawbacks, and process inconsistencies have often led to additional appointments and adjustments. The “impression” experience was often unpleasant for both patient and doctor.

Today, digital impressions, such as those delivered by the iTero scanner, are providing practices with superior accuracy, cost savings, patient satisfaction, restorative solutions, implant solutions and orthodontic solutions as well as supporting multiple practical uses of polyurethane models.

New software enhancements offer users the ability to scan full arches for Invisalign submission. Submission time is dramatically reduced with ClinCheck treatment plans posted in 2-3 days. Features such as an eraser tool and missed data highlight outline tool, further aid users in the efficient capture of full arch scans.

Development of the digital scanning device
Simultaneous with the advances in development of CAD/CAM technology, development of an optical scanning device dates back several decades. Although industry has used many different computer aided design and computer aided manufacturing (CAD/CAM) systems, there has been only one system available to the dental practitioner for taking direct intraoral digital impressions for several past decades. The CEREC system was developed as a one visit in-office scanning and milling system to produce ceramic restorations from prefabricated ceramic “blocks”. The much different Cadent system developed an in–office intraoral optical scanning unit that used digital data sent via the internet to a centralized milling center, or a specific dental laboratory. As the concept of digital impression taking has become more popular, other systems such as E4D, Denysys 3D, Lava C.O.S. and TRIOS have been developed with many others likely to soon reach the market place. This article is intended to give a descriptive review of the iTero scanning technology as well as give an overview of the features and benefits of the iTero system.

Development of the iTero scanning system
Cadent history dates back to the 1995-1999 period when formation and early development began in Israel by veterans of Technomatrix (NASDAQ: TCNO). The first commercial product was released in 2001 with a successful digitized scanning system, termed OrthoCAD. This device allowed conventional stone models to be scanned to produce 3-D computer images. The scanned data could then be used to archive model information, create virtual tooth set-ups, as well as fabrication of urethane models and orthodontic bracket placement applications. This unit is now termed the iOC unit (Figure 1), and it is marketed primarily to the Orthodontic community.

Development continued with introduction of iTero (Figure 2) intra-oral scanning as outlined in (Figure 3). To
summarize Cadent development: In 2006 Cadent launched the iTero Digital Impression System with quadrant scans. Cadent improved the iTero system in 2007 to include measurement tools as well as a hardware upgrade to a quad processor for enhanced capture speeds.

Full arch scanning was added in 2008. Additional upgrades included an enhanced video view window, improvements with a rapid scan technique, and milled reference models were made available for patients without restorative preparations. In 2009, the iTero user interface was upgraded to Windows XP, new software upgrades improved the display of the 3D image, enhanced algorithms for the occlusal clearance map and improved view control tools were added. The iOC powered by iTero orthodontic scanner and software applications was launched in 2010. In conjunction with Whipmix, iTero released a mounting system for Denar articulators (and now Hanau articulators). In 2010, upgrades allowed modeless restorations to be produced in a 100% digital production workflow without a Cadent milled model. In 2011 Cadent partnered with implant companies and dental laboratories such as Glidewell Dental Laboratory, to develop fixture level implant...
scanning with dedicated scan bodies available for different implant systems. The current iTero v 4.05 software was released with full arch scan capability expanded to Invisalign.

**Description of the iTero digital scanning device**

The iTero device consists of a mobile cart measuring about 29 inches in height, 26 inches in width and 15 inches in depth (Figure 4). It is mounted on caster wheels to facilitate moving the unit between operatories. There is a hand held scanner wand attached to the cart via a cord to carry scan data to the unit. A battery is contained in the unit to allow an uninterrupted power supply such that the unit may be unplugged from the AC power source and moved to different locations. The iTero unit has a dedicated wireless router that will send a wireless signal to a modem device thus allowing internet connection capability. A wireless “mouse” and a sealed keyboard on the horizontal surface support data entry, allowing disinfection techniques to be used (Figure 5). Images are displayed on a 19 inch liquid crystal display (LCD) attached to the mobile iTero cart.

A wireless foot control/foot pedal may be used to enter data and navigate the system, allowing the operator to enter data remotely. This may free the operator’s hands to hold the scanner wand, bypassing the keyboard and/or wireless mouse, allowing a single operator to manage the unit.

A hand held scanning wand is used in the patient’s mouth to collect the scan data. The wand contains the laser light source, the focusing motor and analogue to digital converters. The wand is balanced with a “notch” for the operator’s hand at the optimal balance point (Figure 6). Inexpensive single use disposable sleeves, designed to fit over the end of the scanning wand, help prevent patient cross contamination (Figure 7). The scanner sleeve is very useful as a retraction aid for cheeks, tongue, and soft-tissue, as well as offering a method to steady the wand. The optics of the iTero wand, allows a useful feature of resting the “sleeve” directly on the patient’s teeth or soft-tissue (Figure 8).

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**Figure 4: iTero digital scanning unit**

**Figure 5: Sealed keyboard/ wireless mouse**

**Figure 6: Notch for hand at optimal balance point**

**Figure 7: Single use disposable sleeve**
Accuracy Optimizes Results and Efficiency

Accuracy is essential to optimizing clinical results and efficiency, yet producing an accurate replica of the teeth has been a huge challenge. Varying impression materials, including plaster, rubber base material, polyether, reversible hydrocolloid, irreversible hydrocolloid, and VPS (vinyl polysiloxane) material have unique properties and idiosyncrasies, which make it difficult for dentists to produce consistently outstanding results. For example, impression taking with VPS is prone to pulls and tears; bubbles and voids; distortion; tray to tooth contact; poor tray bond; de-lamination; sensitivity to temperature, technique, time and chemistry; varying shrinkage; stone model pouring; and die trimming discrepancies (Figures 9, 10).

The iTero scanning technology eliminates these issues. It does not require any powder, powder dusting or accent frosting, regardless of the type of scan or restoration desired. The full arch scanning and detailed coronal reproduction required for Invisalign submission mandate a high-quality scan with interproximal detail and accuracy. The iTero powder-free technology delivers highly accurate digital impressions of the interproximal areas and ensures arch width dimensional stability.

Accurate reproduction of the coronal portion of the teeth often requires retakes. Studies indicate that about 1/3 of dentists retake impressions three or more times per month, and on average, one-third of dentists reappoint patient impression taking at least once a month.26 Studies have shown iTero optical scanning dramatically reduces retakes.27

Technology Enables Flexibility

There are two different digital scanning technologies available to the dental scanning industry; parallel/confocal and triangulation sampling (Figure 11). The iTero’s scanner’s parallel/confocal scanning technology uses laser and optical scanning to digitally capture teeth, gingival surfaces and contours.

The operative principle used in the iTero scanner is called “parallel confocal”. A light source passes through a small filtering pinhole which focuses the light on the target object. The light then reflects off of the object and only the reflected light that is in focus passes back through the pinhole. Reflected light will be blocked if not in the confocal plane. Only reflected light that is in focus will return through the filtering mechanism. Better images are produced, as out of focus information is rejected and depth of field control is enhanced.

Figure 11: Triangulation sampling vs. Parallel confocal

Other scan systems (CEREC/ E4D)

- Angled cone of light
- Triangulation of light
- Requires powder dusting

iTero Technology

- 100,000 points laser light
- Out of focus light rejected
- No powder dusting
iTero captures 100,000 points of laser light in perfect focus at 300 focal depths in a 14 x 18 mm pattern, producing a 15mm scan depth. An analogue to digital converter in the wand, acts to convert the reflected light into digital data in about 1/3 of a second, with an accuracy of 15 microns. The confocal technology is a true optical scan, and does not require powder dusting.

In contrast, triangulation/sampling technology, as used in devices such as CEREC or E4D, require a powder coating and apply one angled cone of light to capture a single image at 15,000 microns. The term is based on applying the theory of “triangulation of light” such that 3 beams of light intersect to locate a point in space. One of the problems with this technology is that various surfaces disperse light differently and this may affect the accuracy of the scan. In order to reduce this effect, triangulation sampling technology uses a thin coating of an opaque power such as a titanium dioxide/zirconium oxide mix to provide a uniform light dispersion to enhance the accuracy of the scans.

Powderless scanning and 360-degree visualization capabilities enable iTero to operate with surface contact in the scanning technique for highly accurate digital impressions. Accompanying analytical tools enable dentists to measure and verify design of the preparation. The doctor can use the scanner for almost any procedure, select the desired restoration material, and send the scan to a lab of choice. The iTero 4.05 software seems to produce a noticeably better aligner fit. This observation was further supported by a 2011 study, which found that 7 times fewer fit issues occurred with scanning versus impressions.

Improved Patient Experience

Traditional impression taking techniques are unpleasant at best. Patients object to the taste, tray size, bulky material and common gag reflex. Digital scanning eliminates all of these objections. In addition, iTero scanning enhances patient communication because patients can see their dentition on the computer screen as a real-time 3-D representation. The 3-D images are “cleaned” (Figure 12) with extraneous soft-tissue (such as tongue and cheeks) removed in real time without the necessity to send the images electronically to technicians in Israel, as was done in the past with the Cadent process. iTero scans are posted on the Invisalign Doctor Site (Figure 13) in minutes and ClinCheck treatment plans are posted for doctor review in 2-3 days, creating a much reduced time line for Invisalign delivery, resulting in overall aligner delivery time cut by almost one half. iTero software significantly accelerates the ClinCheck treatment plan, which greatly improves patient acceptance and communication.

iTero v 4.05/ Restoration with models

Digital scanning with iTero provides an open platform for creating highly accurate polyurethane models, instead of stone models, that any dental laboratory can use to create any indirect restoration. Current advances in laboratory technology can also use scanned data with CAD/CAM systems to produce modelless milled ceramic restorations. The absence of stone modeling offers a further cost offset versus conventional lab costs.

iTero 4.05 software can support restorative solutions with or without modeling. In the case of modeling, extremely accurate polyurethane models are created with precise dies that fit securely into position (Figure 14) unlike conventional stone modeling with die “wobble” often created from repetitive use during restoration fabrication. A single model functions as both a working model and soft tissue model (Figure 15). The soft-tissue is maintained with the die preparation to allow more accurate and efficient laboratory fabrication of all types of restorations. Models can be mounted using a precise hinge articulator or mounted on a semi-fixed articulator with custom mounting plates to Denar, Hanau and Whipmix articulators (Figure 16).
iTero v4.05/Modeless restoration

The iTero 4.05 software supports construction of modeless restorations that are CAD designed in a virtual, modeless environment and CAM milled from materials such as zirconium. Dental laboratories such as Glidewell, support use of iTero optical scanning, virtual planning, restoration design, and custom milling to create single unit, multiple units as well as bridges in a 100% “modeless” workflow environment (Figure 17). The process is streamlined such that lab fees may be reduced (Glidewell) when restorations are created modeless.

iTero v4.05/Implant restoration

Similarly, implant solutions are supported by the iTero 4.05 software, as purpose made scan bodies may be used with the iTero optical scanner. Digital scanning has advanced implant practice integration as implant companies such as Straumann and 3i have proprietary scan bodies and systems. Dental laboratories such as Glidewell have developed an “open” system of dedicated scan bodies to be used with the iTero optical scanner and 4.05 iTero software. Different unique scan bodies are referenced with a library of virtual implant analogues that fit different implant systems (Figure 18, 19).
Uses of Full Arch Polyurethane models

Full arch scanning allows very precise polyurethane models to be created for a multitude of uses, especially for the GP practice. Uses include: models used to fabricate full arch (Figure 20) thermoplastic appliances, canine to canine (Figure 21) appliances used to aid finishing, occlusal equilibration, occlusal “settling” as well as retention. Models may be used to create “pontic” appliances (Figure 22) used in conjunction with implant solutions, as well as models used to create prosthetic surgical guides (Figure 23). Polyurethane models may be used to fabricate occlusal guards (Figure 24), bleaching trays (Figure 25), and mouth guards (Figure 26). Provisionals (Figure 27), provisional bridges (Figure 28) and even limited removable partial dentures (as tissue scanning may allow) summarize possible uses of iTero polyurethane models supported by the iTero 4.05 software. One of the most useful features of the polyurethane models is that they may be used multiple times, unlike stone models which are often useless after teeth break upon appliance removal. The iTero 4.05 software provides the practitioner with a wide variety of useful tools and features both for restorative solutions and orthodontic evaluation.
Merge of DICOM and STL files
Software development now enables merging of CBCT DICOM files with iTero STL files. Virtual “waxup” and planning may be done to create surgical guides with simultaneous consideration of hard tissue and optimal restoration location. Users may use various third party CAD/CAM services such as implant planning services and digital labs for restorative and orthodontic treatment services. Generic STL files, the CAD/CAM standard format, can now be exported directly from user’s “My Aligntech” accounts.

The iTero software now supports direct export of STL files. This has opened fields such as the merge of CBCT DICOM files and iTero files to create 3-D renderings that support software such as Cybermed/ In-2-Guide, that support virtual planning of prosthetic restoration and crown down planning of hard tissue consideration to allow processing of tooth and soft tissues supported surgical guides. (Figures 29, 30, 31) demonstrate a tooth supported surgical guide made with the merge of CBCT DICOM files and iTero STL files. The pictures are from this author’s patient and depict the intraoral view, software planning and intra-oral guide placement of the In-2-Guide for placement of two Nobel Replace Select fixtures.
Increasing Practice Efficiency

Practice productivity is increased with the new iTero v4.05 enhancements because records and submission times are accelerated. For restorative productivity, restoration time is reduced by approximately 50% due to the iTero scanning accuracy and predictability. The scanner itself may be viewed as cost effective. For example, if we assume $500 of hourly production, an average 15 minutes of chair time saving would compute as $125 savings per production hour. If we assume only one scan per day, and a conservative estimate of 120 production days per year, that computes to a $12,500 to $16,250 savings per year. Even with a conservative model, one can make the case that the technology costs are quickly offset with the projected time savings.

Conclusion

Digital scanning with the iTero system has greatly enhanced clinical accuracy, productivity, and flexibility for a wide variety of tooth movement/alignment and restorative procedures. Digital information can be used for Invisalign submission to create a significantly more efficient work flow. The iTero 4.05 software presents sophisticated software tools that can be used for detailed orthodontic analysis. The iTero 4.05 software helps improve patient communication. Precise polyurethane models offer a wide variety of uses especially in the general dentist practice. Digital scan impressions with the iTero 4.05 software offer real time on-screen visualization and a much improved patient experience with no impression mess. iTero 4.05 offers an open architecture software platform with the ability to use digital data to fabricate all types of restorations from single unit to multiple units. The iTero 4.05 powderless impressions provide digital data that supports the dental laboratory fabrication of any indirect restoration from provisionals, all metal (gold), porcelain fused to metal, porcelain full, partial veneer coverage to inlays/onlays of any type material. The iTero technology supports modeless restorations that are now routine offering improved accuracy, which results in time and cost savings. Implants may be scanned with dedicated scan bodies to create screw or cement retained model or modeless restorations. The merging of CBCT DICOM and iTero STL files offer virtual “waxup” and crown down planning to create precise tissue and tooth supported surgical guides. This article has attempted to present an overview of the features, uses and benefits of the iTero scanning technology. The future of scan technology and its benefits for the everyday practitioner are here today!

References

11. Priest G. Virtual-designed and computer-milled


Author Profile
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Questions

1. Cadent’s development of an optical scanning device began in ______ by Technomatrix veterans.
   a. United States
   b. Israel
   c. Iran
   d. Mexico

2. The original ______ scanning device allowed conventional stone models to be scanned.
   a. OrthoPED
   b. OrthoCAM
   c. OrthoCAD
   d. CAMtech

3. In 2011 Cadent full scan capability was expanded to ______ submissions.
   a. Invisalign
   b. Clear Correct
   c. Simpli 5
   d. Ortho Clear

4. The Cadent unit sits on __________ to allow the unit mobility.
   a. Fixed Legs
   b. Metal supports
   c. Caster wheels
   d. Adjustable rubber legs

5. A ______ is contained in the iTero unit to allow an uninterrupted power supply.
   a. Breaker switch
   b. Voltage meter
   c. Battery
   d. Power cord

6. A single operator may bypass the keyboard and mouse with a wireless __________.
   a. Foot control
   b. Modern
   c. Switch
   d. Camera

7. _________ placed on the wand end aid help prevent cross contamination.
   a. Plastic bags
   b. Glass covers
   c. Disposable sleeves
   d. Cloth inserts

8. The scanner sleeve may be used to directly rest on the patient’s _______ to steady the camera.
   a. Arm
   b. Face
   c. Hand
   d. Teeth

9. Impressions taken with VPS (vinyl polysiloxane) are prone to: _________
   a. Shrinkage
   b. Distortion
   c. De-lamination
   d. All of the above

10. The iTero scanner uses _________ digital scanning technology.
    a. Vertical infusion
    b. Triangulation sampling
    c. Parallel confocal
    d. Horizontal inversion

11. Only reflected light _________ is rejected by a filtering mechanism with parallel confocal.
    a. In focus
    b. Out of focus
    c. Between focus
    d. Spherical

12. _________ scan technology requires powder dusting.
    a. Parallel confocal
    b. Triangulation sampling
    c. Ellipsoid sampling
    d. Square focus

13. The theory of “triangulation of light” applies _________ beams of light to locate a point in space.
    a. 1
    b. 2
    c. 3
    d. 6

14. Patients object to _________ with traditional impression techniques.
    a. Taste
    b. Tray size
    c. Gag reflex
    d. All of the above

15. A single iTero polyurethane model can serve as both working model and ________ model.
    a. Soft tissue
    b. Refractory
    c. Inversion
    d. Porcelain

16. Custom plates allow semi-fixed articulators such as _________ to be used with iTero models.
    a. Hanau
    b. Denar
    c. Whipmix
    d. All of the above

17. Implant solutions are supported by iTero as dedicated _________ bodies may be scanned.
    a. Scan
    b. Porcelain
    c. Dies
    d. Titanium

18. iTero polyurethane models may be used to create _________.
    a. Thermoplastic appliances
    b. Prosthetic appliances
    c. Pontic appliances
    d. All of the above

19. Generic _________ iTero files may be exported directly from “My Aligntech” accounts.
    a. DICOM
    b. STL
    c. ADA
    d. AGD

20. Practice productivity is _________ with iTero 4.05 due to records and submission times being shortened.
    a. Increased
    b. Decreased

21. Digital scans with iTero v4.05 software offer benefits such as: _________.
    a. No impression mess
    b. Powder free scans
    c. Real-time on screen visualization
    d. All of the above

22. Merged CBCT DICOM and iTero STL files offer precise surgical guides for ________ placement.
    a. Implant
    b. Pin
    c. Post
    d. Impression
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