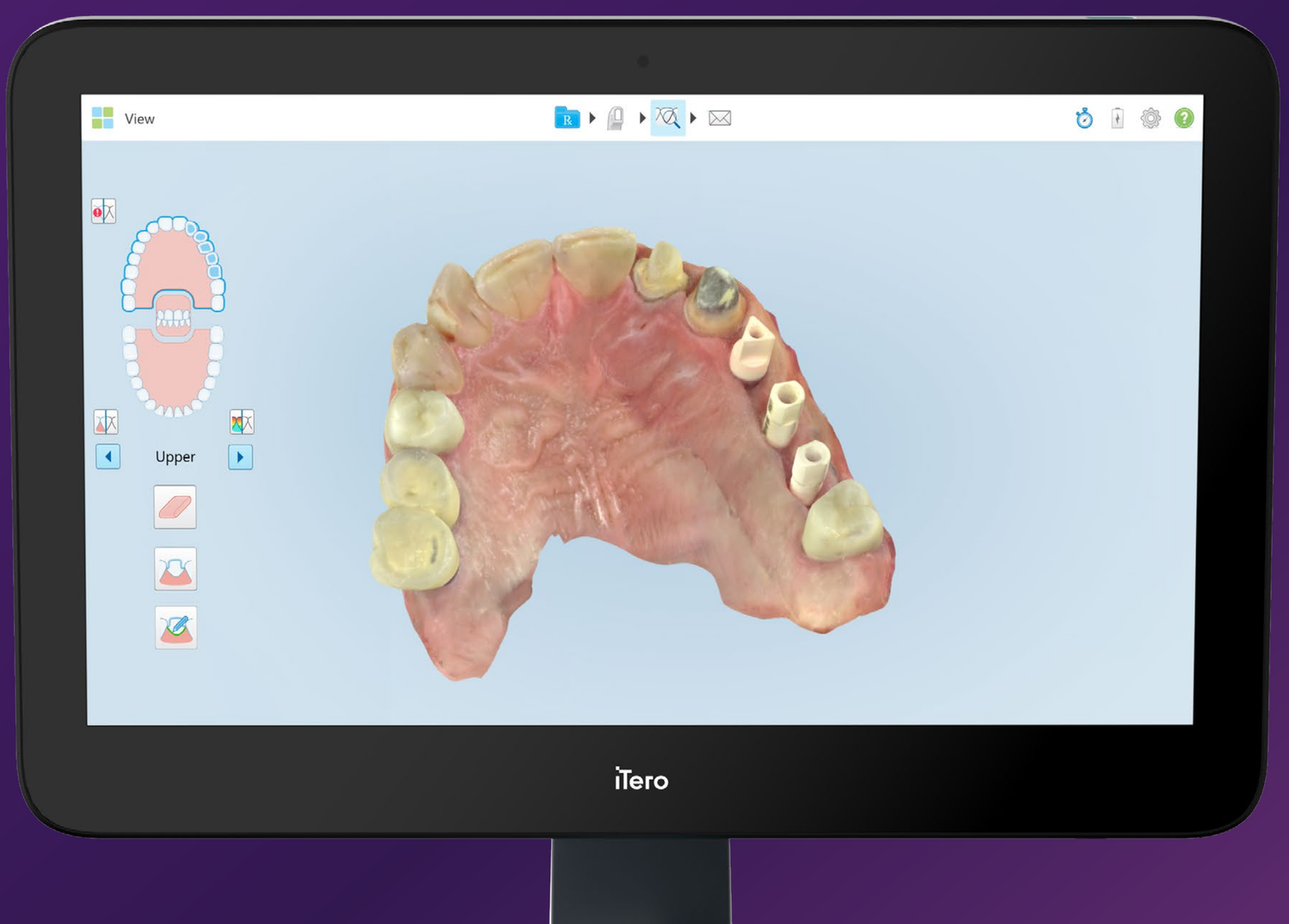
iTero™ Compendium

Simplifying the complex workflows

Restorative cases reports

iTero™ Publications

External Publications



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Contents

Click on the below to be redirected to the associated section

The iTero™ Compendium is an interactive PDF that provides you with the latest available information on iTero digital tools, treatment solutions, and scientific research all in one document. We believe, that it is the most efficient to use this document as a source, sharing a few selected pages at a time, rather than distributing it as a whole. You can find the detailed instructions on how to select and share specific pages on the last page.

Contents

Click on the below to be redirected to the associated section

Contents

Click on the below to be redirected to the associated section

Contents

Click on the below to be redirected to the associated section

Contents

Click on the below to be redirected to the associated section

List of external publications evaluating the iTero scanner

Simplifying the complex workflows

1. Chairside implant & crown
2. Full arch with implants
3. Denture
4. Veneers
5. 3D printing bite splint
6. Chairside efficiency with 3D printing

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Simplify complex restorative treatments with iTero scanners.

With an iTero intraoral scanner, you can capture patient data faster and more comfortably, enhance patient understanding and treatment acceptance, and send scans in seconds to coordinate seamlessly with labs through the iTero scanner's open system.

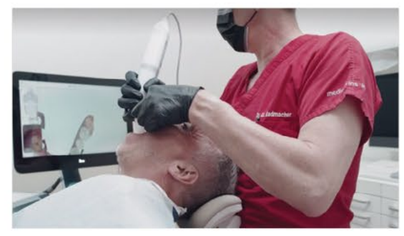
The iTero digital workflow **for a chairside implant and crown.***

01

The first appointment

Efficiently capture accurate digital imagery with the iTero scanner and build trust with your patient.

- Collect patient scans, photos, X-rays, and CBCT
- Initial exam scan with iTero NIRI technology and Occlusogram
- Use exocad CharsideCAD software to create and share smile design with patient

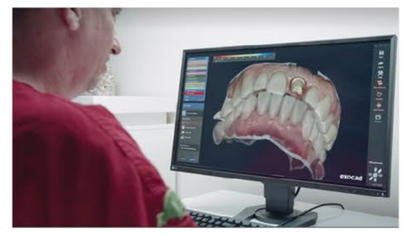


02

Restorative and implant planning

Plan the implant position and provisional crown using exoplan and exocad ChairsideCAD software, prepare provisional restoration, and fabricate provisional crown.

- Create restorative project on exocad CharsideCAD software
- Create implant planning on exoplan software
- Mill provisional restoration

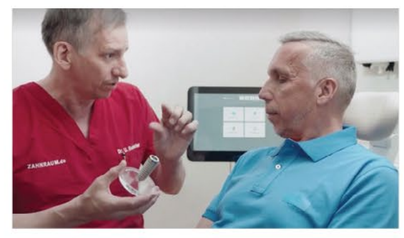


03

The second appointment

Remove the failing crown, extract the residual root, place the implant, and load the provisional crown.

- Implant placement
- Immediate loading with provisional crown



04 The third appointment

Gather records conveniently following iTero scanning protocol before milling and delivering the final restoration.

- Scanning
  1. Scan the arch with provisional crown in place
  2. Scan the opposing arch and bite
  3. Remove provisional crown to scan the surrounding soft tissue emergence profile
  4. Screw scan body onto implant and scan individually and within the arch
- Design of final restoration on exocad ChairsideCAD software
- Chairside milling
- Delivery of final restoration

One scanner. Countless treatments.

From implant and crown to dentures, iTero intraoral scanners can help you simplify complex treatments, work seamlessly with your lab, and increase patient satisfaction. Learn more at iTero.com.

Watch the full tutorial at:
www.youtube.com/watch?v=5VJlWHeXIeM

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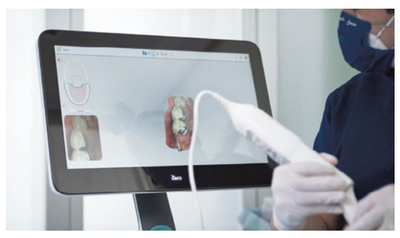
The iTero digital workflow for **full arch rehabilitation with implants.***

01

The initial consultation

Efficiently capture accurate digital imagery with the iTero scanner and build trust with your patient.

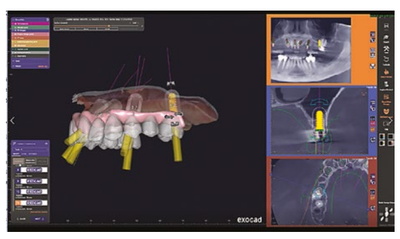


- Create an iRecord prescription to scan the initial failing dentition, opposing jaw, and occlusion.
- Collect scans, CBCT, X-rays, photographs, and videos for proper case analysis and diagnosis.
- Send your prescription and scans to your lab with iTero's seamless chairside and lab software connectivity.

02

The second appointment

Use your lab's digital guides for a successful surgery.

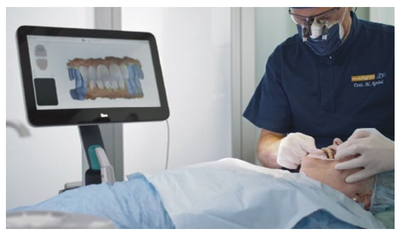


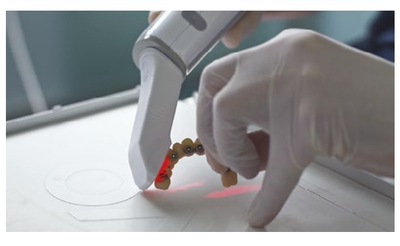
- Place implants in the optimal position using the surgical guide.
- After surgery, finalize provisional restoration for loading.
- Advise your patient on post-op instructions.
- Prepare for the third appointment in three months.

03

The third appointment

Quickly scan your patient and the provisional restoration with the iTero scanner to create a restorative prescription.





- Check for successful osseointegration & healthy soft tissues.
- Create restorative prescription and proceed with the following scanning protocol:

1. Scan treatment arch with provisional in place
2. Scan opposing jaw
3. Scan bite
4. Remove the provisional and screw the scan bodies
5. Scan the scan bodies and capture an HD scan of each scan body
6. Scan the provisional restoration outside the mouth

- Submit your prescription to your lab for the creation of a PMMA prototype try-in and metal bar.

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04 The fourth appointment

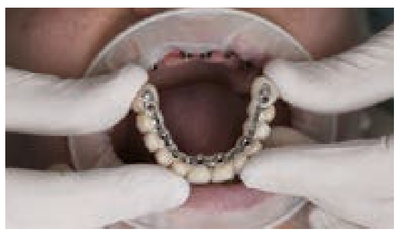
Have your patient test the try-in before arranging for the final restoration to be made.

- Your patient should test the try-in for proper occlusion, comfort, and appearance.
- Advise the lab on prototype modifications or give your lab approval for creation of the final restoration.
- Confirm passive fit of the metal bar on the implants.

05 The fifth appointment

Final check for restoration and delivery.

- Check for a proper fit of the final restoration.
- Screw the restoration onto the implants.
- Confirm a passive fit on implants.
- Treatment concludes and regular patient monitoring resumes.



One scanner. Countless treatments.

From a full arch rehabilitation with implants to veneers and dentures, iTero intraoral scanners can help you simplify complex treatments, work seamlessly with your lab, and increase patient satisfaction.
Learn more at iTero.com.

Watch the full complex workflow tutorial at:
www.youtube.com/watch?v=MvRZ62H-YII

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Edentulous treatment with iTero digital workflow

Create a new removable full arch prosthesis based on the pre-existing one

This workflow is suitable in the clinical context where the patient has a pre-existing full upper denture (or a full lower denture) which can serve as a base for the new denture. Please confirm that the occlusion and the vertical dimension are correct. In case of prosthesis wear, you can add direct composite material or wax to restore or correct the vertical dimension for an accurate jaw relation scan. In case of lack of prosthesis retention, you should first reline the denture with either an impression material or direct reliner before start of the scanning procedure.

Making adjustments with a bur or marking the pre-existing denture will give the lab more information on the desired new prosthesis design. Having the old denture adjusted, you are set to start this workflow.

1st Appointment iTero scanning

Create a new restorative Rx, fill out patient information and select the lab of choice.

1 Start by scanning the old relined and/or adjusted denture 360°.

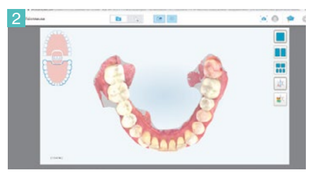
Note: Disable the A.I. Cleanup so that the soft tissue is not automatically trimmed by the software.

2 Scan the lower arch.

3 And finally, place the old denture back to the mouth and proceed to the bite scan.

4 Optionally, you can create a second new Rx and scan the edentulous upper jaw as well. This will provide more information to the lab in case the old denture intaglio is extremely deep and can't be properly scanned.

5 Add any further comments to the Rx notes and send the order to the lab.



Lab work Design of new denture

The lab will take all the information from the scans and your comments on the prescription to digitally design a new denture.

A denture try-in will be created for you.

2nd Appointment New denture try-in

Evaluate denture try-in for function and aesthetics.

If needed, adjust the try-in or mark with a pen where modifications are needed. You can scan the modified try-in, or send it physically back to the lab.

Lab work Manufacturing of final denture

The lab will be able now to manufacture the new denture.

If changes are extensive, the lab may propose a second try-in for your evaluation.

3rd Appointment Delivery of final denture

Delivery of the new denture with the iTero digital workflow.

Watch the full tutorial here

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Simplify complex restorative treatments with iTero scanners.

With an iTero intraoral scanner, you can capture patient data fast and comfortably, enhance patient understanding and treatment acceptance, and send scans in seconds[1] to coordinate seamlessly with labs through iTero scanners' open system.

The iTero digital workflow for **veneers.***

01

The initial consultation

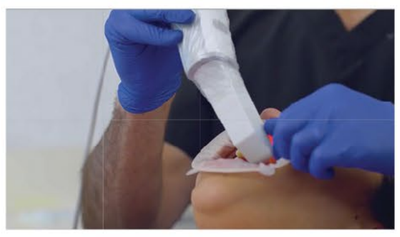
Efficiently capture accurate digital imagery with the iTero scanner and build trust with your patient.

- Gather scans, intra- and extraoral photos, facial dynamic video, and X-rays
- Simulate the clinical outcome with a smile design software
- Present and discuss treatment plan with the patient
- Coordinate case planning with your lab

02

The second appointment

Prepare the teeth using a minimally invasive approach, preferably staying at enamel level. Then, scan the preparations in minutes with the iTero scanner before creating the provisional restoration.

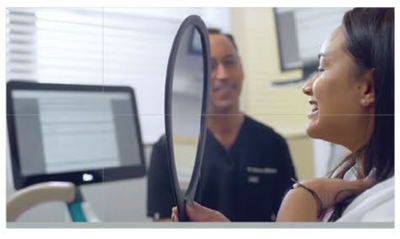


- Use your lab's preparation guide to achieve proper surface reduction
- Scan the preparations
- Create the provisional restorations with the provisional guide
- Discuss hygiene to ensure optimal soft tissue conditions

03

The third appointment

Place the final veneers to complete the treatment.



- Place the final veneers
- Congratulate your patient on their new smile

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One scanner.
Countless treatments.

From veneers to full arch rehabilitation, iTero intraoral scanners can help you simplify complex treatments, work seamlessly with your lab, and increase patient satisfaction. Learn more at iTero.com.

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www.youtube.com/watch?v=pHdTFdCxoMw

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[1] Based on 48 iRecord scanning sessions (24 on DC power / 24 on battery) by 1 experienced person scanning.

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Simplify complex restorative treatments with iTero scanners.

With an iTero intraoral scanner, you can capture clinical patient data fast and comfortably, enhance patient understanding and treatment acceptance, and conveniently send scans to chairside planning softwares for 3D printing.

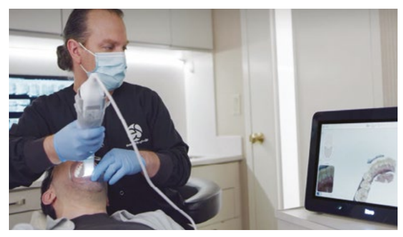
The iTero scanner digital workflow for **3D printing a bite splint.**

01

The initial consultation

Efficiently capture accurate digital imagery with the iTero scanner and build trust with your patient.

- Conduct a full clinical examination
- Gather scans, intra- and extraoral photos, facial dynamic video, and X-rays
- Present and discuss treatment plan with your patient

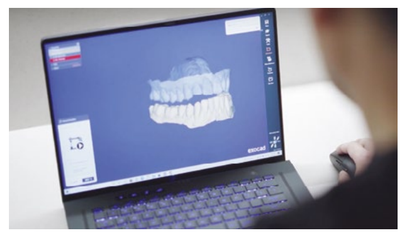


02

Chairside planning and 3D printing

Digitally create the bite splint with exocad software and manufacture it with the 3D printer.

- Export the iTero scan to exocad ChairsideCAD or exocad DentalCAD softwares
- Virtually adjust the occlusion by removing interferences on the bite splint
- Import the designed CAD files into 3D print preparation software
- Print using a 3D printer, such as the Formlabs Form 3B printer
- Wash, dry, and post-cure the printed parts before delivering to your patient

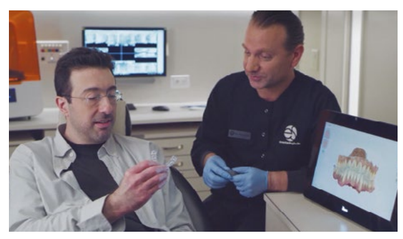


03

The second appointment

Deliver the bite splint.

- Try in the appliance and check for proper adaptation
- If adjustments are necessary: Rescan the bite splint outside the mouth to keep an updated digital record
- Resume routine monitoring



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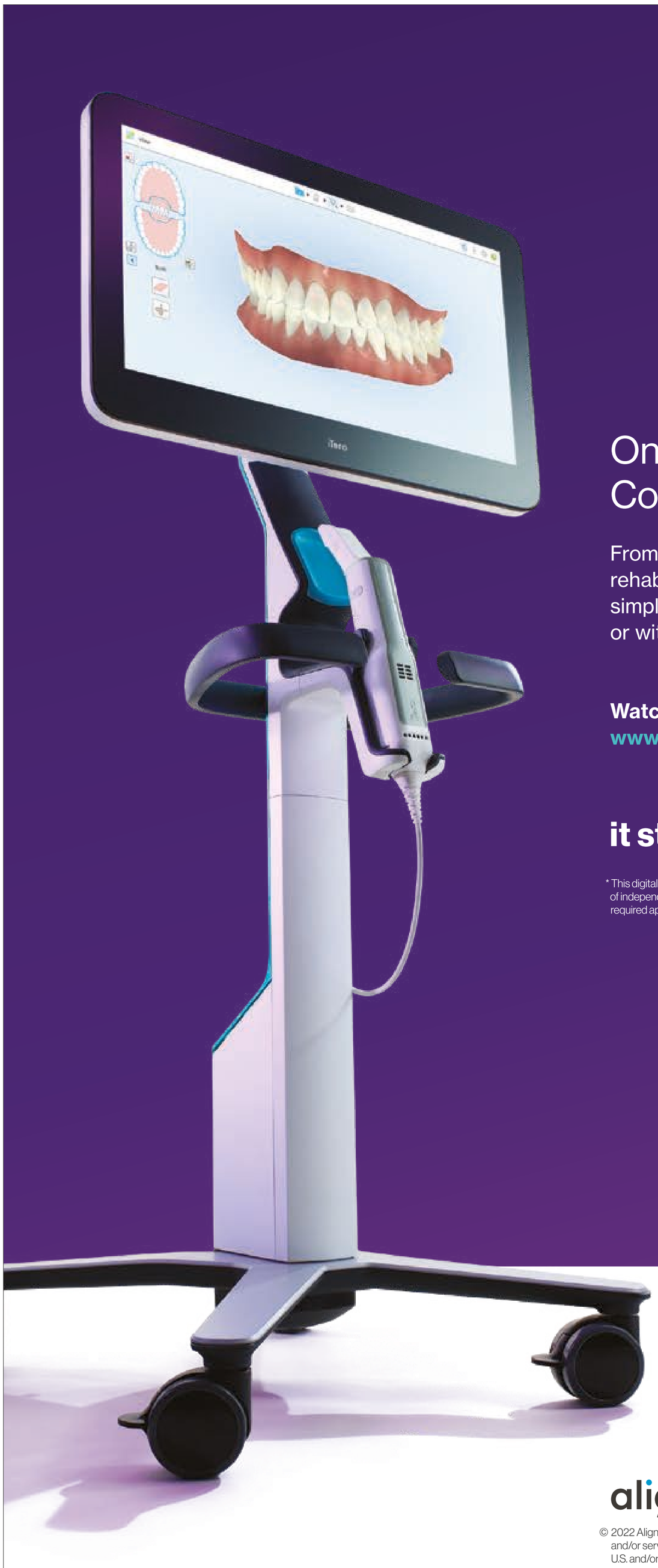

One scanner.
Countless treatments.

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EXPAND your treatment acceptance

Thanks to the iTero scanner's open system, you have a powerful tool you can use to print 3D mockups of recommended treatments, gain case acceptance, and grow your practice.

How to **encourage case acceptance and grow your practice** using your iTero scanner and 3D printer.

01

Scan your patient at the initial consultation

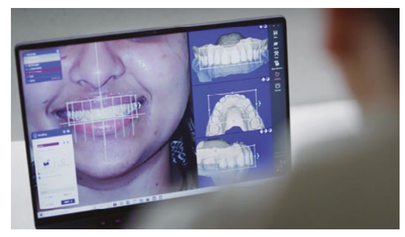
Efficiently capture accurate digital imagery with the iTero scanner and build trust with your patient.

- Conduct a full clinical examination
- Gather scans, intra- and extraoral photos, facial dynamic video, and X-rays
- Present and discuss treatment plan with your patient
- Use exocad Smile Creator software to design the smile mock-up

02

Send captured scans to your 3D printer

Once you've shared your diagnosis and digital treatment plan with your patient, you can give them a physical preview by 3D printing the smile mock-up. This will help the patient to better understand and get motivated for the treatment.

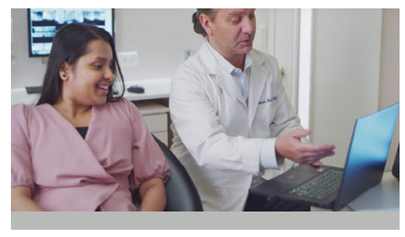


- Export the scan from your iTero scanner to a 3D printing software.

03

Install the 3D-printed mock-up in your patient's mouth

When your patient can see and feel what the restorative mockup is like, they'll be more likely to accept your recommended treatment.



04

Start treatment

With your patient's acceptance, you can proceed with the treatment as planned and create their new smile.

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Interested in expanding your restorative treatment possibilities?

From 3D printing restorative mockups to performing a full arch rehabilitation, iTero intraoral scanners can help you increase case volume, simplify complex treatments, and improve the patient experience.

Learn more at:
www.youtube.com/watch?v=ulHYjAx9fSY

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Restorative cases reports

Implant supported edentulous rehabilitation
Dr. Andrea Agnini

3 unit Bridge - #25 - #27
Dr. Gianluca Plotino

Implant-supported bridge - #14 - #16
Dr. Gianluca Plotino and Dr. Ferruccio Torsello

Single Crown - #25 / Implant-supported crown - #26
Dr. Gianluca Plotino and Dr. Ferruccio Torsello

Implant-supported fixed complete denture
Dr. Jack Bruce Milgate

Implant supported edentulous rehabilitation

Dr. Andrea Agnini and Dr. Alessandro Agnini

Chief Complaint :

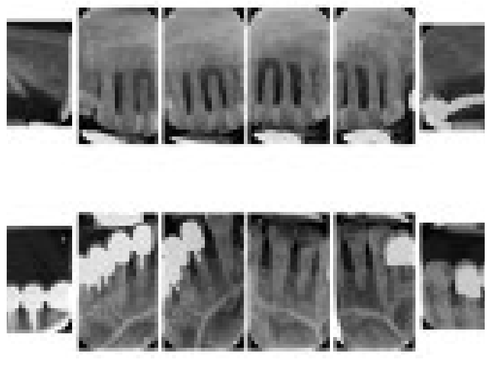
- Advanced periodontitis, with generalized tooth mobility and patient discomfort
- Patient didn't want any removable prosthesis, not even as temporary solution

Initial clinical status and treatment outcome

Before restoration:

Intraoral photograph

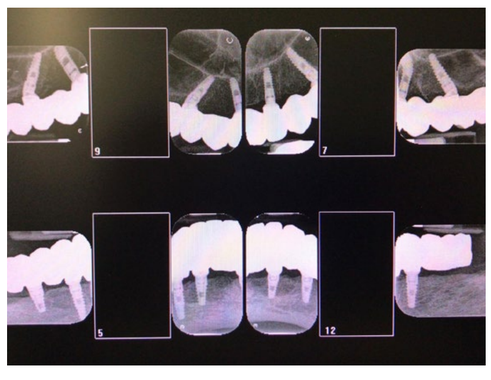
X-Ray



After restoration:

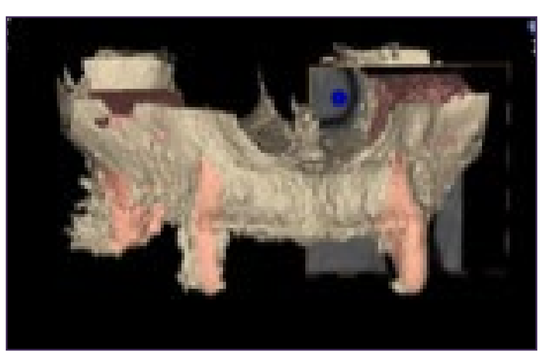
Intraoral photograph

X-Ray

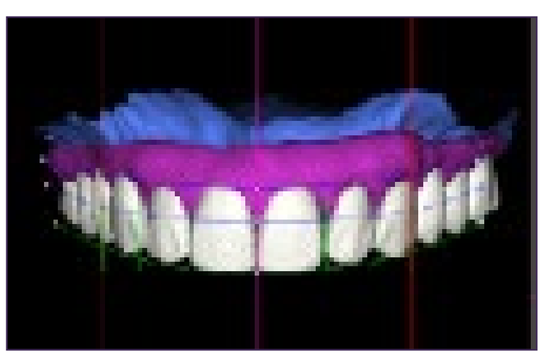


Treatment progress images

CBCT pre-op



DSD planning



Scan body Scan

Provisonal restoration in occlusion scan

Materials and Method

- Teeth were extracted
- Implants were placed following the digital planning done with the DSD Evaluation and an immediate loading protocol.
- The Provisional restoration was reinforced with a titanium bar. The restorative material chosen was a combination of acrilic resin and composite.
- After the healing and osseointegration period, the final restoration was fabricated based on the iTero™ scans.
- The material chosen for the final restorations was titanium bar and monolithic zirconia teeth

Discussion & Conclusion

Succeeding in Full Mouth Restorations requires a multidisciplinary treatment plan.

iTero Element 5D imaging system and its versatility, together with DSD, helped clinicians in communicating with the patients.

Workflow, strategic treatment planning of implant proper positioning and final restorations are all completed using a completely digital environment.

3 unit Bridge - #25 - #27

Dr. Gianluca Plotino

Chief Complaint :

The patient complained of pulp sensitivity on both teeth 25 and 27 under the old bridge.

Initial clinical status and treatment outcome

Before restoration:

Intraoral photograph

X-Ray

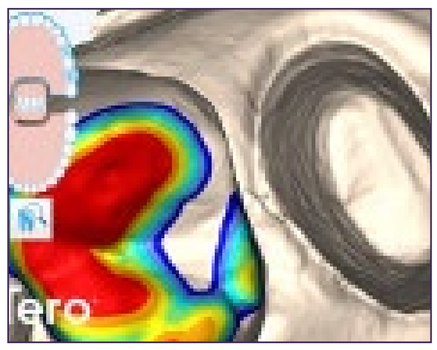
After restoration:

Intraoral photograph

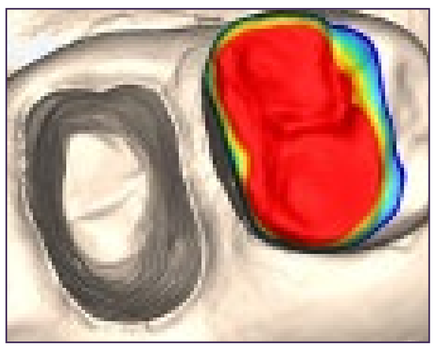
X-Ray

iTero™ diagnostic tools

Occlusogram



Occlusogram



Treatment progress images

Prep scan

Bite

CAD/CAM design

Materials and Method

- After the endodontic treatment of teeth 25 and 27, the doctor proceeded with a vertical edgeless preparation on both teeth.
- The two cords technique was used to retract the gingival tissue using a 00 cord deep in the sulcus and a 0 cord coronally to open the sulcus. The 0 cord was removed immediately before the scan. The second cord was removed upon the completion of the scan.
- The material chosen for the bridge was monolithic zirconia.

Discussion & Conclusion

Devitalised teeth with their natural fragility to fractures require a perfectly balanced occlusion to ensure the long-term clinical stability.

The Occlusogram tool was the key tool in two trivial treatment steps:

- To ensure the adequate space for the restorative material.
- To check the final occlusion balance.

Implant-supported bridge - #14 - #16

Dr. Gianluca Plotino and Dr. Ferruccio Torsello

Chief Complaint :

- Patient presented to the doctor with an old bridge on 16-15 and a crown on 14.
- Teeth 16 and 14 were fractured
- Tooth 15 had not enough coronal structure to retain a crown

Initial clinical status and treatment outcome

Before restoration:

Intraoral photograph

X-Ray

After restoration:

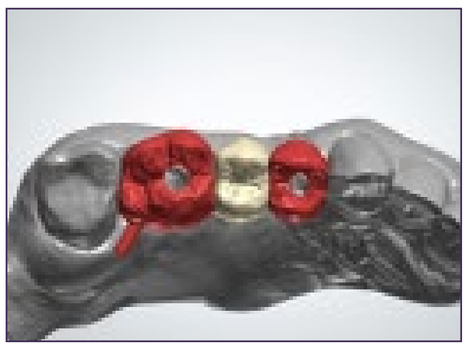
Intraoral photograph

X-Ray

Treatment progress images

Pre operatory CBCT

Prosthetic design



Final Restoration scans

Treatment steps

Phase 1:

- Teeth #16 and #14 were extracted
- Implants were placed on #16 and #14 areas
- iTero Element™ 5D imaging system was used for the digital impression to produce the provisional restoration
- A temporary screw-retained bridge was used supported by tooth #15, in order to reduce the loading forces on the recent placed implants.

Phase 2:

- After 4 months, the implants indicated osseointegration
- Tooth #15 was extracted
- iTero Element 5D imaging system was used for the final digital impression
- A final screw-retained monolithic zircona implant-supported bridge was fabricated and delivered.

Discussion & Conclusion

The loading of the implants in the provisionalization phase must allow for the osseointegration process. In the final restoration, the slight underload will ensure the long-term stability.

The accuracy of the scanner, allowed the delivery of both steps without the need of adjustments.

Single Crown #25 / implant-supported crown #26

Dr. Gianluca Plotino and Dr. Ferruccio Torsello

Chief Complaint :

- Lost tooth supported crown #27
- Edentulous space #26
- Non aesthetic crown #25

Initial clinical status and treatment outcome

Before restoration:

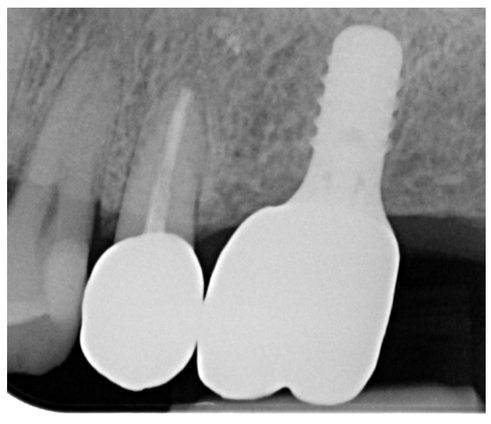
Intraoral photograph

X-Ray

After restoration:

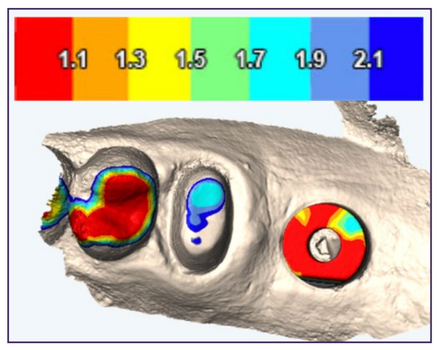
Intraoral photograph

X-Ray

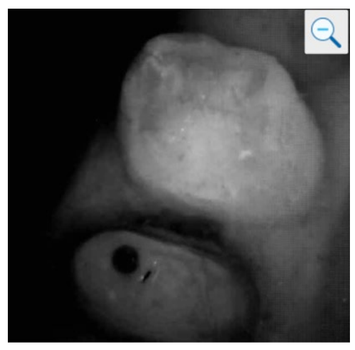


iTero™ diagnostic tools

Occlusogram



NIRI

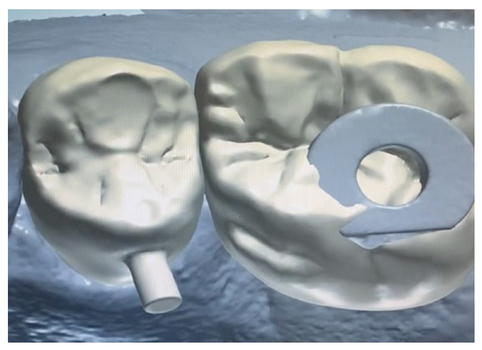


Treatment progress images

Prep scan

Bite

CAD/CAM design



Materials and Method

- Tooth 25 was prepared with a vertical edgeless margin
- The two cords technique was used to scan tooth 25 using a 00 cord deep in the sulcus and a 0 cord coronally to open the sulcus
- 0 cord was removed immediately before the scan, cord 00 was removed after the completion of the scan
- A scan body was used on implant on 26
- iTero Element 5D imaging system was used for the final digital impression
- Tooth #25 was restored with a cemented monolithic zirconia single crown
- Implant #26 was restored with a screw-retained monolithic zirconia crown

Discussion & Conclusion

A comprehensive diagnosis and precise treatment planning are key factors for the clinical success.

In this case, iTero Element 5D imaging system tools like iTero NIRI technology and Occlusogram, acted as an aid in caries lesion detection and ensuring proper occlusion, which consequently guaranteed the appropriate loading distribution between the teeth and the implant.

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CASE REPORT PEER REVIEWED | OPEN ACCESS

Using iTero Element intra-oral scanner to scan for implant-supported fixed complete dentures

Jack Bruce Milgate, Niti Sarawgi, Raviv Zary

ABSTRACT

Introduction: Impressions in implant dentistry aim to accurately relate an analogue of the implant or implant abutment to the other structures in the dental arch. The impression material, impression technique, implant angulation, and the number of implants, all affect the accuracy. In the case of implant-supported fixed complete dentures (ISFCDs) traditional impression techniques require the doctor to accurately capture multiple units in one step. Doctors often encounter cases where one unit is not captured properly while another is perfect, so they take another impression only to find that they captured the problematic unit, but the impression of the previously perfect unit is no longer acceptable. Recent data suggests that intra-oral digital impressions may be considered a reliable alternative to conventional impression materials for ISFCDs. The ability to "segment" the impression process of large restorations and scan different segments individually eliminates much of the uncertainty that is part of taking a multi-unit conventional impression. It also ensures that units are scanned at the appropriate time, when in an ideal soft tissue condition.

Case Report: We report the case of a 48-year-old male presenting with a chief complaint of difficulty to eat due to mobile removable denture, looking for a fixed solution. This case report reviews in detail the steps followed to acquire an accurate digital impression for implant-supported fixed complete dentures using the iTero Element intra-oral scanner.

Conclusion: Digital review allowed for simpler design and easier transfer of occlusal records.

Keywords: Dental equipment, Dental implantation, Dental prosthesis, Mouth rehabilitation

How to cite this article

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Jack Bruce Milgate[1], Niti Sarawgi[2], Raviv Zary[3]

Affiliations: [1]Owner/Lead Doctor at Barwon Heads Dental, 43 Hitchcock Avenue, Barwon Heads, Victoria 3227, Australia; [2]Clinical Trainer at INVISALIGN Singapore PTE. LTD, 491B River Valley Road, Singapore 248373, Singapore; [3]Sr. Manager Global Clinical Applications at Align Technology LTD, 3rd Ariel Sharon Boulevard, Or Yehuda 6037606, Israel.

Corresponding Author: Jack Bruce Milgate, Owner/Lead Doctor at Barwon Heads Dental, 43 Hitchcock Avenue, Barwon Heads, Victoria 3227, Australia; Email: jbmilgate@hotmail.com

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INTRODUCTION

Obtaining accurate dental impressions for implant-supported fixed complete dentures (ISFCDs) is a challenge faced by clinicians on a daily basis. Ill-fitting prostheses may add unnecessary strain on the various prosthetic components in the system and ultimately result in complications [1–5].

Clinical studies assessing the threshold for clinically acceptable fit of ISFCDs have reported that it lies within a range of 59–200 μm [6–8].

The advantages of digital scanning include the elimination of errors during the procedure, dispensing and polymerization stages of conventional impression materials. Eliminating the need for disinfection, shipping to the laboratory, and increased patient comfort also help to reduce errors [9–10]. Digital intra-oral scanners (IOS) acquire single images that are stitched together using a "best-fit" algorithm to produce a virtual 3D model. Stitching can introduce errors into large scan distance such as the full-arch situation [11–13].

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Our review found only two relevant publications from in vivo prospective trials. In 2019, Paolo et al. used clinical and radiological endpoints to compare conventional versus digital impressions in 50 edentulous patients. In this trial intraoral scanning reported to show satisfactory accuracy, providing a reliable alternative in clinical practice for implant full-arch rehabilitations [14].

More recently, Chochlidakis et al. published a prospective clinical study to compare for the first time the accuracy of digital and conventional maxillary implant impressions in 16 edentulous patients. The 162 μm found as mean 3D deviation between the casts generated from full-arch digital and the conventional impression, appears to be in agreement with what has been previously reported in the literature and within the aforementioned threshold for clinically acceptable fit [15].

To the best of our knowledge this is the first case report to describe full arch implant workflow utilizing the iTero Element intra-oral scanner.

CASE REPORT

We report the case of a 48-year-old male with a chief complaint of difficulty to eat due to mobile removable denture, looking for a fixed solution.

The patient had a history of failing dentition due to chronic periodontitis, Type II diabetes mellitus, and is a current smoker with a history of long-term smoking.

On intra-oral examination, the patient presented with an edentulous upper arch and a partially edentulous lower arch with periodontally compromised lower dentition. The patient was wearing an acrylic removable complete denture for the upper arch. The denture presented an intentional midline diastema that the patient wanted replicated in the final prosthesis. The patient was evaluated using an orthopantomogram (OPG) and a treatment plan was formulated to maintain lower failing dentition while the patient underwent an all-on-six implant supported denture for the upper jaw (Figure 1). The patient was referred to the periodontal surgeon for implant placement.

Surgical procedure for implant placement

Implant surgery was performed by periodontal surgeon based on cone-beam computed tomography (CBCT) analysis. It was a free hand surgery without the use of surgical guide. The surgery was performed keeping in consideration the patient's medical and habitual history.

The patient had upper dentition removed nine months prior to initial implant fixture placement.

Initially 6 × Straumann BL Roxolid implants were placed. At 12 weeks integration testing, two implants showed poor osseointegration and were replaced. 10 weeks later, review of these fixtures revealed that one of the implants failed to integrate (21 area). Remaining five implants tested as stable and osseointegrated.

Taking into account the patient's periodontal condition, medical history and continued smoking habits, it was deemed essential that a permanent restoration should be designed to allow easy maintenance and cleansing in combination with strict oral hygiene instruction and follow-ups.

Restoration for the implants

The digital method (iTero Element 2, Align Technology, Inc.) was utilized for the entire restorative process. The following steps were used to achieve the desired outcome:

- Five Straumann BL scan bodies were ordered and utilized for the restorative phase.
- Patient's denture was scanned in the mouth to use as a copy for the final restoration (patient requested final prostheses to have the same aesthetics including midline diastema as current prostheses). Scanning the denture in situ also allowed recognition of soft tissue landmarks (frenulum) which then allowed for cross-scan calibration, articulation, and mounting of the implant scan [including replicating occlusal vertical dimension (OVD) and occlusal position].
- Lower dentition was scanned first, with the healing abutments in the upper still in place (Figure 2).
- Scanning lower prior to removal of healing abutments, minimizes time with healing abutment removed and is favorable to minimize soft tissue "collapse," enabling capture of emergence profile and reducing discomfort to the patient.
- Upper scan was performed after taking an OPG to confirm correct seating of scan bodies (Figure 3).
- Upper scan was performed to include frenulum and full sulcus/palate (Figure 4).

Figure 1: OPG showing edentulous upper arch and periodontally compromised lower dentition.

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Figure 2: Healing abutments retained for upper jaw while scanning the lower jaw first.

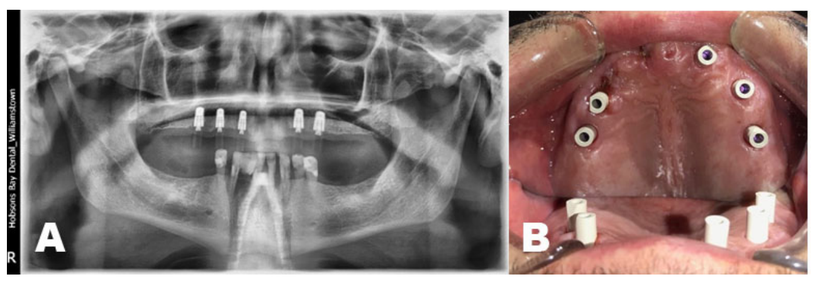

Figure 3: Maxillary arch. (A) The scan bodies in place confirmed before scanning (OPG). (B) Intra-oral image with the scan bodies in place.

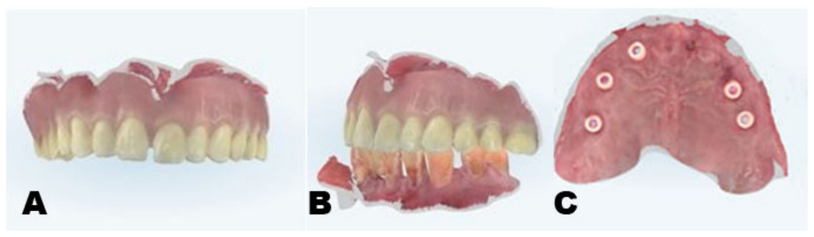

Figure 4: iTero scan. (A) Denture inside patient's mouth. (B) Bite registration with the denture ensuring same vertical dimension (VD) for final prosthesis. (C) Scan bodies in the maxillary arch.

Scan protocol for digital impression (iTero Element):

- The scans were performed using the scanning protocol of occlusal-palatal/lingual-buccal (Figure 5).
- It was ensured that the head of the scanner is placed deep in the sulcus area to capture it completely while using the other side to retract the soft tissues. (The size and softness of the scanner head enabled this with maximum efficiency and minimum discomfort to the patient.)
- It was important to be vigilant while scanning multiple scan-bodies to avoid a double image of multiple scan-bodies. As the scan-bodies were identical the scanner found it difficult to differentiate between them. Placing the scanner at an angle while following the basic protocol helped avoid double images.
- Good inter-scan body soft tissue capture and ensuring the scanner angle is such that it does not capture both the scan-bodies—one that is currently being scanned and the contralateral (opposing side) scan body reduces this problem.
- The scanners ability to capture the color of the scan body fixture screw enabled getting the depth of the scan body cylinder.
- If the scan does capture multiple scan-bodies overlapping one another, the scan must be deleted and started again. There was no time constraint for this case, however, for a time constraint good scan technique and practice will reduce this issue.

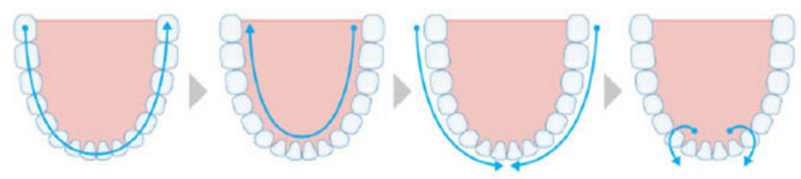

Figure 5: iTero scanning protocol: Occlusal-Lingual-Buccal (adapted from iTero Element instructions for use).

After the scans were captured completely and evaluated, they were sent to the lab for fabrication of the restoration.

Lab procedure

- The restorative lab utilized EXOCAD design software for designing the prosthesis. In combination with the scans sent from iTero (including bite registration, and prostheses aesthetics (denture copy) (Figure 6).
- The try-in bar, teeth and soft tissue were 3D printed using stereolithography (SLA) resin (Figure 7).
- These were then tried in the patient to confirm the fit, midline symmetry, and the prosthesis and soft tissue interface to make sure enough space for easy cleansing and maintenance. Modifications were drawn with a single use indelible marker directly on the printed try-in prosthesis (Figure 8).
- After modifications, there was a second try-in of the bar to ensure the final prosthesis had adequate notches to ensure easy cleaning (Figure 9).
- After the design was approved, milled titanium bar and polymethyl methacrylate (PMMA) teeth were used for the final prosthesis, keeping in mind the lower periodontally compromised dentition (Figure 10).

Implant-supported fixed complete denture

- Abutment access holes were filled with a Teflon tape spacer and finally a modified Glass-ionomer cement. Fit was good and the patient has been on regular follow-ups to ensure maintenance (Figures 11 and 12).

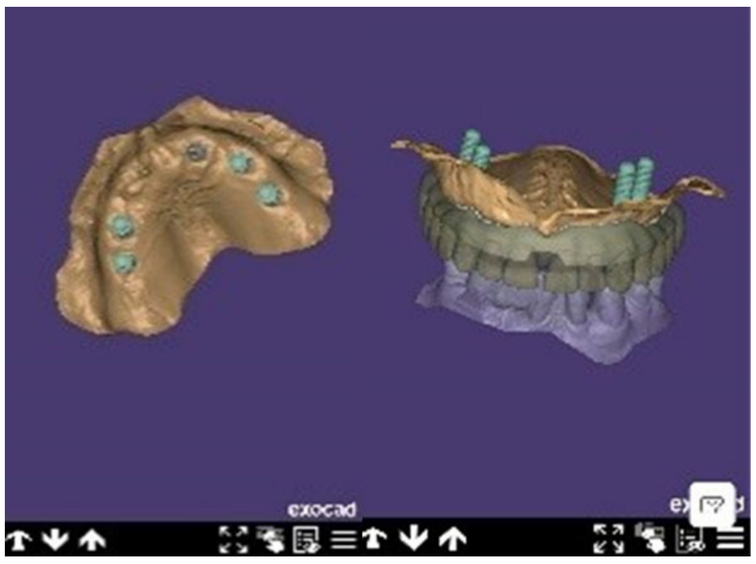

Figure 6: (A) EXOCAD software utilizing the iTero scan of scan body for prosthesis design. (B) Superimposition of the denture scan, bite registration, and scan body scan to design the prosthesis.

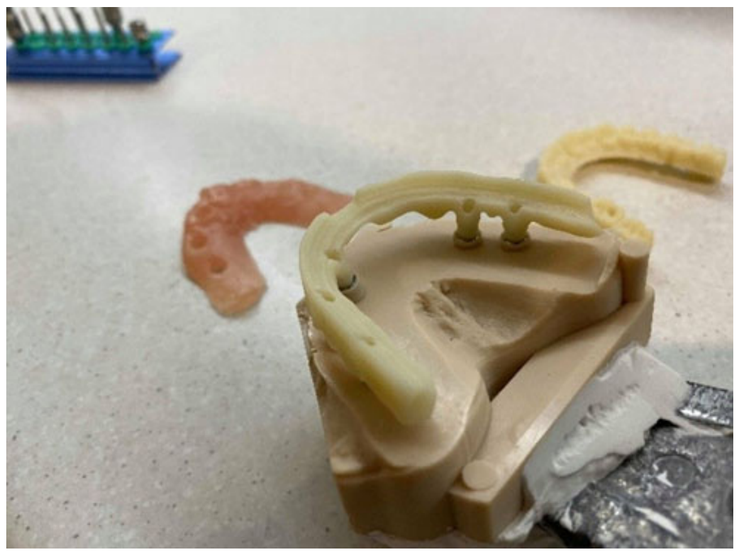

Figure 7: SLA resin try-in bar, soft tissue and teeth printed based on the EXOCAD design.

Figure 8: Modifications drawn on the try-in bar for changes easily communicated to the lab.

Figure 9: Try-in of the bar to ensure fit, midline symmetry, and cleansibility.

Figure 10: Titanium bar and PMMA teeth for the final prosthesis.

Figure 11: Final prosthesis in place with good fit and adequate cleansing areas.

Figure 12: Follow-up after six months.

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DISCUSSION

The accuracy for full arch dentate scans has been evaluated previously. Review of the literature showed 10 publications where iTero Element scanner was evaluated for full arch scan accuracy:

In 2019, Keul and Güth compared the accuracy of full-arch digital impressions to conventional impressions in vivo [16]. Their conclusion was that using the iTero Element intraoral scanning device resulted in the same and for single parameters even in higher accuracy than the indirect digitalization of the impression or the gypsum cast using a desktop scanner.

Two recent comparative studies used all-on-six implant models to test iTero Element versus conventional impressions as well as several other latest generation intra-oral scanners [17, 18]. While different levels of trueness and precision were found among the included IOSs, in both studies iTero was able to provide a reliable alternative to complete-arch implant impression procedures.

Five in vitro comparative studies used different edentulous and dentate models to test full arch scans accuracy [19–23]. Accuracy results for iTero were all within the aforementioned threshold for clinically acceptable fit.

Dutton et al. [24] and Revilla-León et al. [25] tested several scanners, including iTero Element, for the effect of common dental substrates and lighting conditions respectively on full arch scan accuracy. The new generation of scanners was deemed remarkably accurate across all substrates. For the iTero Element scanner, chair (10,000 lux) and room (1003 lux) lighting improved the trueness and precision mean values.

This case presented several advantages in comparison to conventional flow for both the dentist and the patient. With regard to the patient: 1) in conventional impression the periodontally compromised lower teeth were at risk for iatrogenic extraction, this was overcome using digital tools that do not apply any forces. 2) The patient was more comfortable with no gag. 3) The digital workflow and the eraser tool associated with the iTero scanner provided the ability for instant review of captured data preventing inconvenience due to retakes. 4) If there were any errors in the impression, that part could be recaptured and the whole scan did not have to be repeated, making the process much faster. 5) Any non-parallelism of the implant angle and under-cut that poses difficulty in removal of conventional impression can be overcome during digital. For the dentist: 1) the seamless digital workflow that involved capturing and data transfer is one of the biggest attractions associated with this treatment type. The requirement to not package and manually deliver impressions and bite registrations increased speed and delivery of lab work. 2) The process had increased patient compliance as it was not messy, and the patient did not experience gag. 3) The disposable sleeves and digital impression minimized contact with saliva and blood, providing a safer option to prevent cross infection. 4) The ability to instantly review the impression and modify it increased the efficiency of work. That said, there were a few challenges that needs to be overcome with practice and mastering the technique. 1) The limitation of this digital transfer namely presents itself regarding the labs ability to receive and efficiently interpret the digital data provided. This can be overcome with good lab training and communication. 2) During the scanning process for a full arch rehabilitation, the scan body tends to be “double-detected,” this can be overcome with angulation of the wand at 45° to ensure capturing only the required scan body.

The patient comfort is a major aspect of digital full arch scanning that makes it an attractive proposition.

Burzynski et al. compared patient acceptance and efficiency of digital intraoral scanners and alginate impressions [26]. The results of this trial showed that subjects were more comfortable, reporting less pain and dry mouth sensations with the iTero scanner than with the other methods tested. There was a significant difference in both measured time and time perception between the iTero and alginate impressions arms.

The ability to have breaks, review scans, and often not re-take impressions is very attractive for the patient. Full arch implant impressions with both open and closed tray can often be cumbersome and intrusive for the patient, and when non-parallel implants present it can create difficulties regarding post poly-vinyl siloxane (PVS) setting removal.

By far the most questionable and in this case successful part of treatment is in regard to accuracy and cross-arch stability of the multiple implant scans. The scanning technique like most aspects of dentistry takes time and practice to develop proficiency and accuracy. In this case the multiple identical scan bodies required specific scanner head angulation to limit capturing of multiple scan bodies and the scanner being able to disseminate between locations. This can be further complicated with non-parallel or in implants with minimal space inter-proximally.

Overall, the ease of scanning and comfort for the patient, communication and speed of delivery with manufacturing lab and accuracy of data make full arch implant scanning an attractive option for full arch prostheses production. Limitations regarding implant position and double capture of identical scan body data can be eliminated with good operator skill and practice.

CONCLUSION

The accuracy of iTero Element scanner in this case appeared flawless. The final prostheses were inserted passively with nil complications. Minor occlusal adjustments were required as this is likely due to the lack of stability of the patient’s lower arch (to be restored at a later date). Digital review allowed for simpler design and easier transfer of occlusal records.

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Author Contributions

Jack Bruce Milgate – Conception of the work, Design of the work, Acquisition of data, Analysis of data, Interpretation of data, Drafting the work, Revising the work critically for important intellectual content, Final approval of the version to be published, Agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

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Niti Sarawgi – Conception of the work, Design of the work, Acquisition of data, Analysis of data, Interpretation of data, Drafting the work, Revising the work critically for important intellectual content, Final approval of the version to be published, Agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

Raviv Zary – Conception of the work, Design of the work, Acquisition of data, Analysis of data, Interpretation of data, Drafting the work, Revising the work critically for important intellectual content, Final approval of the version to be published, Agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

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The corresponding author is the guarantor of submission.

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Authors declare no conflict of interest.

Data Availability
All relevant data are within the paper and its Supporting Information files.

ABOUT THE AUTHORS

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Jack Bruce Milgate is Private practitioner and owner at Barwon Heads Dental, 43 Hitchcock Avenue, Barwon Heads, Victoria, Australia. He earned undergraduate degrees Ba.HS (Dent) Ma. (Dent) from La Trobe University, Victoria, Australia. Jack is an experienced private clinician with a large focus on clear aligner orthodontics and modern digital dentistry. He is a Diamond Invisalign® provider and has completed over 500 Invisalign cases. He co-founded digital mouthguard company 3DGuard® and was heavily involved in the development and manufacture of concussion detection mouthguards for use in professional sport. Jack is a clinical speaker for Invisalign® speaks internationally for Align Technology® on Invisalign® and intra-oral scanning procedures.

Niti Sarawgi is a Clinical Trainer at INVISALIGN Singapore PTE. LTD, 491B River Valley Road, Singapore 248373, Singapore.

Raviv Zary is a Sr. Manager Global Clinical Applications at Align Technology LTD, 3rd Ariel Sharon Boulevard, Or Yehuda 6037606, Israel.

iTero™ publications

A Fully Integrated Diagnostic Process Through Advances in Scanning Technology

by Tim Nolting, Dr MSc, Frédéric Poirier, DDS, and Thomas Giblin, BSc, BDent(Hons)

Abstract

The iTero Element 5D imaging system is the first intraoral 3D scanner integrated with near-infrared imaging (NIRI) technology. NIRI has the potential to revolutionize patient treatment and the overall workflow in dental offices. This technology provides practitioners with an aid for early detection of interproximal caries above the gingiva, which is one of the gravest threats to oral health (equal in seriousness to periodontal disease) per the World Health Organization (WHO).

In the near-infrared electromagnetic spectrum range of 0.7 to 2.0 µm, the iTero Element 5D Imaging System uses light of wavelength (= 850 nm), which interacts with the hard tissue to provide additional data of the tooth structure. The dentin will appear bright, with areas of pathology or demineralization appearing as white spots on the display. The iTero Element 5D imaging system, the latest incarnation of NIRI technology, is an "innovative, integrated optical diagnostic aid," using a class 1 laser, as Keshav stated in the iTero Element 5D Clinical Guide (Near-infrared imaging technology in dentistry — iTero Element 5D). It gives practitioners the ability to view multiple dimensions of data, as well as to virtually manipulate the model for a comprehensive view. It is the logical next step in digital diagnostic technology and is quickly replacing both conventional impressions and first-generation intraoral scanners. Advanced scanning technology together with artificial intelligence (AI), streamline the treatment and diagnosis process into the future of dentistry.

Keywords

iTero Element 5D imaging system, patient education, near-infrared imaging (NIRI) technology, dental diagnostics, interproximal caries, restorations, technology adoption, office workflow, practice growth, artificial intelligence (AI)

This white paper has been co-written by 3 dentists who have been using the iTero Element 5D for at least 6 months and refers to a survey of 15 dentists practicing in Germany, Italy, United Kingdom, France, Hong Kong, Australia, and Canada.

Introduction: Impact of Technology Adoption for Practice Growth

In this paper, the ways that adoption and integration of new technologies [particularly, NIRI, the iTero Element 5D imaging system, and artificial intelligence (AI)] will overhaul dental office workflow, optimize diagnosis and treatment planning, and improve practice efficiency are highlighted. Conventional methods of diagnosing dental caries and other oral pathologies rely on visual and tactile methods coupled with radiography (X-ray). These methods can have significant drawbacks based on visibility, accessibility, and subjective judgment, equal in seriousness to periodontal disease.[1]

First-generation intraoral scanners (IOS) required the application of powder to the teeth for opacification; this could be clumsy and messy for the practitioner or dental assistant, as well as the patient. Moreover, these early intraoral scanners functioned as little more than digital impression systems. Since then, advances in laser technology and scanning speed, as well as enhanced displays featuring in-color 3D models of the dental arches, like the iTero Element 5D imaging system, have broadened the appeal and functionality of IOS technology for use in general dentistry.[1]

The most cutting edge of these is the use of NIRI for diagnostic imaging, which works by emitting infrared light into the surface of the tooth. The light diffuses through the highly scattering dentin, reflecting off the enamel of the crowns and creating an image of the occlusal surfaces. While much new decay occurs in pits and fissures, and therefore cannot be detected with conventional X-rays because of the overlapping topography of the tooth surface of posterior teeth,[2,3] dentists can check for this type of caries with a probe. NIRI scanning is especially useful for detecting interproximal caries above the gingiva that is difficult to see with the naked eye or X-rays, and impossible to detect by probing. In a survey of practitioners who use the iTero Element 5D scanner as part of their diagnostic protocol, 87% of surveyed participants indicated they increased the number of diagnosed interproximal caries above the gingiva by 56% on average. Near-infrared imaging has the potential to allow for superior diagnostic efficiency, particularly when synced with emerging dental AI technologies for enhanced diagnostics and restoration design.

Patient Experience During the Visit

Unlike conventional dental X-rays, NIRI does not expose the patient or the practitioner to ionizing radiation and its potentially harmful effects, and is therefore safe to use whenever a clinician suspects the presence of dental caries or other pathology that may be hidden by enamel.[1] A scan can provide more nuanced information and serve as an adjunct to traditional radiographs and intraoral photos, and in some cases even replace conventional diagnostic methods. This a clear advantage, improving patient education and dental office workflow, and reducing risk associated with diagnostic X-rays.

IOS has the broadest indications for clinical use; virtual impressions created with NIRI technology are used in a wide range of procedures in general dentistry and across specialist disciplines, including prosthodontics, implantology, and orthodontics.[4] The images can be worked with easily to give a comprehensive view of the oral anatomy. Dental researchers, including those who conducted a 2017 Massachusetts Institute of Technology study of 10 subjects with varying dental conditions, agree that quality of near-infrared images is superior to that of conventional radiographs; they are a better diagnostic aid.[3,1,5,6] Likewise, a 2018 study compared NIRI to digital bitewing (DBW) radiography for both intra- and interexaminer reliability, using 12 examiners and 100 images. Reliability on both counts was significantly better with the near-infrared images when used for caries detection.[6]

Better Patient Communication and Comfort

Patients today are more educated and better informed about their health than ever before. Most want to understand the diagnosis process and be proactive in treatment. However, in a 2013 study on patient understanding and recall by Misra et al., the authors strongly concluded that "patients do not recall as much advice and agreed actions about future dental care as dentists believe they have discussed. These results have implications for patient adherence with oral health instructions."[7]

It is reasonable to assume that the disconnect between the information doctors provide and what patients can recall could be improved by utilizing visual aids, including scans. The ability to show patients a picture of their oral health, as opposed to, or as an aid to, merely explaining it to them verbally, is a powerful educational tool with the potential to improve patient compliance. As an example of the power of harnessing technology, a 2018 study of 291 adolescent dental patients showed that the influence of a mobile app for oral health education increased users' knowledge and produced a measurably better standard of oral hygiene.[8] Overall, this indicated that patients respond positively to technological and visual aids.

The iTero Element 5D imaging system has a larger display screen and is built to capture data faster than the previous generations of the Element scanners. These features enable the doctor to evaluate the patient scan chairside and direct a patient's attention to particular areas shown on the screen as a diagnosis is delivered. As we like to say, a picture is worth a thousand words, and indeed, patients show more confidence and greater understanding in interpreting scanned images alongside their doctors than they do when being shown a dental radiograph. Images produced by the iTero Element 5D imaging system look familiar to the layperson; they closely resemble digital photos and other common computer images that have become ubiquitous in everyday life. This can be helpful in the education of patients and help them to better understand treatment. In fact, out of practitioners surveyed, 100% of users agree that the iTero Element 5D scanner enables better patient education and understanding of their oral health. This, in turn, can translate into increased patient acceptance of treatment. For instance, the same survey found agreement among users that the imaging and visualization capabilities of iTero Element 5D scanner lead to increased patient acceptance of recommended caries treatment.

Patient experience is also augmented due to the fact that the process of taking the scan is often more comfortable than traditional impressions and radiographs. The speed and ability of discussing their images chairside with their doctor also please the patient. Engaging them in this process encourages them to ask questions, thereby allowing the dentist to address any concerns. This ultimately empowers the patients to make well-informed decisions on treatment.

In particular, the time lapse feature distinctly highlights any change over time, whether the topic of concern is tooth wear or movement. The outcome simulator gives a 60-second demonstration of the potential outcome, along with time lapse, which compares scans over time to infer progress.[3] Patients can therefore see and easily understand the changes occurring in their mouth. They are much more likely to proceed with treatment when they fully comprehend the situation and the implications of choosing not to treat. With a scan, they can fully visualize what is going on.

Time saved by using an advanced scanning diagnostic aid such as the iTero Element 5D imaging system allows doctors and technicians to dedicate attention to patients' personal experience and increases their acceptance of recommended treatment. The presence of cutting-edge technology in the dental office fosters patient confidence, as they can see that their doctor uses the most up-to-date diagnostics. This added confidence can further lead to increased acceptance of treatment. For example, a survey of practitioners who incorporated the iTero Element 5D scanner into their diagnostic protocol found that 79% of participants reported an average increase in patient acceptance of interproximal caries treatment by 71%. In the final analysis, more advanced diagnostics fosters better communication and happier, healthier patients. The combination of patient satisfaction and higher rates of recommended treatment acceptance due to better diagnostics, along with the timesaving efficiency of NIRI scanning, is an equation for boosting practice incomes.

Increased Restorative Cases with Better Clinical Outcomes

The iTero Element 5D imaging system's overall efficiency creates a more streamlined workflow in the dental office. With the iTero Element 5D, a scan is taken at the beginning of every visit. Other diagnostic methods may or may not be necessary, as the scan does not replace the physical intraoral or extraoral examination. However, it is our experience that an initial scan often eliminates the need for cumbersome, time-consuming X-rays, which would also mean that patients are not subjected to the emission of ionizing radiation.

In his practice, Dr. Nolting found that by using the iTero Element 5D imaging system, approximately 5% more caries was detected than with conventional diagnostics. This is partly attributable to the streamlining effect on office workflow — now doctors using advanced scanners can see more patients because of the reduced time involved, but they can also detect pathologies that might previously have been overlooked. Compared to conventional radiographs, a 3D scan provides a more comprehensive approach that enables the doctor to view all surfaces of every tooth. Thus, scanning is more efficient for revealing interproximal caries decay above the gingiva.

In a survey of practitioners incorporating the iTero Element 5D scanner into their current diagnostic protocol, 79% of survey participants reported an average increase of 32% in the number of treated restorative cases, while reporting an average increase of 57% in the number of treated interproximal caries. These increases resulted in an average hike in business revenue of 25% and 34% for the practice, respectively. Also, in treatment, being able to see into the tooth's internal anatomy allows dentists to be more conservative with the tooth structure, based on the quality of enamel that is preserved. This leads to increased patient health, preventative efficacy, well-documented practice volume and growth, as well as improved retention of patients. In a survey of iTero Element 5D scanner users, 93% of those surveyed agreed that with the improved communication capabilities of the iTero Element 5D scanner, they expect to improve practice patients' retention rate. By starting every appointment with a scan, practitioners will have the upper hand in detecting interproximal caries above the gingiva in its earliest stages, even before it shows up on a bitewing radiograph.

Creating Efficiency for Restorative Workflows and Labs

In the past, many dentists have felt pressured to invest in maintaining in-house laboratories for creating accurate restorations. Now, scanning can replace the time-consuming process of creating a model and then using wax to build the teeth back up in the laboratory, which can take a significant amount of time per tooth.

With the iTero Element 5D imaging system, the dental assistant, hygienist, or the dentist performs the scan and hits "send" — it's that simple.

Models can be delivered to the office within 2–3 days using a lab workflow or fabricated chairside within 1–2 hours using a 3D printer. This replaces the traditional processes that required having a full-time technician on staff and the additional physical space for a lab. A streamlined practice resulting from adopting new digital technologies will need fewer employees and less space, thus positioning NIRI scanning as the default method of monitoring and diagnostics.

In terms of restorations, for example, a major implication is the time savings that can be achieved per crown. Digital impressions have been shown to be a satisfactory alternative to conventional methods for creating impressions.

A 2013 study by Seelbach et al. concluded that digital impression systems allow the fabrication of fixed prosthetic restorations with similar accuracy to that of conventional impression methods.[9] Thus, scanning saves precious office time, enabling dentists to outsource many of the tedious steps associated with restorations, and to focus their own efforts on design and finishing. It is also a useful method of documenting ongoing problems and treatment.

Not only useful for crown and bridge work and diagnostics, scanning can be seamlessly incorporated into everyday practice to help practitioners monitor patient oral health. The iTero Element 5D imaging system is more versatile than older generations of scanners, and it is expressly compatible with Invisalign. With Invisalign's solid comparability behind the iTero, there is a drive to continue to improve design and functionality, to make it more than just a scanner, but a more comprehensive diagnostic aid.

Ease of Use and Accuracy

The iTero Element 5D imaging system offers a light and sleek scanning wand. It is user-friendly; scanning at a rate of 6,000 frames per second, 20 times faster than the earlier models of the iTero scanner with little to no learning curve.[10] This system offers screenshot capability as well as various views including intraoral camera, NIRI, and monochrome. A comprehensive archive of instructional videos is available on iTero's Support website,[11] making it simple and easy for technicians to get questions answered and get quick training on how to use the technology in every diagnostic context. The system's website (myitero.com) also provides the clinician with the ability to store cases, a feature that affords the practitioner the luxury of reviewing cases at their own discretion.

Scanning is noninvasive. When compared to conventional impressions, the use of an intraoral scanner has the ability to improve the patient experience with regard to comfort, gagging, breathability, tastes, and smells. It is easier, cleaner, safer, and more patient-friendly than other diagnostic aids and methods.

Prevention of Harmful Radiation Associated with Radiographs

The advantages of NIRI imaging over X-rays cannot be overstated. Beside the practical advantages — overall time efficiency, labor (and, thus money)-saving, files that are easy to delete and redo, ease of storing files in digital form, and transfer of images between practitioners via electronic transfer,[4] the most obvious desirable outcome is eliminating the risk of irradiation for both patient and practitioner. In 2018, Hwang et al. published a review of 2,158 studies to summarize the results of studies of the association between exposure to dental X-rays and health risk. Although

the level of exposure from dental diagnostic X-rays is lower than that of medical radiation, there is an innate risk from radiation exposure.[12] Therefore, for certain categories of patients, notably those at low risk of developing caries, and also pregnant women, regular bitewing radiographs are neither indicated nor advisable.[13,6] Any diagnostic aid or technology that helps eliminate the need for X-rays marks an advance in treatment approach.

Moreover, NIRI technology is shown to be as effective in detecting interproximal caries above the gingiva as radiography,[1] perhaps even better — a University of California School of Dentistry study found that with traditional radiography, interproximal caries above the gingiva are undiagnosed up to 40% of the time.[14] For conventional X-rays to reliably detect a carious lesion, there must be a certain amount of decay present. A near-infrared image can help the dentist to detect interproximal caries above the gingiva weeks or months before it is severe enough to show up on a conventional radiograph. Starting every appointment with a scan will reduce the number of X-rays taken, and thus reduce exposure to radiation, while increasing diagnostic accuracy. Even in ambiguous cases, where the doctor feels an X-ray is required to be more confident in diagnosis, an initial scan is always an effective aid to rule out an unnecessary step and increase patient confidence.

Evolution of Dental Office Technology

As has been true in other professions, technological advances are streamlining the dental workplace and

Case Reviews Supporting Efficiency and Better Clinical Outcomes with Scanning

Figure 1. iTero Element 5D scan

Figure 2. Intraoral photo

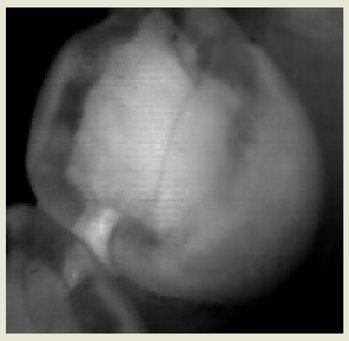

Figure 3. NIRI image

Figure 4. Affected teeth, ready for treatment

Figure 5. Decayed carious lesion found

FIRST CASE REVIEW — *Proximal Carious Lesion*

In a routine dental checkup, the patient exhibited neither symptoms nor clearly visible signs of caries; however, a scan revealed a proximal carious lesion. The iTero Element 5D scan (Figure 1) produced the same information as that gleaned from intraoral photos (Figure 2) — small white surface spots on #5.[1]

While periapical X-rays showed no significant pathology, the iTero color scan and NIRI findings (bright spots in the distal area) (Figure 3) prompted removal of the superficial tooth structure to reveal an advanced carious lesion (Figure 4), which was then treated.[1] Figure 5 shows the decayed carious lesion. Periapical X-rays were prescribed as a part of routine check-up. The radiograph suggested no significant findings (Figure 6).

Figure 6. Periapical radiograph

helping reduce health risks to clinicians and patients alike. NIRI technology fits in well with the prevailing mode of comprehensive dentistry, as it is a way for clinicians to include the patient, clearly showing them, with easy-to-understand images, the intricate relationship between good oral health and overall well-being. It seems reasonable to extrapolate that NIRI technology should be a useful aid for underscoring the implications of forgoing treatment.

For practices that were already on the way to digitizing much of the paper workflow and daily management (scheduling, communications, etc.), using digital diagnostics actually speeds up the integration of new technology. The trend toward turning practices digital is saving time, energy, and money and preserving the best possible oral health for patients.

In a current dental practice, every visit should begin with a scan. Whereas a full set of intraoral photos is recommended for new patients, a 3D scan combined with 2D high-quality image capturing eliminates this need. The more ubiquitous NIRI technology becomes, the greater the comfort and familiarity it will have for both patients and office staff. Office staff prefer the ease and efficiency of scanning to old-school methods like impressions and X-rays.

Figure 7. Intraoral photo showing calculus

Figure 8. NIRI image showing calculus

Figure 9. Color scan showing calculus

SECOND CASE REVIEW — *Calculus*

In this case, calculus is clearly visible in the intraoral photos (Figure 7). The same area of calculus appears in the NIRI image (Figure 8) as brightened areas around the tooth. The scanned color view shown in Figure 9 closely matches what can be seen from the intraoral photo. Also, the presence of calculus does not interfere with the quality of the scan.[1]

THIRD CASE REVIEW — *Dental Fluorosis*

These images show a common enamel disorder — dental fluorosis. Fluorosis, resulting from excess fluoride exposure during tooth formation, can give teeth a white, opaque appearance. In more severe cases, pitting and enamel loss can occur, leading to brown stains that can mimic the appearance of dental caries.[15] Fluorosis can affect the structural anatomy of the tooth. This case highlights NIRI's advantage in detecting changes in the structural integrity of the enamel.

Figure 10 shows a color scan of the affected area. Note the opaque white coloration at the top of the cuspid. Intraoral photo (Figure 11) of the same area looks much the same, with the affected tooth showing the same discoloration. Finally, the NIRI image (Figure 12) shows dental fluorosis on the mandibular left canine #22.

Figure 10. Color scan of the affected area

Figure 11. Intraoral photo of affected tooth

Figure 12. NIRI image of the internal anatomy shows dental fluorosis on the mandibular left canine #22.

AI in Practice

The use of AI in mainstream medical and dental practices is now possible and becoming more common every day. What is AI, and how will it be integrated into modern dental practice? Generally, the term AI is used colloquially to refer to "smart" machines, those that can learn, communicate, or otherwise display cognitive features and functions that we associate with human beings. However, this is a misnomer — AI is not really "artificial," but, in fact, is just another aspect of human intelligence and creativity. The intelligence behind the novel technologies associated with AI is human intelligence. These machines are created by humans to perform some of the tasks we do, in the same way that we do them, but often more efficiently.[15] As in many other professions, and indeed, in our everyday lives, some argue that AI will soon become an integral player in diagnosis and treatment in the dental field, especially as dental medicine is becoming more tied in with the medical community in general. Dental care is now recognized as an important aspect of overall healthcare. Just as AI is already being utilized in medicine and medical research, it will inevitably pervade dental practice.

Many dentists today do not fully realize the impact AI could soon have on their potential production.[15] The advent of cloud computing has given intelligent technologies and intelligent machines a foothold in medical and dental practices, and it is likely here to stay. AI is an aid for quick diagnosis and treatment planning.[16] This is particularly true in radiology, where deep convolutional neural networks (CNNs), a computational tool that enables computers to map images in layers, and thus to rapidly scan for certain features, enable computers to identify caries and other oral pathology, often as accurately as a human

examiner — sometimes more so. CNNs are one of the tools in facial recognition technology that has become so familiar with the use of smartphones.[17,15] The combination of AI with near-infrared scanning technology confers distinct advantages for diagnosis and treatment in general dentistry.

Machines can work longer and harder than humans in intensive detail-oriented tasks like reading and comparing scans and X-rays. They can rapidly access and sort through massive bodies of archived data for comparisons. In a new study published in July 2019, Hung et al. encourage the use of these kinds of machine-learning methods in diagnosis, particularly for predicting root caries, in older patients. In their study, the algorithms produced had high accuracy in early intervention and treatment in the aging population of the United States.[18]

In use for some time in orthodontic treatment and monitoring, AI is now also coming to the forefront in restorative and prosthetic dentistry.[19] Using AI for design and manufacturing helps to maximize comfortable fit, correct function, and create pleasing esthetics. Designers are already working to make AI user-friendly, with features like voice command and conversational interface, much like the ubiquitous Siri or Alexa. One seemingly mundane, but clever, use of this technology will include smart treatment chairs that can sense the patient's weight, vitals, and emotional state, and adjust for maximum comfort, safety, and information to the clinician. No longer a futuristic myth, AI dentistry is the new reality.

In short, advances in scanning technology and their integration with smart computing platforms will facilitate production and a higher degree of accuracy.

A Roundup of the Benefits

The iTero Element 5D imaging system is leaps and bounds ahead of earlier generation intraoral scanners because of NIRI technology. It is the first integrated dental imaging system to simultaneously record 3D, intraoral color, and NIRI images. Three-dimensional scanning and virtual models are already rapidly replacing plaster models in orthodontia, prompted by the enormous popularity of clear aligners like Invisalign. In that field, the more steps between impressions and the fitting of a final appliance, the more opportunities for information to be lost or blurred. Therefore, appliances from a digital impression tend to fit better and are more likely to fit as intended. Scanning is noninvasive and can be used as often as desired to provide the best patient outcomes for early detection of interproximal caries above the gingiva. Case studies have shown that it takes approximately 4 years before an interproximal lesion is clinically visible,[1] whereas the same lesions are potentially discoverable much earlier on a NIRI image. This saves time and money and helps prevent further damage to the teeth.

The iTero Element 5D imaging system is an ideal vehicle for chairside education, allowing patients to participate more fully and understand all aspects of their oral health. It is fast and streamlined, comfortable for the patient, and easy for users to master. In addition, the advent of new modes of AI will maximize information gleaned from scans by reliably finding hidden or interproximal caries above the gingiva.

AI can then communicate with vast databases known as big data for the most up-to-date treatment options and comparisons, including advanced restorations and prosthetics. All of this can be done rapidly and efficiently, greatly reducing the practice workload while increasing overall productivity. With the ease of just a single scan, the practitioner, the practice, and the patient are awarded all of these benefits.

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These claims area based on a survey conducted in May 2019 of n = 15 practitioners who participated in a global limited market release, working with iTero Element 5D for an average period of 6 months, representing both GPs and Orthos in CAN, EU, and APAC, who were presented with a level of agreement scale from strongly agree to strongly disagree with the following statement: "Incorporating the iTero Element 5D scanner into my current diagnostic protocol, I've diagnosed a higher number of interproximal caries above the gingiva, on my patients at my practice," and then asked to estimate the average increase.

About the Authors

Tim Nolting, Dr MSc

Dr. Nolting received the Master of Science degree in implantology. He specializes in many fields, including oral surgery, periodontology, and laser dentistry. He is certified by the German Society for Ultrasound in Medicine (DEGUM), one of the largest medical and scientific societies in Germany and one of the largest ultrasound societies worldwide, in head and neck ultrasound applications. Dr. Nolting is also certified to perform Botox and filler treatment procedures. He is an Investigator in clinical studies.

Frédéric Poirier, DDS

Dr. Poirier received the dental degree from the University of Montreal in 1992, after also receiving a degree in microbiology from the same institution. He opened his private practice in Montreal after graduating in 1996. Dr. Poirier expanded into orthodontics through the Institut Dentaire International (IDI) in Quebec in 1999, an organization affiliated with IAO, where he has successfully treated more than 2000 orthodontic patients in his practice. His professional interests include complete and interceptive orthodontic treatments using functional appliances, braces, and Invisalign, mechanical endodontics, CEREC, esthetics, and occlusion.

Dr. Poirier is a member of l'Ordre des Dentistes du Québec, the Canadian Dental Association, and the International Association for Orthodontics. He is also an active member of Gnathos, whose main focus is to offer high-quality continuing education on orthodontics. Dr. Poirier has attended a number of CE classes on orthodontics and has many public speaking experiences to his credit, mostly centered on Invisalign.

Thomas Giblin, BSc, BDent(Hons)

Dr. Giblin, a Specialist Prosthodontist, received the degree in dentistry from Sydney University with honors in 2004. In 2007, after a stint in private practice, Dr. Giblin was accepted into a 3-year Advanced Prosthodontics Residency at the University of Texas Health Science Center in San Antonio, regarded as the top program in the USA. While there, he gained a broad education in all aspects of dentistry, including implant, fixed and removable prosthodontics, as well as sleep dentistry, occlusion, and TMD. Since returning to Australia, he worked in several locations before establishing his current practice, Northern Dental Specialties, Northern Beaches.

Near infrared imaging (NIRI) technology in dentistry - **iTero Element 5D.**

This clinical guide presents the promising features of the iTero Element 5D Imaging System designed with NIRI technology and its application into every day dentistry. NIRI technology of the iTero Element 5D aids in detection and monitoring of interproximal caries lesions above the gingiva without using harmful radiation.

Author: Dr. Priyanka Keshav BDS, iTero Global Education

Background

In 2001, the National Institutes of Health Consensus Conference on the Diagnosis and Management of Dental Caries throughout life stated that “Dental caries is an infectious, communicable disease resulting in destruction of tooth structure by acid-forming bacteria found in dental plaque, an intraoral biofilm, in the presence of sugar. The infection results in the loss of tooth minerals that begins with the outer surface of the tooth and can progress through the dentin to the pulp, ultimately compromising the vitality of the tooth”[1].

Although largely preventable, dental caries is one of the two biggest threats to oral health and is amongst the most common chronic diseases in the United States. Dental caries is the most common chronic disease in children; it is about five times as common as asthma and seven times as common as hay fever[2]. Majorities of adults today live with untreated tooth decay in their permanent teeth; this makes the early detection of caries vital to identify and combat these pathological lesions in the early stages. The World Health Organization estimates that 60-90% of school children and nearly 100% of adults have or have had caries[3].

The concept of dental caries has changed significantly over the last decade. While the only way of managing caries used to be the complete removal of the demineralized tissues, today, caries is considered a dynamic process, which, if diagnosed in time, could be reversed.
The current treatment philosophy is to prevent and detect dental disease at the earliest stage in order to avoid invasive treatment. With the current understanding of the nature of dental disease and its process, the treatment philosophy is now changing to a more conservative approach and the concept of minimal intervention is gaining popularity in modern dentistry throughout the world. Early caries detection is essential for minimal intervention dentistry because it could give the opportunity to reverse the process and eliminate or at least postpone the surgical treatment. The ideal caries detection device should be able to detect the caries from the earliest stages, when the organic matrix is still not damaged, to the latest stages of cavitated lesion[4]. Current conventional diagnostic methods rely mainly on visual, tactile methods paired with radiographs. Each of these methods have significant drawbacks; Visual examination is highly technique sensitive and subjective, and tactile methods of examination are unreliable for examining proximal areas due to lack of eye contact with the proximal surface itself and some studies have indicated that the tip of the probe may cause micro abrasions of the enamel or damage to areas of remineralization if present.

Additonally, radiographs are known to expose the patient to harmful ionizing radiation present with technique sensitivity cannot be used frequently. New imaging technologies are in demand for the early detection of such lesions. Moreover, the treatment for early dental decay or caries is shifting away from aggressive cavity preparations that attempt aggressive removal of demineralized tooth structure toward non-surgical or minimally invasive restorative techniques[5].

Near infrared imaging technology

Near Infrared Imaging serves as a valuable diagnostic aid in the early detection of interproximal caries. The near infrared (NIR) is the region of the electromagnetic spectrum between 0.7 to 2.0 micrometers (μm)[6]. The iTero Element 5D Imaging System uses light of wavelength (= 850nm) in the electromagnetic spectrum which on interaction with the hard tissue of the tooth provides additional data of its structure. Enamel is transparent to NIRI due to the reduced scattering co-efficient of light, allowing it to pass through its entire thickness and present as a dark area, whereas the dentin appears bright due to the scattering effect of light caused by the orientation of the dentinal tubules, any interferences/pathological lesions/ areas of demineralization appear as bright areas in a NIRI image due to the increased scattering within the region.

iTero Element 5D Imaging System is an innovative integrated optical diagnostic aid (uses class 1 laser) and is the first 3D intraoral scanner with NIRI technology. With one scan, it is possible to view multiple layers of data: 3D model, 2D color images and NIRI images mapped to the 3D model. The user can rotate a 3D model of the teeth on the computer monitor and without looking at the patient to evaluate it from different angles and review the corresponding color and NIRI images at the same time to gather a comprehensive view of the situation. The system digitally captures the 3D geometry and color of the patient's intraoral dental structures using a proprietary optical, non-contact, focus detection technique.

The device also includes capabilities of NIRI function that captures data beneath the tooth surface using NIRI illumination during routine scanning. Incorporating both the NIRI images and the color images captured by the system can aid in the detection of caries. Images are available in real time on the screen, can be enlarged, and contrasts can be adjusted based on preference. Additionally, scans can be saved and viewed later as desired or paired with tools such as TimeLapse to monitor areas of interest.

Optical methods have the advantage that they do not use ionizing radiation. For this reason, these procedures can be used as often as desired to monitor caries. Several clinical studies have showed NIRI sensitivity to be as potent as radiographic examinations and are well suited for the detection and imaging of interproximal caries[7].

*iTero Element 5D is not yet available for sale in the US.*iTero Element 5D is currently available in European Union countries with exception in Switzerland and Norway.

Literature

Numerous studies have been conducted concerning near infrared imaging that can be traced back to the early 1990s. Some noteworthy articles have been mentioned as follows:

1. Fried D, Glena RE, Featherstone JD, Seka W. Nature of light scattering in dental enamel and dentin at visible and nearinfrared wavelengths. Applied Optics. 1995;34(7):12781286[8]

Objective: In this study, Fried et al. measured the optical properties of fully index-matched samples of enamel and dentin as a step in calculating the distribution of deposited energy in teeth. The light-scattering properties of dental enamel and dentin were measured at 543, 632, and 1053 nm between 0° and 180° in appropriate index-matching baths. From the measured distributions and comparison with Monte Carlo 1MC2 simulations of light scattering in these tissues, the optical coefficients, the nature of the phase function, and the scattering anisotropy were derived for dentin and enamel at these wavelengths.

Results: In the visible and NIR wavelengths, dentin and enamel weakly absorb light, and light scattering plays an important role in determining the deposited energy distribution in the tissue. The scattering and absorption coefficients of enamel compare favorably with literature values measured using an integrating sphere. The measured scattering and absorption coefficients of dentin are both almost an order of magnitude larger than for enamel. Preliminary, two-dimensional, spatially resolved MC simulations using the optical parameters determined in this study indicate that the use of visible and NIR laser beams of, 1-mm diameter on the enamel surface may lead to preferential energy deposition near the dentin–enamel interface. This may have negative consequences such as subsurface heating and cracking.

Relevance: Use of NIRI has been studied in enamel, which shows high transparency. There is published data available regarding this technology in teeth, and more specifically in enamel and dentin. There is substantial evidence dating from 1990 for the potential use of NIR light for detecting caries in enamel, due to its high transparency when illuminated by Near Infra-Red light.

2. Comparison of diagnostic methods for early interproximal caries detection with near-infrared light transillumination: an in vivo study Ismail Hakki Baltacioglu and Kaan Orhan[9]

Background: Although numerous studies have used digital intraoral imaging, only a few studies have used photo-optical methods for the diagnosis of caries. Moreover, several limitations exist in terms of observers (experience and specialty) and the caries lesion itself. Hence, the aims of this study were to evaluate the diagnostic capability of near-infrared light transillumination (NILT) and PSP-Bitewing radiographs and to compare the interobserver and intraobserver differences in addition to observers' experience level to detect early interproximal caries lesions in vivo

Methods: A total of 52 untreated posterior teeth with and without varying degrees of early interproximal carious lesions were included. Bitewing radiographs using digital phosphor plates (PSP-Bitewing) and NILT were used to clarify the diagnosis. An oral and maxillofacial radiologist and a restorative dentistry consultant evaluated the images twice. A separate appointment for clinical validation and restoration was made. Kappa coefficients were calculated to assess both intraobserver and interobserver agreements for each evaluation method. Scores obtained from PSP-Bitewing and NILT were compared with the clinical validation via receiver operating characteristic (ROC) analysis.

Results: No significant differences were found between PSP-Bitewing radiography and NILT for detecting early interproximal carious lesions with high average Az results. Both intraobserver and interobserver agreement values were relatively higher for NILT evaluation. The Az values increased at second evaluations for both caries detection methods.

Conclusion: NILT examination has an appropriate sensitivity and diagnostic accuracy for detecting early interproximal caries lesions and can be considered as a method of choice for detecting caries without the use of ionizing radiation.

3. Evaluation of two imaging techniques: near-infrared transillumination and dental radiographs for the detection of early approximal enamel caries. Maia AM, Karlsson L, Margulis W, Gomes AS.[10]

Objective: The aim of this paper was to evaluate a transillumination (TI) system using near-infrared (NIR) light and bitewing radiographs for the detection of early approximal enamel caries lesions.

Methods: Mesiodistal sections of teeth (n = 14) were cut with various thicknesses from 1.5 mm to 4.75 mm. Both sides of each section were included, 17 approximal surfaces with natural enamel caries and 11 surfaces considered intact. The approximal surfaces were illuminated by NIR light and X-ray. Captured images were analysed by two calibrated specialists in radiology, and re-analysed after 6 months using stereomicroscope images as a gold standard.

Results: The interexaminer reliability (Kappa test statistic) for the NIR TI technique showed moderate agreement on first (0.55) and second (0.48) evaluation, and low agreement for bitewing radiographs on first (0.26) and second (0.32) evaluation. In terms of accuracy, the sensitivity for the NIR TI system was 0.88 and the specificity was 0.72. For the bitewing radiographs the sensitivity ranged from 0.35 to 0.53 and the specificity ranged from 0.50 to 0.72.

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Conclusion: In the same samples and conditions tested, NIR TI images showed reliability and the enamel caries surfaces were better identified than on dental radiographs.

4. Russotto, F, Tirone, F, Salzano, S, Borga, FC, Paolino, D, Ferraro, A, Botasso, S. Clinical evaluation of near-infrared light transillumination (NIRT) as an interproximal caries detection tool in a large sample of patients in a private practice. J Radiol Imaging. 2016;1(1):1-5[11]

Background: A study has been carried out in order to evaluate in vivo the diagnostic performance of near-infrared light transillumination (NIRT) compared to digital radiographic examination (RE) in the detection of class II carious lesions.

Methods: A total of 114 patients were included, and 2957 proximal surfaces were considered. Surfaces were imaged by means of NIRT and radiographed with a photostimulable phosphor system. NIRT and radiographic images were observed by two blinded operators. Their diagnoses were compared with those made while visiting the patients, when visual-tactile, radiographic and NIRT data were matched by expert operators to obtain the reference diagnoses. Sensitivity, specificity and inter-observer consistency were calculated.

Results: Throughout the visits, 395 caries were detected. When investigating without clinical information and in a blind manner, RE performed significantly better than NIRT regarding sensitivity analysis (0.591 vs. 0.456, p<0.001), and NIRT performed significantly better than Radiographic examination (RE) regarding specificity analysis (0.980 vs 0.933,p<0.001). However, NIRT showed sensitivity similar to RE when only enamel caries were concerned. With regard to no agreement between the two positives for enamel caries (95% from 0.699 to 0.791) was observed in RE. NIRT was very likely to detect and correct the erroneous positive diagnosis of enamel carious lesions obtained using RE (955 CI for probability from 0.938 to 0.979).

Conclusions: NIRT should be used in caries diagnosis in combination with radiographic images. In fact, NIRT can help to correct a false positive diagnosis of enamel caries. Furthermore, NIRT could be used to detect caries in patients for whom non-urgent radiographic exposition is contraindicated and to monitor caries in medically treated patients.

5. Caries Detecion and Diagnostics with near – infrared light transillumination : Clinical experiences .Friederike Sochtig, DDS/Reinhard Hickel,DDS./Jan Kuhnisch,DDS,MDS[12]

The aim of the study was to present the function and potential of diagnosing caries lesions using a recently introduced near-infrared(NIR) transillumination technique (DIAGNOcam, KaVO).

Materials and Methods: The study included 130 adolescents and adults with complete permanent dentition (age >12). All patients underwent visual examination and, if necessary, bitewing radiographs. Proximal and occlusal surfaces, which had not yet been restored, were photographed by a NIR transillumination camera system using light of 780nm rather than ionizing radiation. OF the study patients.85 showed 127 proximal dentin caries lesions that were treated operatively.

Results: Based on the practical experiences to date by the authors, a possible classification of diagnosis was introduced. The main result of the study was that NIR light was able to visualize caries lesions on proximal and occlusal surfaces.

Conclusion: The study suggests that NIR Trans illumination is a method that may help to avoid bitewing radiographs for diagnosis of caries in everyday clinical practice.

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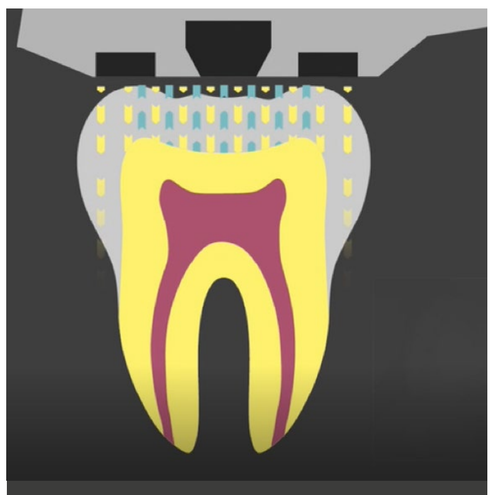
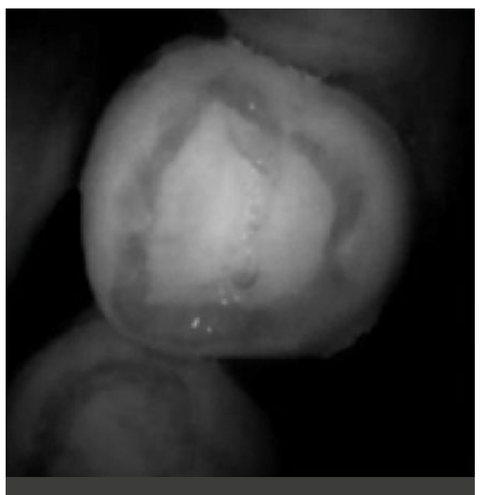
NIRI - A reflective concept of light and its mechanism of action



The iTero Element 5D intraoral scanner uses light of 850nm that penetrates into the tooth structure to produce a NIRI image.



NIRI image of a healthy tooth

NIRI as a diagnostic aid for interproximal caries detection above the gingiva without use of radiation:

Interproximal carious lesions are clinically apparent as a chalky white discoloration. It is estimated that it takes about 4 years for an inital proximal lesion to be seen clinically[13]. Effective diagnosis of interproximal carious lesions is affected by the natural anatomy of the tooth, alignment within the arch and technique sensitivity involved with radiographs.

A study conducted at the University of California (UCLA) School of Dentistry found that when using traditional film radiographs, caries presence and depth are misdiagnosed up to 40% of the time. In addition, healthy teeth are misdiagnosed as having caries up to 20% of the time.

Hence, using effective tools that aid in confirming the presence of a lesion at it's earliest stage can prove to be a major advantage while treating patients.

Image interpretation - Healthy tooth

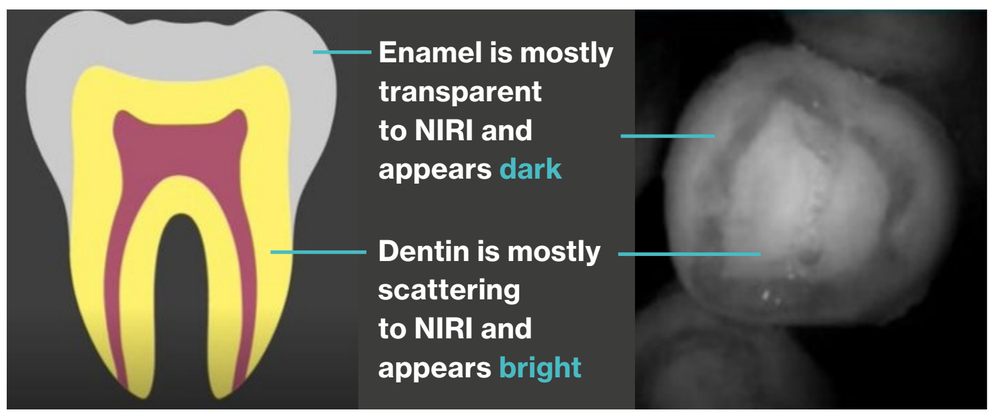
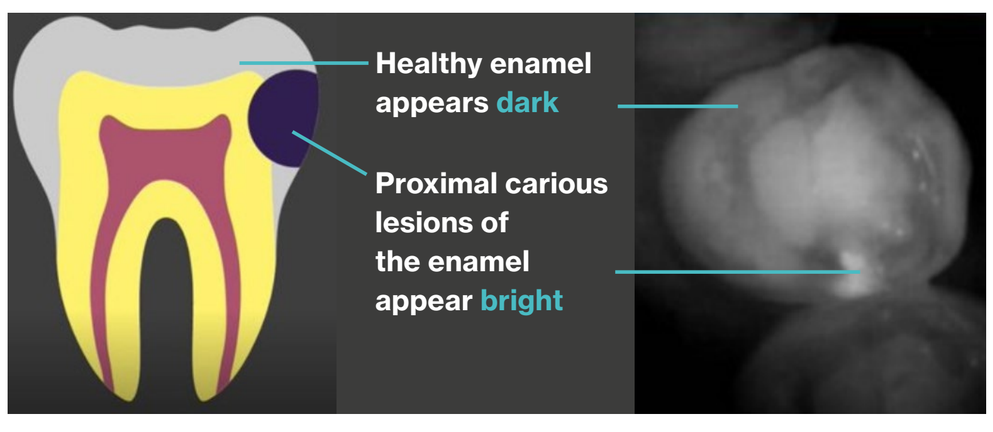


Image interpretation - Tooth with caries



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Case presentation 1:
Healthy tooth structure (maxillary premolar #12)

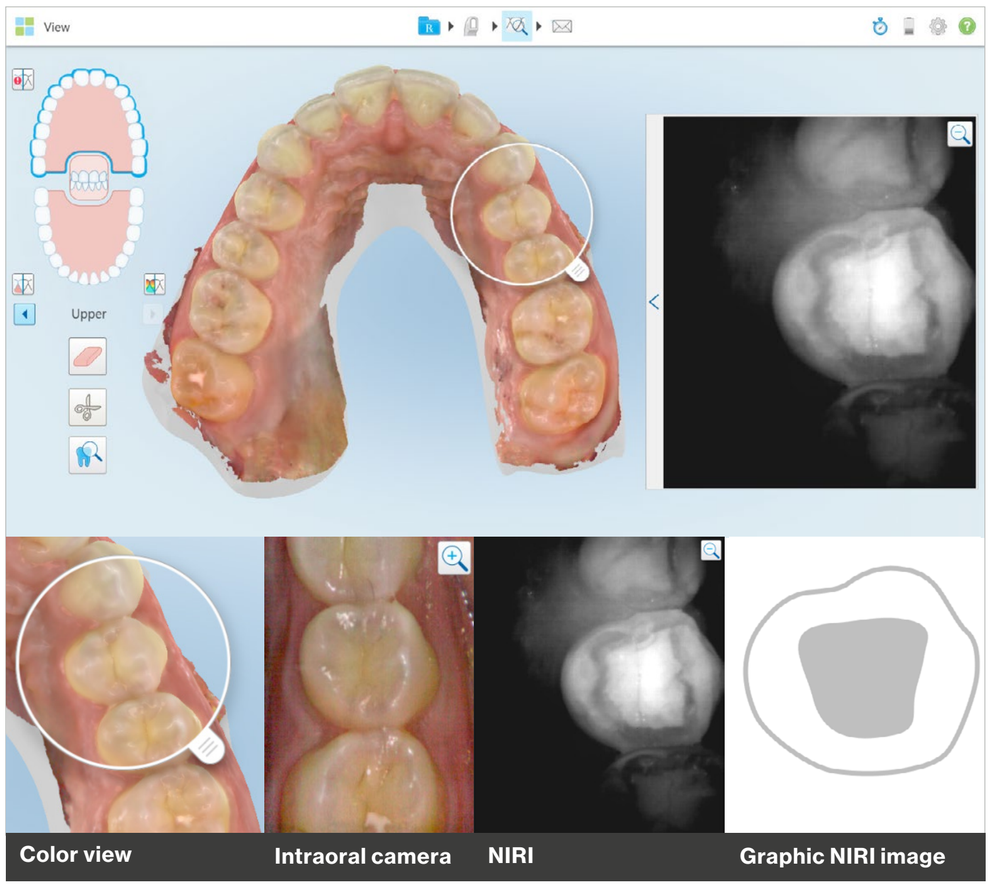

Fig. 1

Figure 1: Image demonstrating the left maxillary premolar #12 as seen in NIRI. A uniformly dark outer enamel layer with a bright center indicating the dentin is a classic example of a healthy tooth structure with no apparent lesions, note the constrast between the enamel-dentin provides a clear, appreciable demaraction between the two.

When examined in multiple modes (color view, intraoral camera view and NIRI) comparisons can be made to aid in differential diagnosis; in this case, uniform color of the tooth with no apparent discoloration or loss of structural integrity indicates the presence of a healthy tooth.

Case presentation 2:
Healthy tooth #10 with an Invisalign attachment

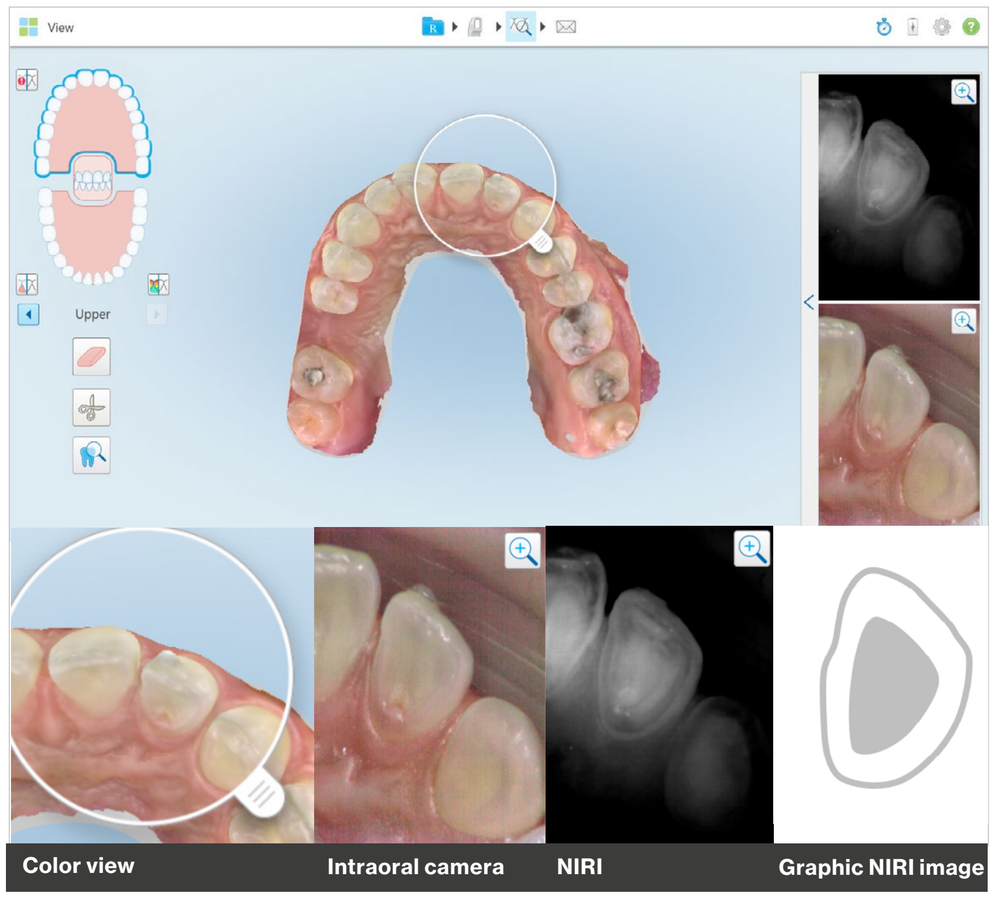

Fig. 2

Figure 2: Image showing (#10) left maxillary lateral incisor with an Invisalign attachment on the buccal. Inspection of the occlusal surface under NIRI suggests a healthy tooth structure with no evidence of carious lesions or enamel demineralization.

Note: The presence of attachments in this case does not have any negative effect on the NIRI image.

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Case presentation 3:
Proximal carious lesion (maxillary premolar #13)

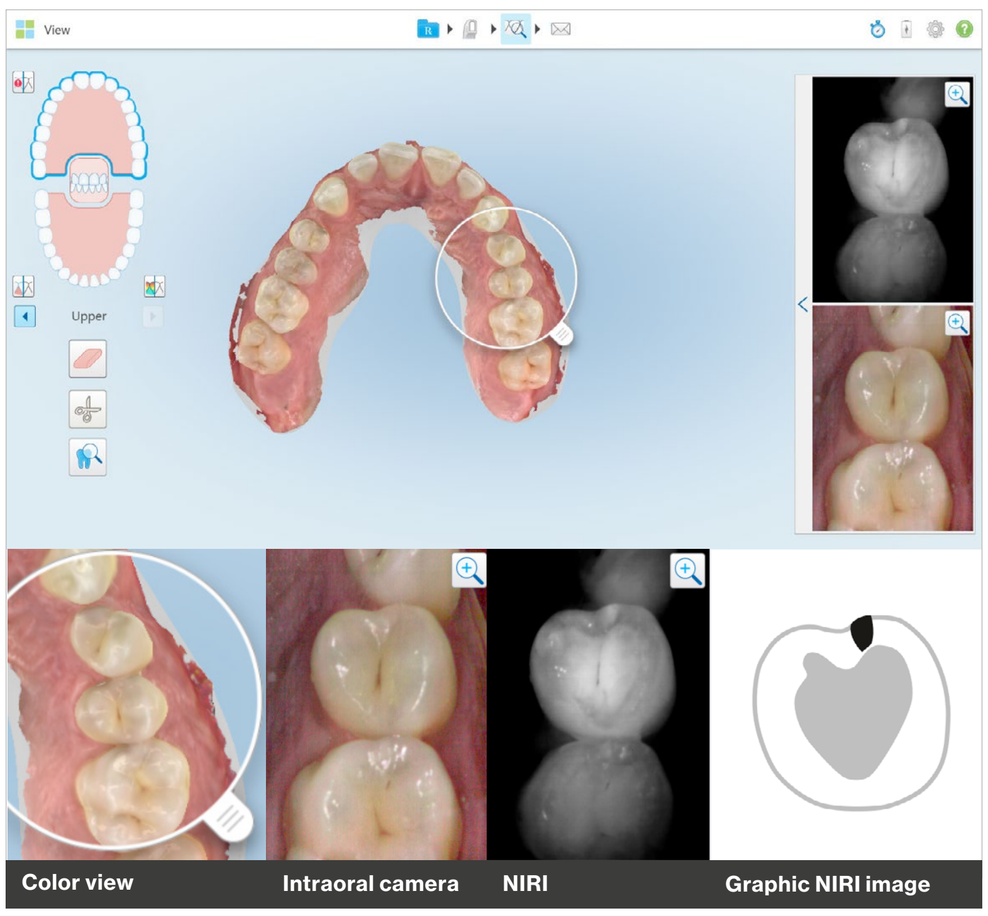

Fig. 3

Figure 3: A bright spot in the mesial aspect of the left maxillary premolar indicates the presence of a proximal carious lesion. The position of #12 (rotated and inclined) in relation to #13 creates a narrow area which is difficult to clean and may favor accumulation of food and debris over time. Note in the image from the intraoral camera there is no evidence of underlying carious activity.

Case presentation 4:
Proximal carious lesion and composite filling (Maxillary premolar #13)

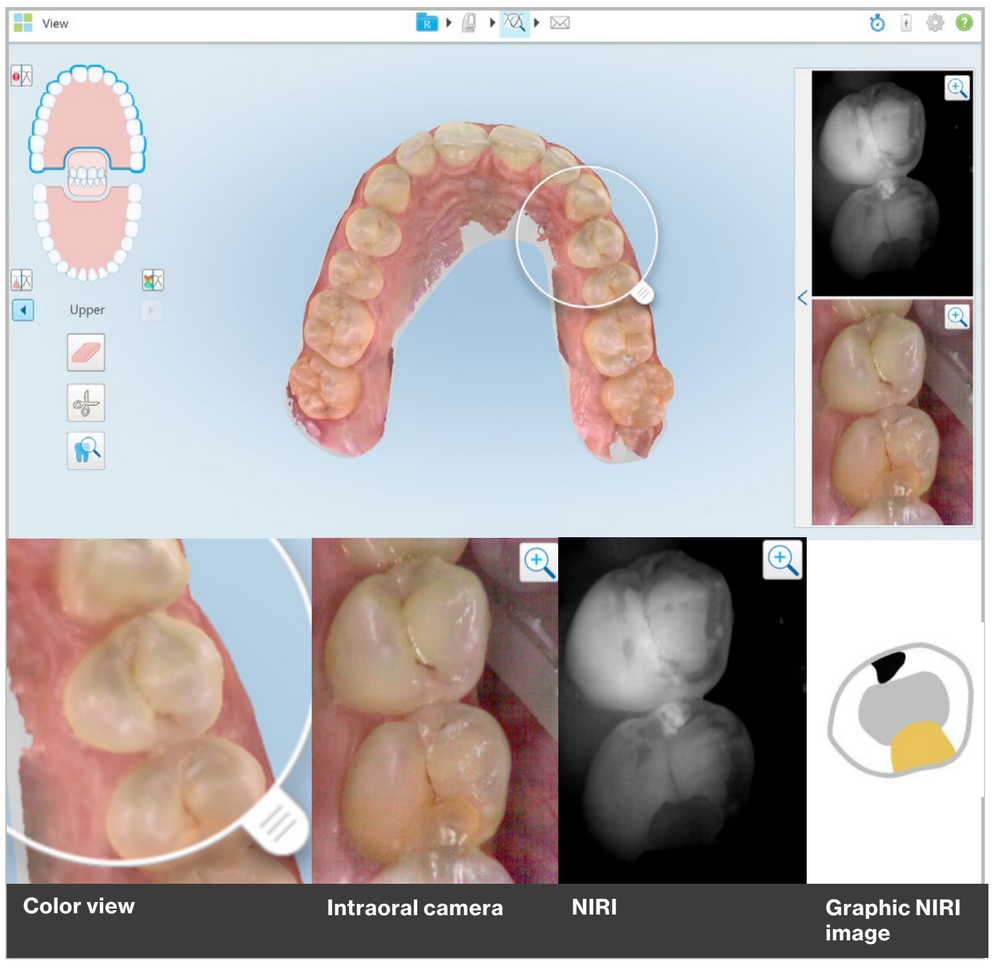

Fig. 4

Figure 4: A mesial bright spot in the left maxillary premolar (#13) indicates the presence of a carious lesion. Note the distal of #13 presents with a dark area, on comparison with the color image from the intraoral camera, the presence of an existing composite restoration is confirmed.

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Case presentation 5:
Proximal carious lesion (maxillary premolar #4

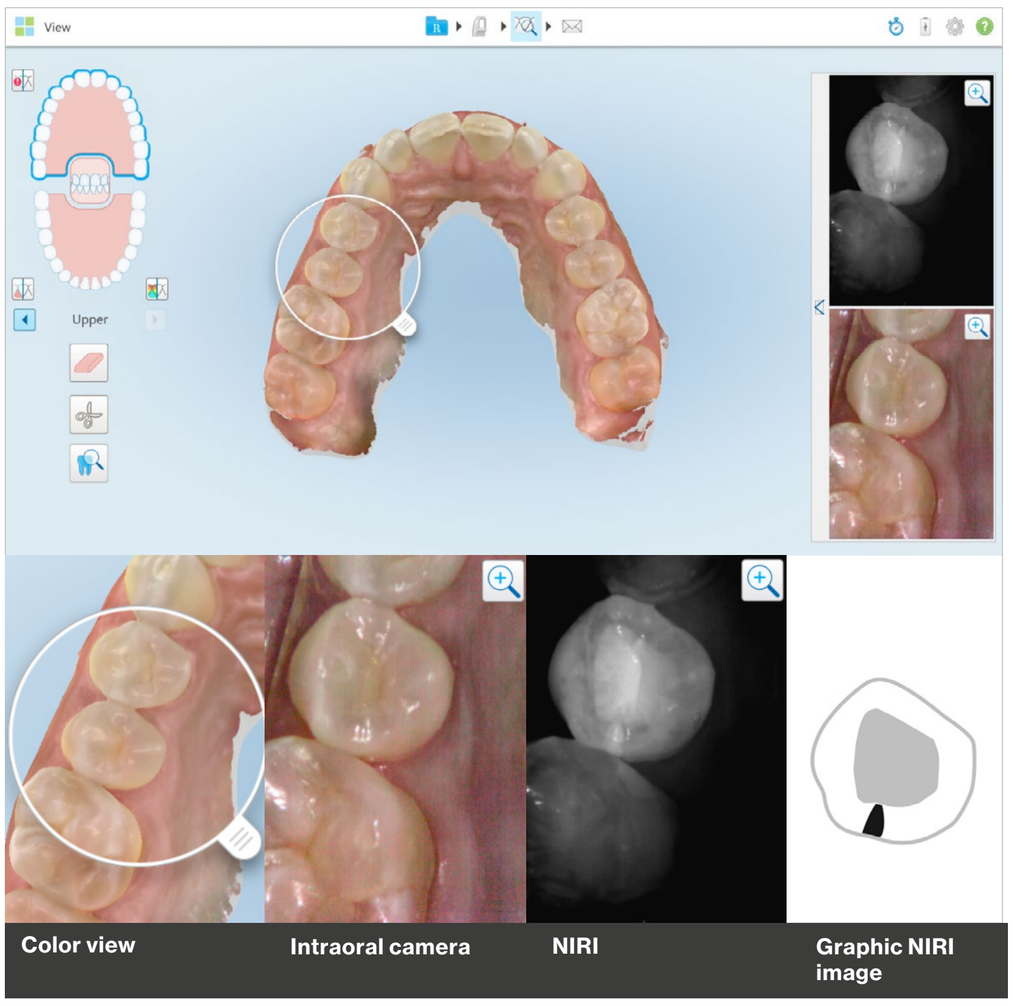

Fig. 5

Figure 5: NIRI image of #4 indicates a bright wedge shaped area advancing towards the DEJ suggesting the presence of carious activity.

Case presentation 6:
Proximal carious lesion (maxillary premolar #12)

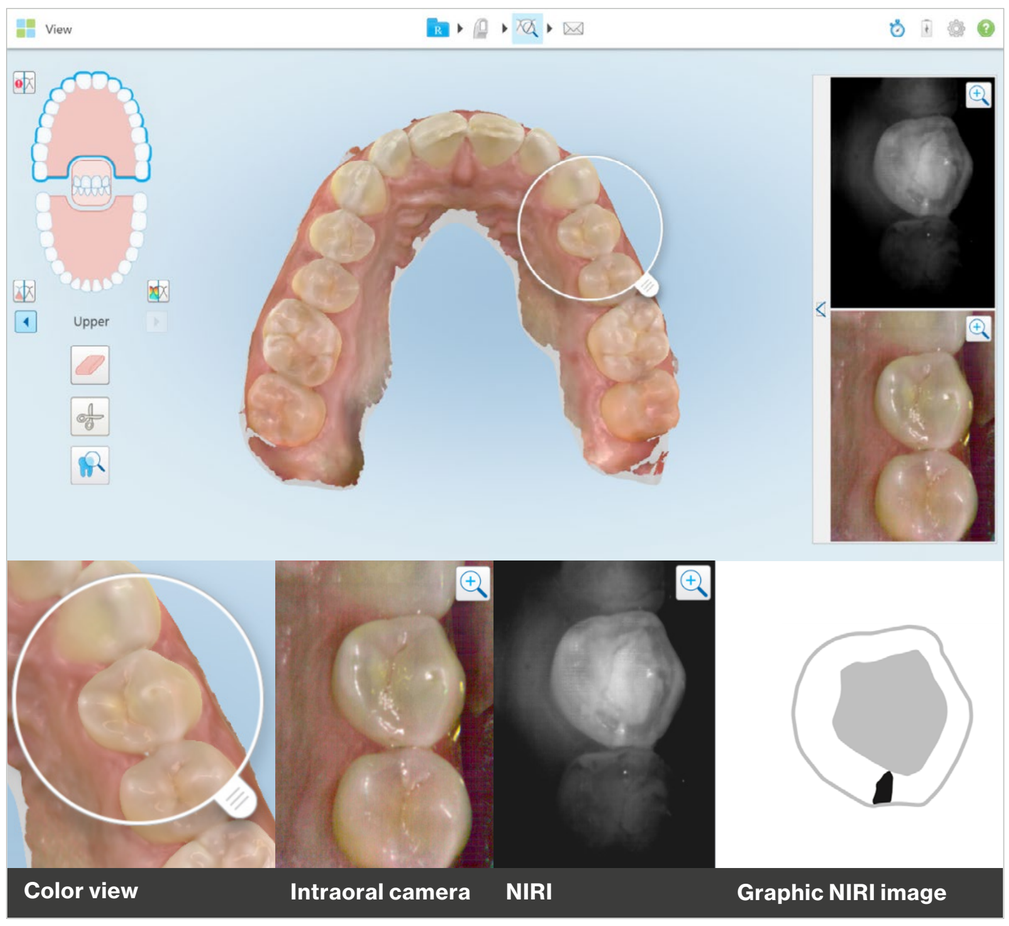

Fig. 6

Figure 6: NIRI image of #12 indicates the presence of a proximal carious lesion (distal).

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Case presentation 7:
Healthy tooth (maxillary left premolar #12)

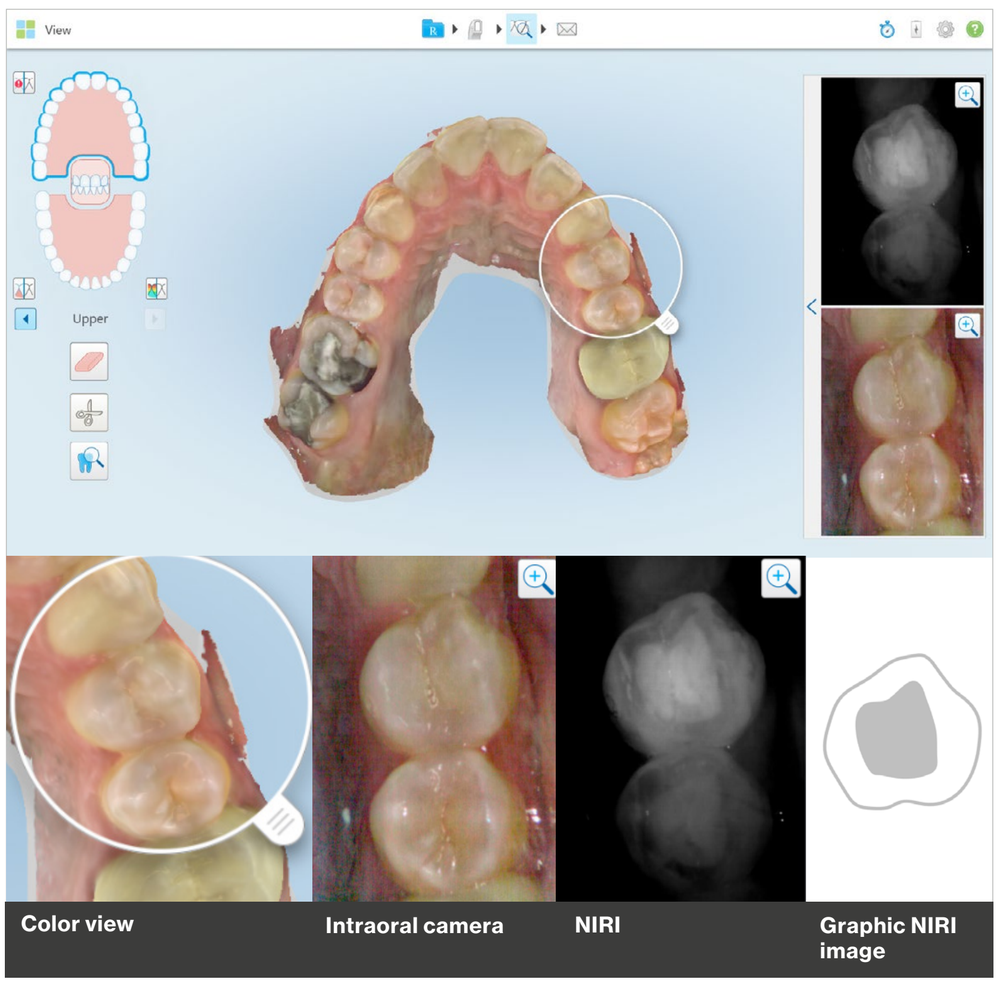

Fig. 7

Figure 7: Image showing (#12) left maxillary premolar, corresponding NIRI image suggests a healthy tooth structure with no evidence of carious lesions or enamel demineralization

Case presentation 8:
Dental fluorosis (mandibular left canine #22), distal interproximal carious lesion (#21)

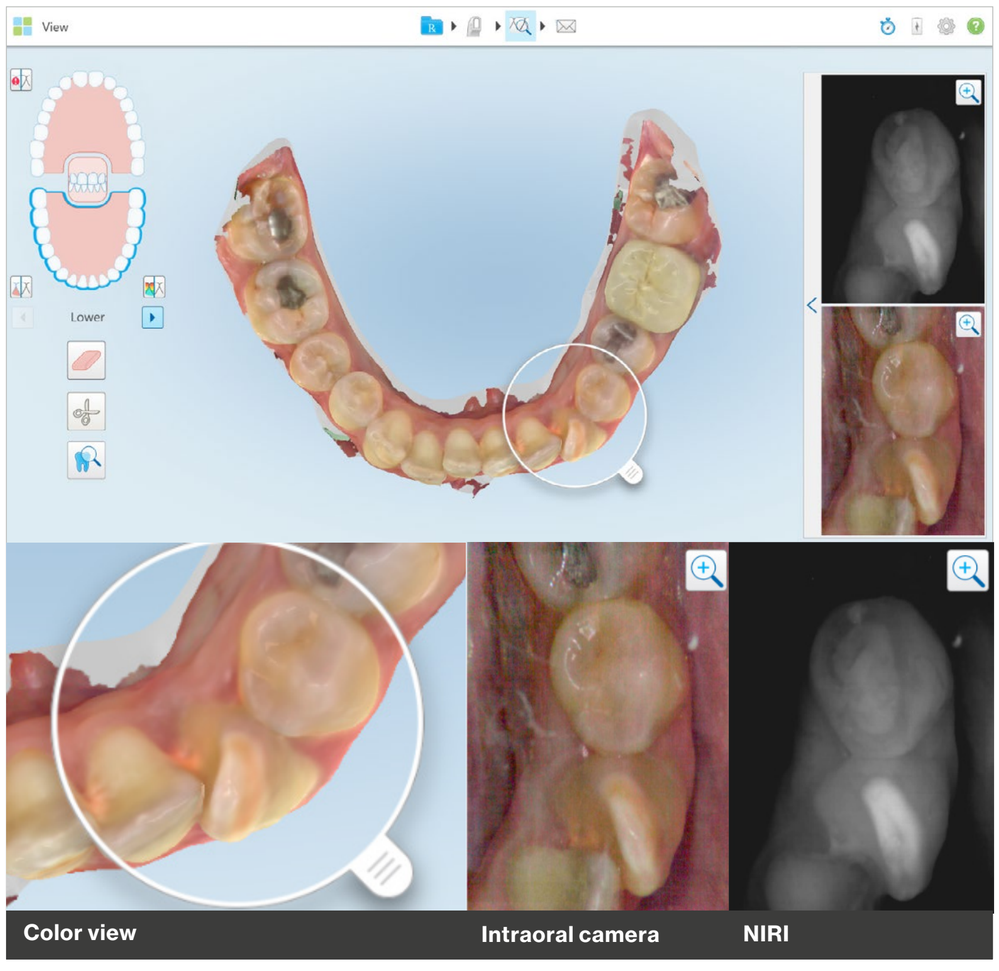

Fig. 8

Figure 8: Dental flurosis is one of the most common disorders of the enamel presenting with characteristic permanent discoloration. This case is particularly interesting as is it shows the ability of NIRI to detect the changes in the structural integrity of enamel. Note: Instances like these may mimick the presence of caries, in such instances it is valueable to make comparisons with color images before arriving at a conclusion. Also seen in this image is a distal interproximal carious lesion on #21.

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Case presentation 9:
Bonded mandibular lingual arch wire

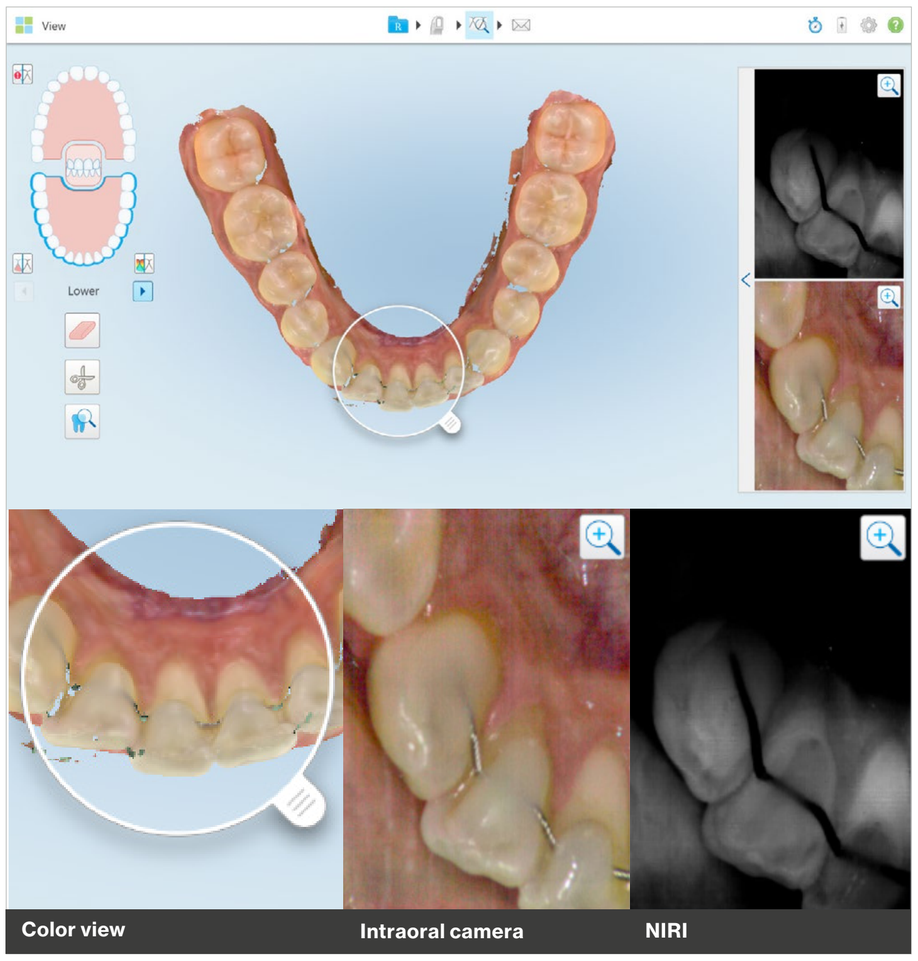

Fig. 9

Figure 9: Image shows a good example of a bonded lingual arch wire in the mandibular anteriors. Note: The NIRI image remains abolsutely clear of any obstacles and ready for interpretation.

Case presentation 10:
Stains in the mandibular anteriors (lingual)

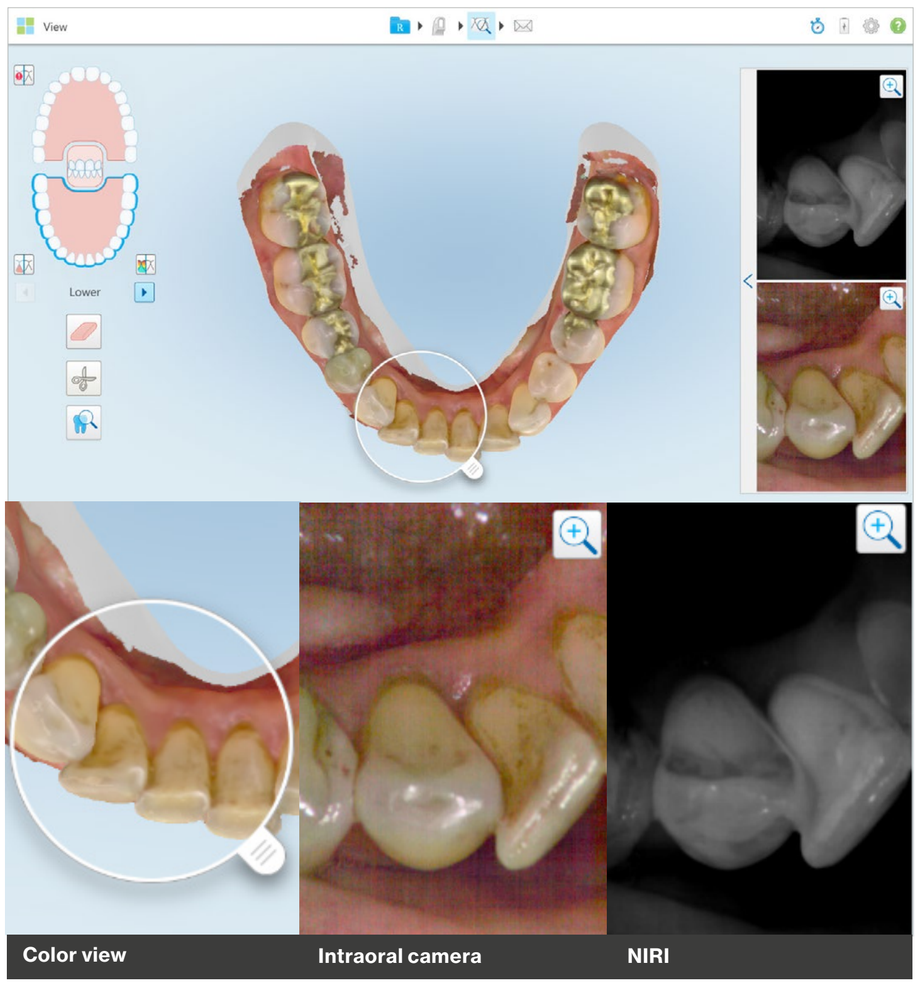

Fig. 10

Figure 10: Stains are commonly seen in the mouth especially in individuals who have a habit of smoking. The above image suggests that stains do not have any significant effect on the resultant NIRI image.

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Case presentation 11:

Proximal carious lesion (mesial#4 and distal #5) with treatment plan

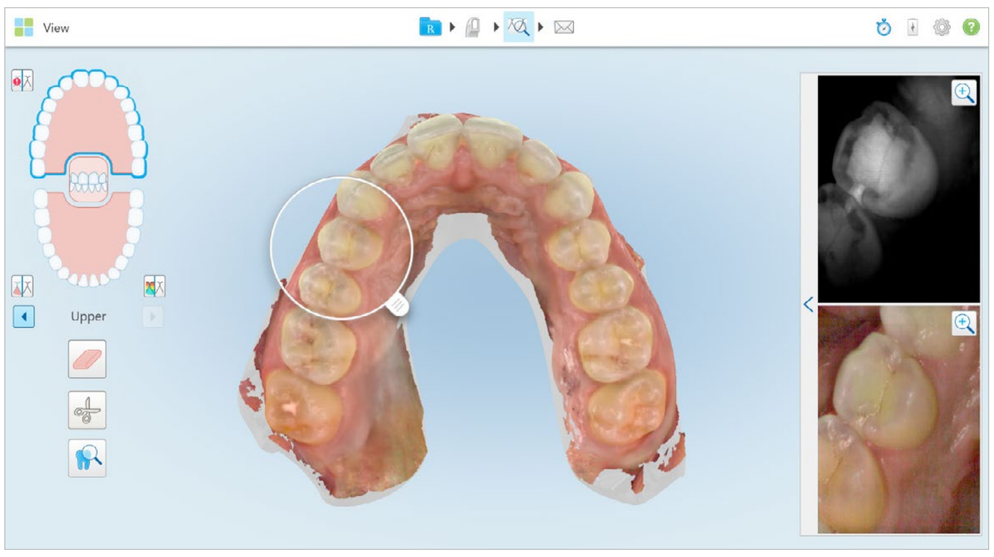


Fig. 11

Figure 11: Image on the left shows a patient scan from a routine dental check-up appointment. Patient had no visual intraoral signs of caries or any associated pain. Find below a detailed summary of the steps taken in the diagnosis and treatment planning which lead to successfully restoring a proximal carious lesion in #5 in the early stages completed in a single visit.

01

Image from the intraoral camera

On visual examination, small white surface spots were present on #5.

Patient did not feel any pain associated with #5.

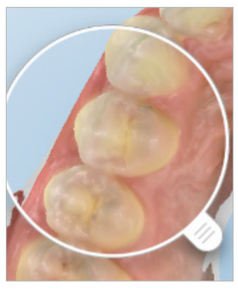
02

Periapical radiographs

Periapical x-rays were prescribed as a part of routine check-up.

Radiograph suggested no significant findings.

03



iTero scan in colour

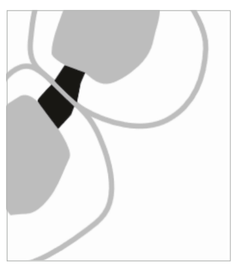
Findings from the scan were same as that from the intra oral camera.

04

NIRI image

The NIRI image of the same area shows bright spots in the distal area of #5 suggesting the presence of a proximal carious lesion advancing towards the DEJ.

05



Graphic representation

Graphic representation of #5

06

Treatment procedure photograph

Based on the findings from NIRI, on removal of superficial tooth structure, brown, decayed carious lesion in the distal aspect was found.

07

Post treatment photograph

Based on the findings from NIRI, on removal of superficial tooth structure, brown, decayed carious lesion in the distal aspect was found.

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Case presentation 12:
Calculus and stains in the mandibular anterior teeth

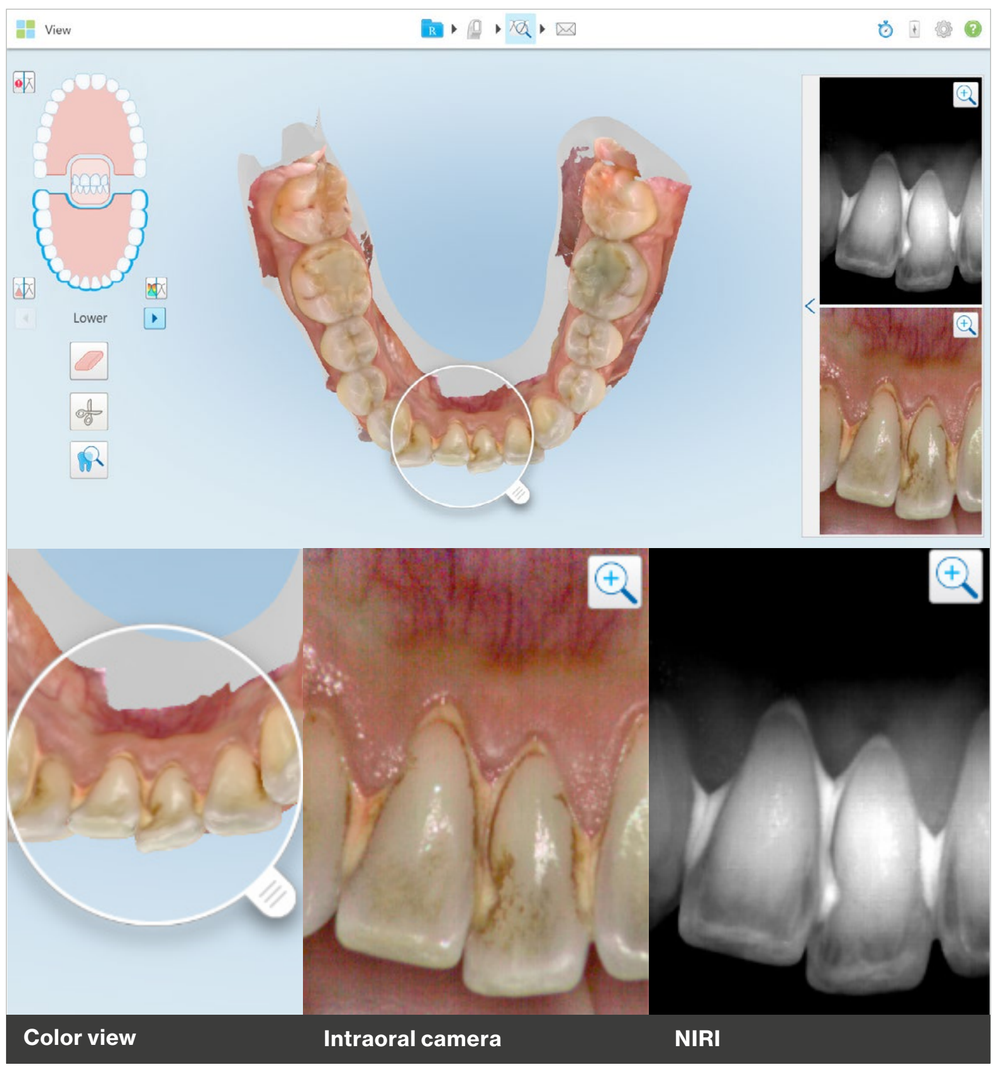

Fig. 12

Figure 12: The formation of calculus can be triggered by multiple factors; most commonly diet, poor oral hygiene, systemic disease or medication. The presence of calculus does not have any significant effect on the tooth in NIRI; Calculus itself presents as areas of brightness in NIRI.

Case presentation 13:
Proximal carious lesion in the mesial of #31 with treatment planning

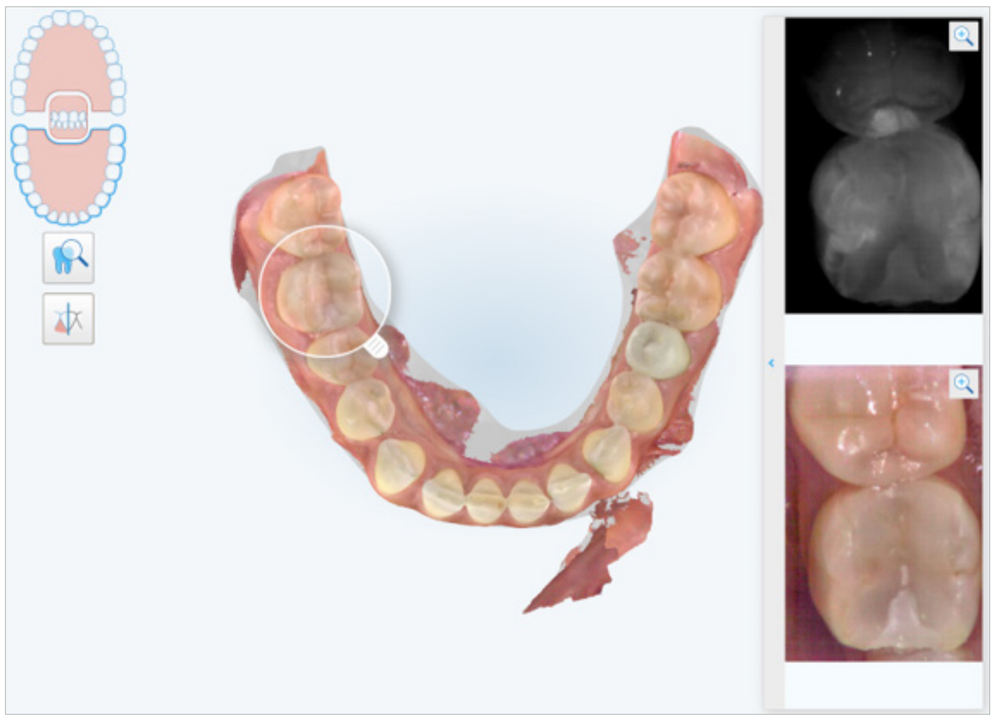

Fig. 13

Figure 13: Image to the left shows a patient scan from a routine dental check up appointment. Patient had no symptoms of caries or any associated pain. Find below a detailed summary of the steps taken to diagnose and plan treatment for a proximal carious lesion in the mesial of tooth #31.

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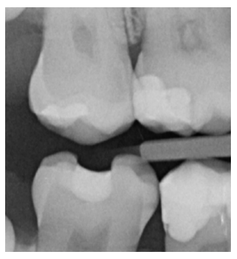
01

Image from the Intraoral camera

On visual examination, mild discoloration with existing composite restorations on tooth #30 and #31 were seen.

02



Bitewing Radiographs

Bite wing radiographs were prescribed as a part of the routine check up.

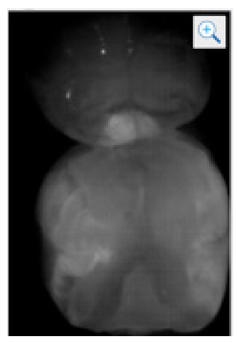
03

OPG

An OPG was also taken for this case, OPG verifies the existing restorations on tooth #30 and #31.

The radiograph indicates a presence of an interproximal lesion on #31 and an existing restoration on #30

04



NIRI image

The NIRI image suggests a bright conical lesion with its apex directed towards the dentin suggests the presence of a carious lesion in the mesial of #31.

Also seen in this image is a dark area in the mesial of #30 suggesting presence of a restoration.

05

Graphic representation

Graphic representation of #31.

06

Restorative procedure

With the NIRI image used as a reference, the affected tooth structure was removed and was followed by a restorative procedure.

Limitations of the technology: Current limitations of the technology are mostly around existing restorations. In the presence of restorations such as amalgam or composite resins, NIRI is unable to penetrate through the structure of the tooth. The insufficient data from the scan in these scenarios causes a blurry, dark and ill-defined resultant image that is not suitable for examination.

Instances mimicking interproximal caries: Teeth involving enamel demineralization conditions such as tooth wear, enamel hypoplasia and fluorosis (as seen in case 7) may mimic the presence of interproximal caries under NIRI; some dental cements (such as oxides and phosphates) may also exhibit the same behavior on interaction with NIRI, best practices to avoid misinterpretation in such cases would be to compare the NIRI images with the color images from the scan and other applicable examination techniques.

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Case presentation 14:
Composite restoration (mandibular right #29#30)

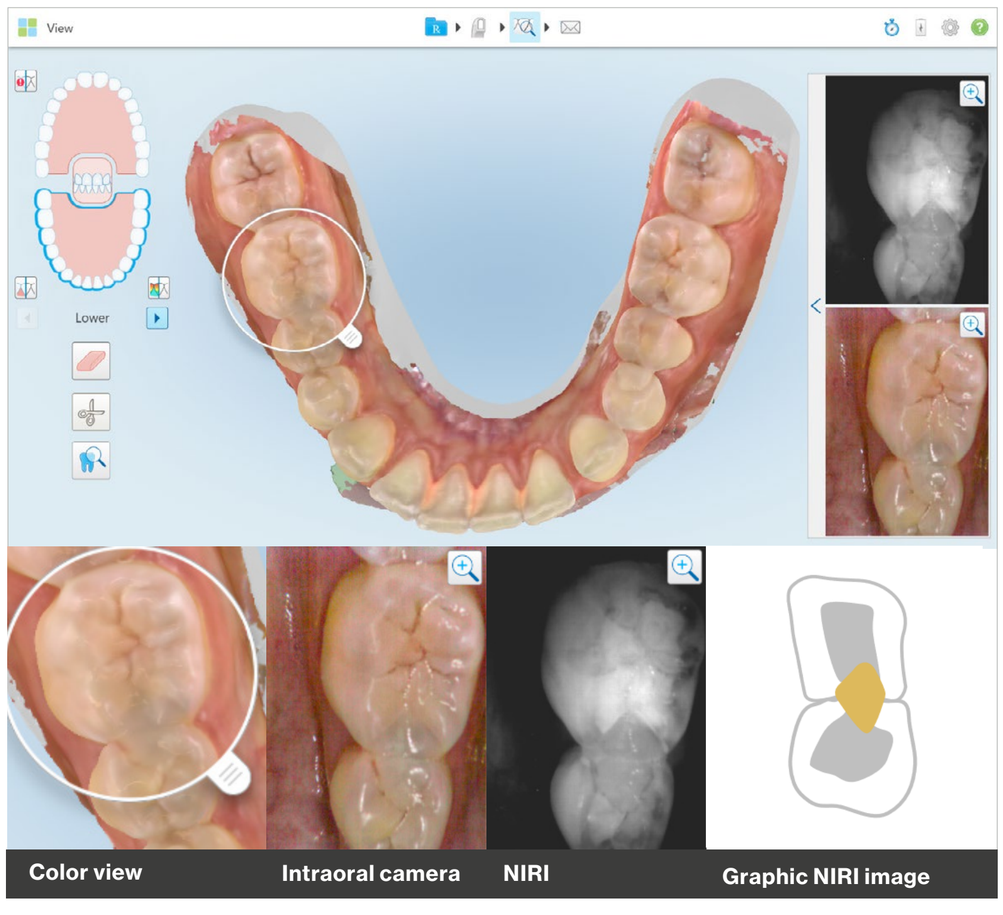

Fig. 14

Figure 14: Composite restoration in the distal of #29 and mesial of #30 presents as a dark area which is comparitively dull in constrast when compared with the adjacent structures. The inabiltiy of Near infrared light to pass through existing restoration results in the presentation of a dark area.

Case presentation 15:
Amalgam restoration (maxillary right molar #3)

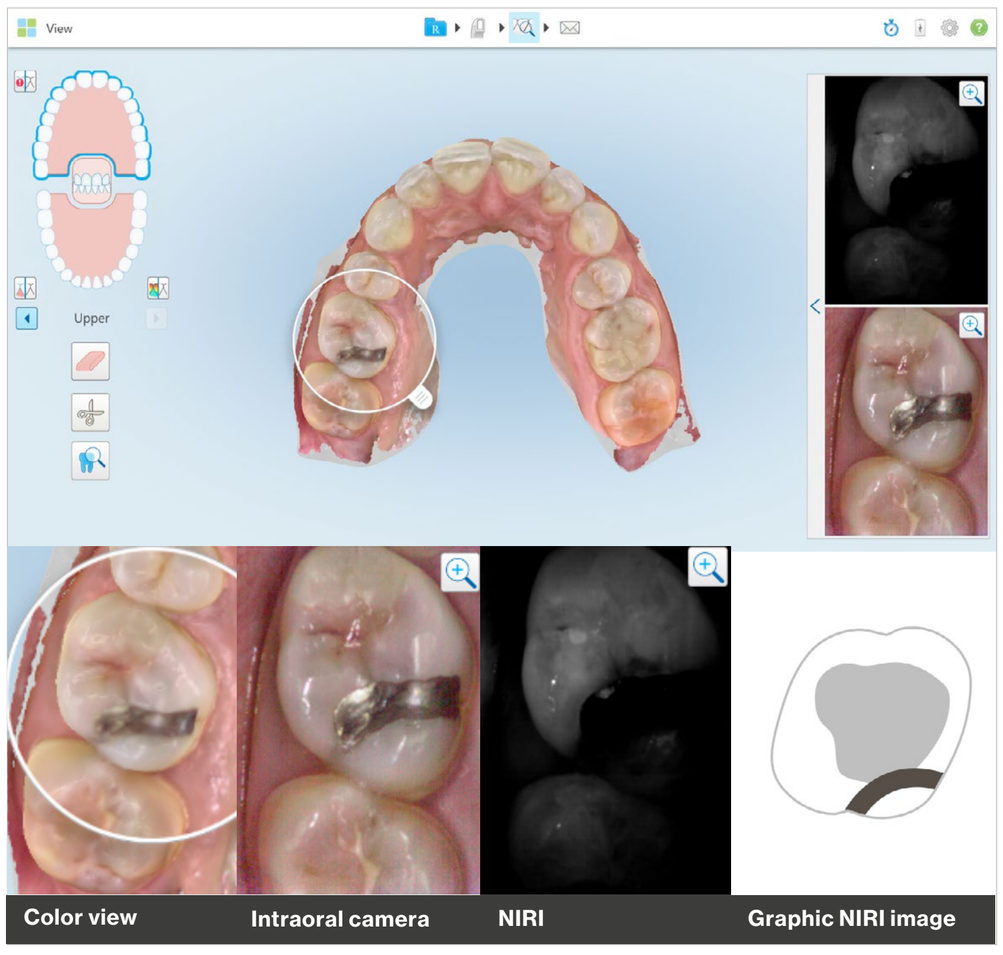

Fig. 15

Figure 15: Exisiting amalgam restorations (as seen to the left). Amalgam being an alloy creates a highly scattering effect on Near infrared light resulting in a dark image with ill defined anatomical landmarks which makes the image unsuitable for interpretation. In such cases, comparison with other available data is recommended.

*iTero Element 5D is not yet available for sale in the US.*iTero Element 5D is currently available in European Union countries with exception in Switzerland and Norway.

Conclusion: Constant improvements in dental technology are shaping the way clinicians practice across the globe. Interactive technology also serves as an added benefit to patients of all ages who may be apprehensive about their dental visits.

As seen from all the case presentations in this article, NIRI has demonstrated to be an effective tool in aiding the diagnosis and monitoring early stages of interproximal caries above the gingiva in a wide array of clinical scenarios, ultimately leading towards the successful management of caries even in its earliest stages. NIRI, which is non-invasive by nature, can be used as frequently as required to monitor the patient's oral health and provide the patient with chairside education, which enables patients to appreciate and understand the finer details associated with their oral health.

The iTero Element 5D imaging system helps turn the concept of comprehensive dentistry into a reality in every dental practice.

*iTero Element 5D is not yet available for sale in the US.*iTero Element 5D is currently available in European Union countries with exception in Switzerland and Norway.

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Mirela-Marinova – Tokorova

Clinical Evaluation of Near Infrared light transillumination as an interproximal caries detection tool in a large sample of patients in a private practice – Francesco Russotto,F Tirone,Stepho Salzano, Borga, Ferraro,S.Botasso 2016

DIAGNOcam--a Near Infrared Digital Imaging Transillumination (NIDIT) technology.

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Special acknowledgement: Align would like to thank Dr. Ingo Baresel, Dr.Olivier Boujenah, Dr. Timo Weihard for their contribution to this article.

*iTero Element 5D is not yet available for sale in the US.*iTero Element 5D is currently available in European Union countries with exception in Switzerland and Norway.

Best Practices

Restorative dentistry and digital scanning with the iTero Element™ Intraoral Scanner.

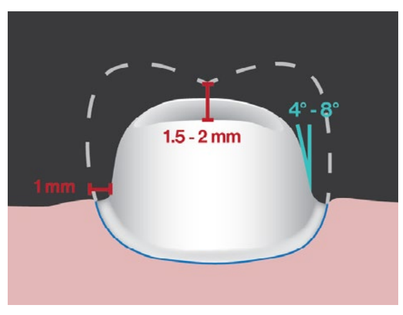
To download the full PDF please click here

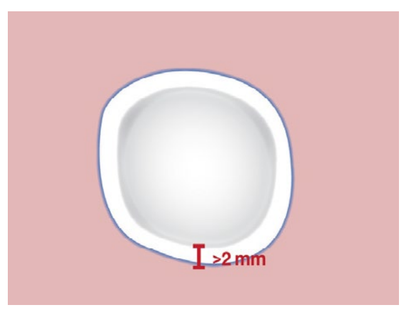
Dental restorations are designed to help maintain the form, function, and aesthetics of teeth. The accuracy of the final restoration depends on the accuracy of the recorded dimensions of the preparation. Margin placement and margin design are known to be the two main factors that govern the future health of a restored tooth. Therefore, careful step by step planning and clear communication with your lab is vital to achieving a successful result.

A few preliminary considerations in operative dentistry

Zirconia is a popular material of choice in contemporary restorative dentistry for crowns, dental bridges, and implants with characteristic properties such as compatibility, high fracture resistance, radiopacity, and super aesthetics. The following guidelines apply to Zirconia restorations and materials with similar properties.[1,2]

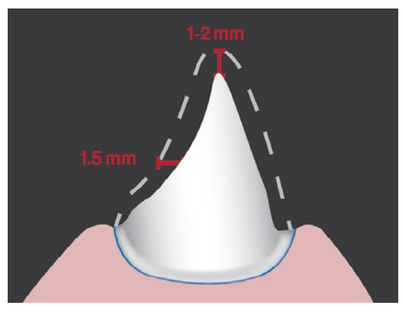
Preparation guidelines

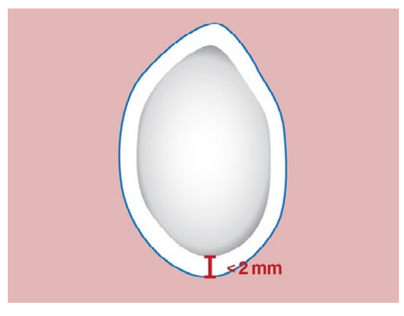




Posterior crowns

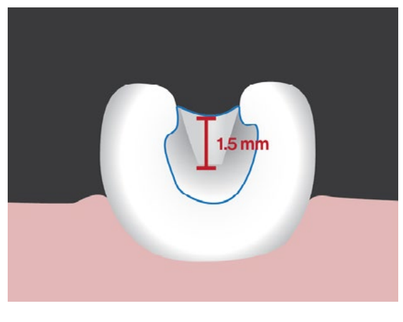
- Sufficient room for wall thickness with a minimum of 0.5mm and between 1-1.5mm or 1.5 to 2mm occlusal reduction
- Prep taper to be in between an angle of 4-8 degrees
- Visible and continuous circumferential chamfer
- Well rounded occlusal edges

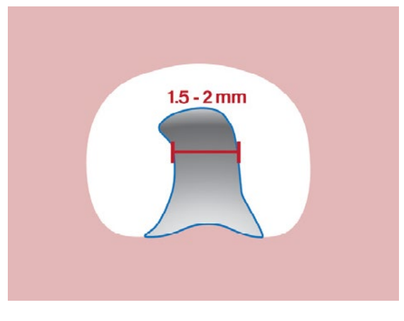




Anterior restorations

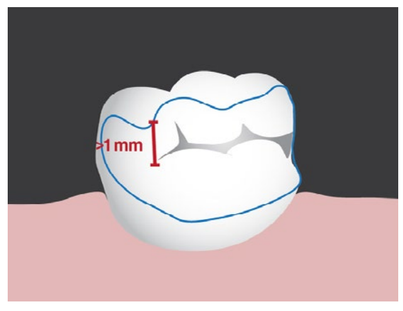
- Sufficient room for wall thickness with a minimum of 0.3mm and between 1-1.5mm or 1.8 to 2mm incisal reduction
- Visible and continuous circumferential chamfer with at least 0.5mm reduction at the gingival margin
- Vertical and horizontal prep of the tooth should have an angle of approximately 5 degrees
- Well rounded incisal edges

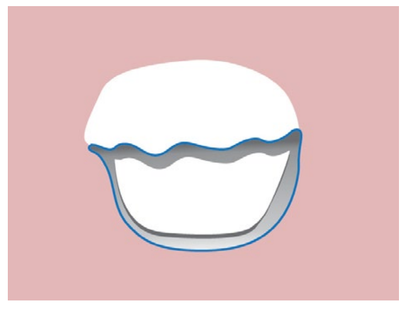




Inlay restorations

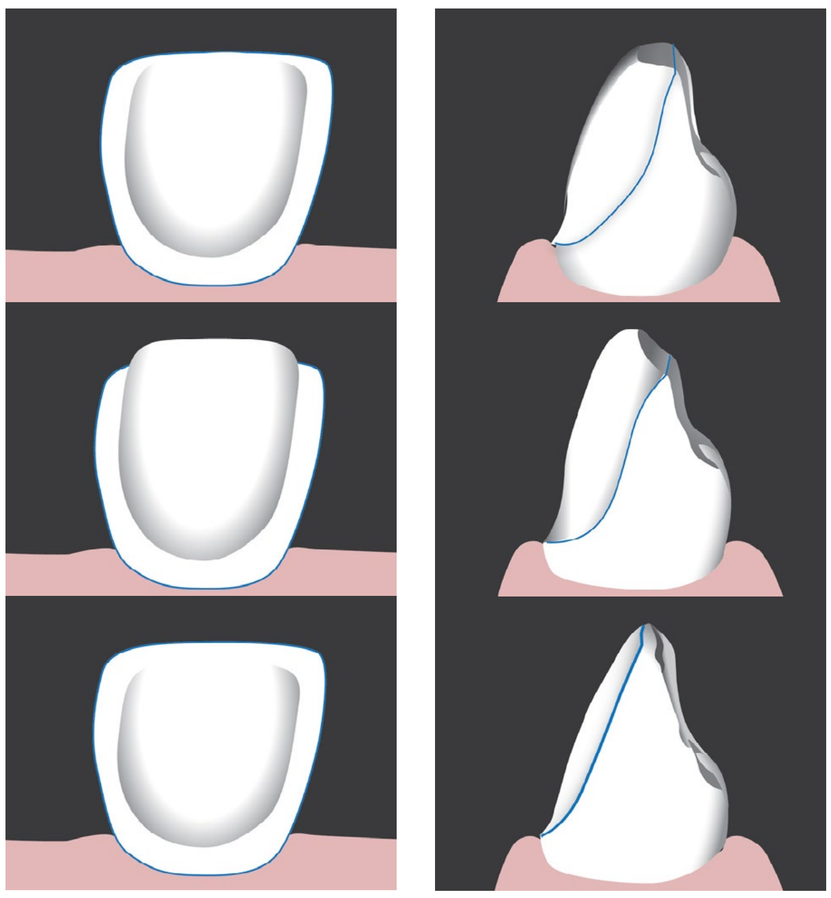
- Rounded internal line angles
- Butt joint margin
- 1 to 1.5mm wide gingival floor
- 1.5-2mm isthmus width
- 1.5mm isthmus depth





Onlay restorations

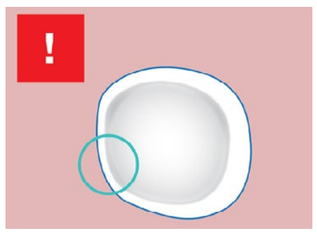
- Rounded internal line angles
- Butt joint margin
- 1 to 1.5mm wide gingival floor
- 1.5-2mm isthmus width



Veneers

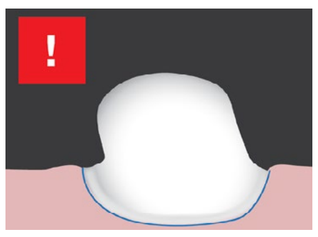
- A circumferential, continuous clear visible chamfer margin
- Provide the horizontal and vertical preparation with an angle of at least 5 degrees - avoid beveling
- Incisal reduction between 1.5-2mm
- All occlusal and incisal edges should be rounded
- Correct preparation of the chamfer margins interproximally allows the appropriate bulk of ceramic

Factors to consider while evaluating the tooth preparation for a crown (extracoronal restoration)



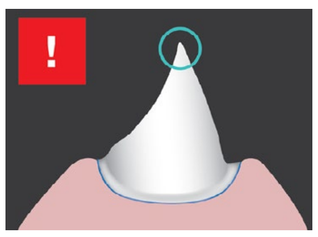
Feather edge

- While Knife edge/Feather edge margins provide conservation of tooth structure and acute margins in some cases, it may also create complications in milling with material limitations. Feather-edged margins on full coverage restorations should be avoided as they may result in:
  - Axial reduction fading out
  - Over-contouring
  - Susceptibility to distortion



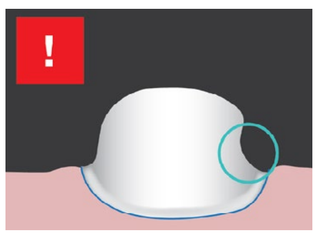
Angled preps

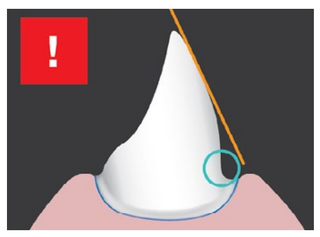
- Angled and inconsistency in tooth preparations leads to compromised retention and presents challenges for milling



Sharp incisal or occlusal edges

- Sharp incisal or occlusal edges may cause minor/major fit problems or in some cases, premature fractures of the restoration



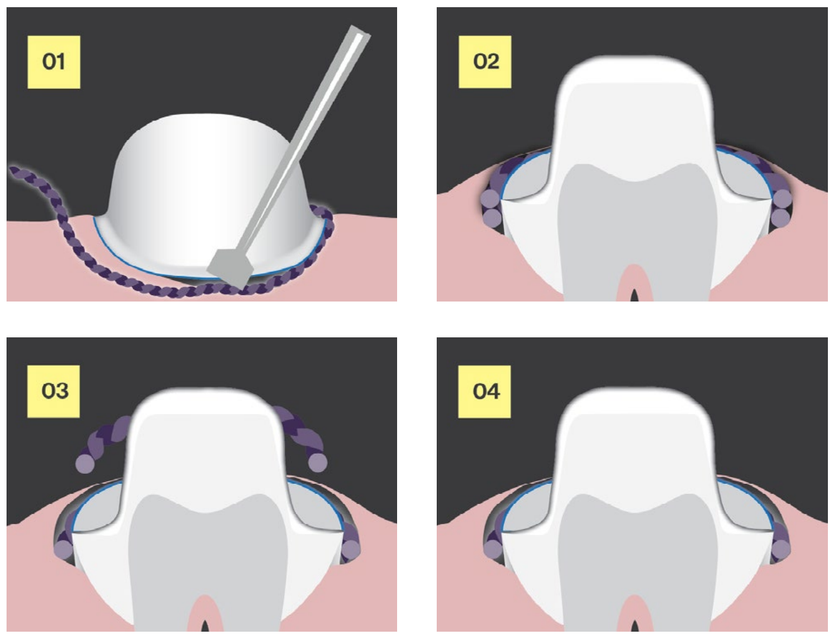


Undercuts

- Undercuts may be present where two axial walls face in opposite directions. In some cases, the presence of undercuts cause failure of seating the restoration

iTero™ restorative scan plan

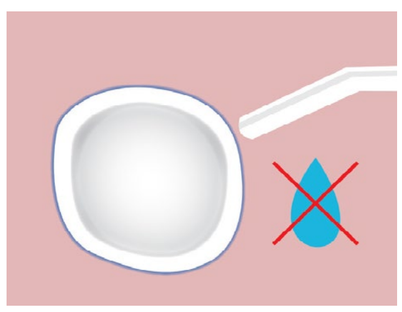
Best practices to achieve a high quality digital scan



Ensure clear and visible margins

Soft tissue retraction: Double cord technique

- A double cord gingival retraction method is recommended with one cord left in the sulcus during the scanning procedure in order to record clear and conscise margins



Isolation of the operative field

Goals of isolation:

- Moisture control (saliva, blood and/or GCF, retraction and access, safe and aseptic operating field)
- Commonly used isolation methods:

  Rubber dam, gingival retraction cord, cotton rolls, air syringe, and medications as needed

Utilise the dental chair light as needed

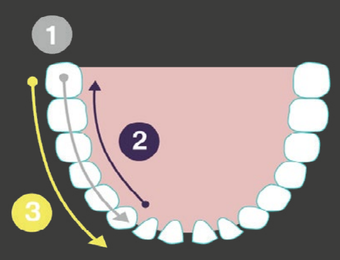
- Arrangements for alternative sources of light during scanning is not required as the iTero Element intraoral scanner has its own source of light

iTero restorative scanning protocol

To begin scanning: Light will be emitted from the wand when activated. Wait 10 seconds to allow for defogging of the lens. Place the wand in the patient's mouth at the starting point before pressing and releasing a side button to start scanning.

STEPS

01

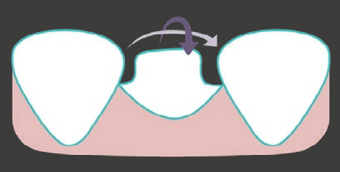


Step 1: Scanning the opposing arch

- Begin by placing the wand flat on the occlusal surface. Once the starting location in the viewfinder is confirmed, press and release either of the side buttons to begin scanning
- After scanning the occlusal anatomy, roll to the lingual, and finish with the buccal

Note: Full arch scan is not necessary if prepping one tooth

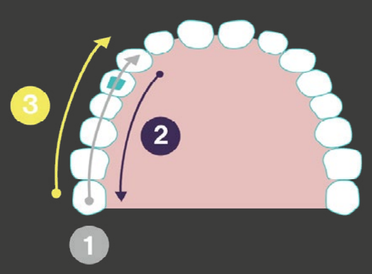
02



Step 2: Scanning the prep tooth

- Ensure that the prepped tooth is dry
- Center the prep within the viewfinder crosshair
- Begin scanning with an occlusal view of the prep to visualise the margin
- Roll from the lingual to the buccal of the prep
- Roll from the distal to the mesial of the prep
- Immediately review and fill any significant voids

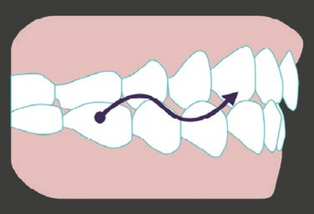
03



Step 3: Scanning the prep arch

- Scan the occlusal surface for the desired area
- Roll to the lingual to scan the lingual surfaces
- Roll to the buccal to scan the buccal surfaces
- To capture the adjacent contacts lay the wand tip flat on the occlusal surface and angle the wand tip to capture desired areas, or place the wand tip on the side of the prep and rotate the wand tip to capture the contacts

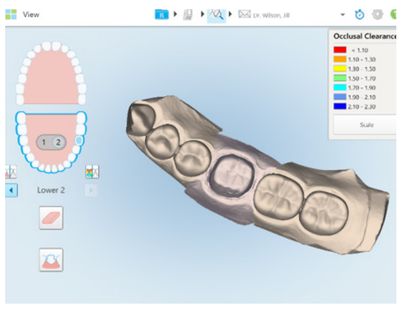
04



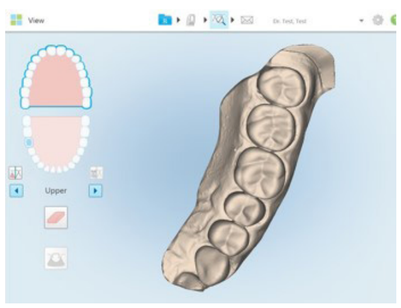
Step 4: Scanning the bite

- Scan the patient while biting in centric occlusion
- Be sure to scan the bite in a previosly captured area
- Center the wand between the upper and lower arches and slowly move the wand in a wave-like motion to ensure sufficient capture of the occlusion

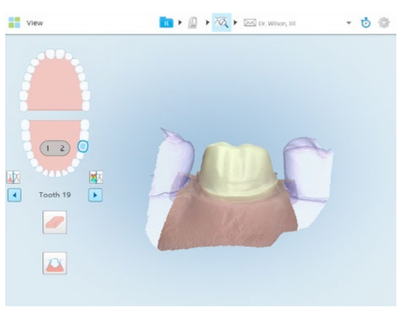
Evaluating the digital model



- Rotate the model to evaluate occlusal, lingual, buccal, mesial, and distal surfaces of the adjacent teeth

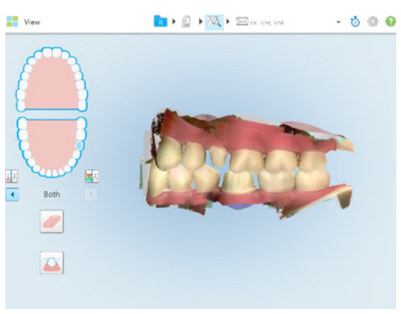


- Once the segments have been scanned, tap the view icon at the top of the touchscreen display to view the digital model in high resolution. After the case has been processed, evaluate the model to ensure that it is accurate and complete (i.e., check for any missing areas of anatomy)



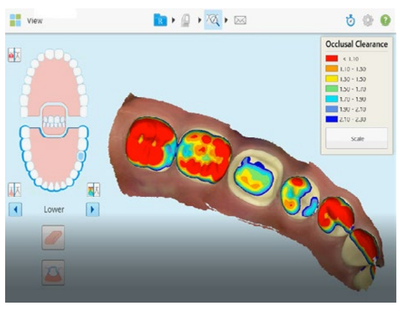
- Prep review checklist:

  Margin is clearly visible, prep is fully captured, prep is clear of overlapping tissue or other obstructions that affect the margin



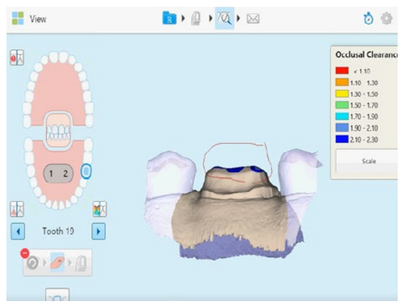
- Verify that the patient's bite is in centric occlusion

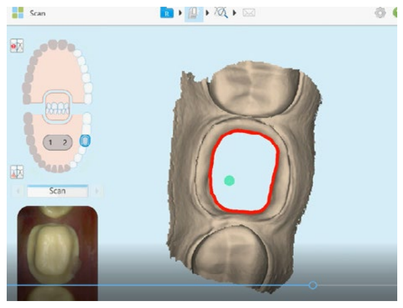
Additional tools

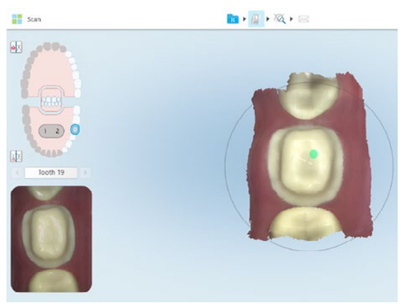


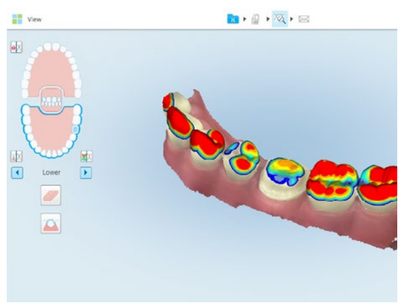
Occlusogram

- The Occlusal Clearance Tool ensures that the prep has sufficient reduction for the material chosen in the Rx







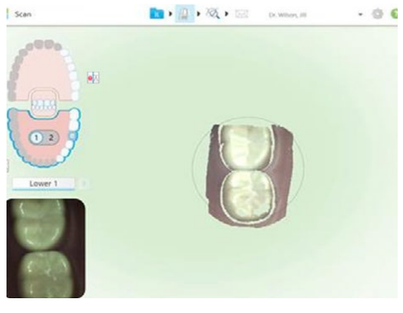


Occlusal Clearance Legend

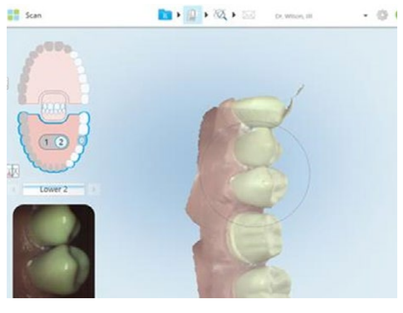
- Utilise the Occlusal Clearance Legend to determine the distance between opposing teeth
- Red areas on the prep indicate areas of inadequate occlusal clearance for the restoration, reduce the prep as required and rescan using the Eraser Tool
- To make any adjustments ensure that you are in the buccal view, then select the Eraser Tool
- Circle the area that will be modified on the model
- Adjust the clearance on patient's tooth
- Select Scan Tool to scan the modified circled area
- Activate View Tool
- Confirm the reduction was adequate

Prep Separation Tool

- The Prep Separation Tool is used to analyse the tooth prep and surrounding areas in high resolution



"1" Pre-treatment, indicated by the green background



"2" Post-treatment, indicated by the blue background

Pre-treatment scan

- Allows recording the tooth anatomy before the tooth preparation
- Enables the lab to copy the original anatomy to the new restoration
- Data will be available on the following CAD-CAM System: 3 Shape and Exocad

Learn more at **iTero.com**

[1] Strudevant's Art and Science of Operative dentistry, Seventh edition – Andre V. Ritter, Lee Q. Boushell, Ricardo Walter
[2] Phillip's science of dental materials, Anusavice – Eleventh edition

Published June 2019
MKT-0003191 Rev A

Pediatric patient case report

Improving operational efficiency in a multi-disciplinary practice by using the iTero™ scanner and ADAPT services.

Dr. Todd Moore (Vancouver, BC, Canada)
Dr. Todd Moore is a practicing orthodontist who completed a Master of Science degree in dental science studying protein biochemistry at the University of British Columbia before attending dental school at the University of Western Ontario. He completed his orthodontic residency at Eastman Dental Center in Rochester NY. He currently teaches part-time at UBC while working full-time at the Pediatric Dental Group (PDG). PDG is a group practice comprised of six clinics in four locations and two operatories at a separate surgery center in Vancouver BC and the surrounding areas (**www.pdgdental.com**). As a child, Dr. Moore was a patient of PDG and Dr. David Kennedy (founder of PDG with Dr Richard Kramer over 50 years ago), who inspired him to pursue a career in orthodontics. Dr. Moore was a member of the pilot cohort of the Align Digital and Practice Transformation (ADAPT) service to optimize operational workflows and processes to enhance the patient's experience and improve customer and staff satisfaction.

Executive summary:

1. Align Technology's ADAPT consulting service helped us identify areas for improvement in our practice and implement meaningful changes resulting in an increase in net production and net collections, revenue growth, and an increase in total exams and case starts.
2. We started more Invisalign® cases when we took an iTero scan on every patient at the time of their in-person exam by the pediatric dentist. The scan is used to screen for potential bite problems, dental problems, and gingival problems. The patient is then referred to see an orthodontist and the scans can be used by the orthodontist if there is a need for early interceptive treatment. This approach allowed the team at the orthodontist office to visually communicate findings with the parent and the patient, implement virtual consults, and ultimately reduce the doctor's chair time per patient.
3. Our new patient intake process leveraging the iTero scanner has been scalable for the staff, thereby freeing up the doctor's capacity to see more patients.
4. The Invisalign® Outcome Simulator on the iTero scanner is a helpful interactive tool that allows the team to visually communicate a patient's functional problems along with the treatment plan in real time.
5. Parents are more accepting of a 2-phase treatment approach when they learn that the Phase 1 treatment philosophy in our office primarily addresses functional concerns and not just esthetics, which allows for an easier, more esthetics-focused Phase 2 treatment later.

Practice background

Our pediatric-orthodontic group (PDG) consists of six clinics in four office locations, and two operatories at a shared surgical center. The group has seven pediatric dental specialists and three orthodontists. The group's co-founder, Dr. David Kennedy, was one of the first orthodontists to partner with Ms. Karen Moawad at Hummingbird Associates. Together, they pioneered an approach to doctor-time scheduling to optimize the rate-limiting resource of the doctor's time in an orthodontic practice. This was done by measuring the number of minutes needed for each orthodontic procedure performed and identifying whose time is needed during each appointment.

Since then, we have continued to improve our processes, and we enrolled in Align Digital and Practice Transformation (ADAPT) consulting service to help our practice create personalized strategies to achieve our goals. This engagement focused on leveraging digital orthodontics to achieve greater efficiency, profitability, and patient and staff satisfaction. During our 12-month engagement period with ADAPT, a highly-personalized fee-based consulting service, the practice's operations were assessed from various perspectives including production, marketing, finance, and customer experience.

The ADAPT program overview

The ADAPT (Align Digital And Practice Transformation) service is a highly-personalized fee-based consulting service. The service is a 12-month process which consists of weekly or bi-weekly team meetings at convenient times to minimize office disruption. The ADAPT service leverages the practice's data to develop an analysis of key performance indicators (KPIs) to help drive awareness into areas of opportunity. With the data from your practice, ADAPT develops a strategy with recommendations to optimize and grow your practice. If additional data is needed, the ADAPT team can help provide the tools needed to collect the information. Once alignment on the strategy is achieved, an implementation plan is created which focuses on the key areas identified.

The process begins with doctor and team member interviews, in-office observations, and surveys to understand the daily workflows of the practice as they are today. Once the data has been collected, an office assessment is created. Presented in the office assessment are performance metrics that the action plan will aim to improve. When areas for improvement are identified, tangible next steps are introduced.

In the first phase of the ADAPT service, the customer acquisition journey is reviewed, including how prospective patients find the office, schedule an initial consultation, and experience your practice for the first time. In the second phase, the operational efficiency of the practice is evaluated, to help streamline and optimize processes towards making scheduling and treatment workflows as efficient as possible. The third phase of the ADAPT service focuses on demand generation. We begin by leveraging your existing customer database to develop nurturing campaigns and targeted marketing to get new leads and referrals from existing patients. We then transition to a fourth phase which focuses on external marketing to drive new patients to your practice. This can include social media and external agency marketing options. All the proposals presented are tied to specific goals that use performance metrics to gauge their impact. For additional program details, please visit: **www.adaptbyalign.com**.

Practice bottlenecks prior to enrolling in the ADAPT program

The initial assessment revealed the following opportunities for improvement:

1. **Revenue generation from new case starts**

   Most of our starts were coming from pending cases already in the pipeline, but the pipeline was not being replenished. This situation would eventually keep the practice from generating enough revenue to sustain healthy operations.

2. **Operational efficiency in appointment scheduling**

   The clinic was booking too much orthodontist time for the initial screening visits, and that we needed a way to identify potential treatments earlier in the process. If the patient's clinical needs could be identified earlier, the type of appointment and the amount of orthodontist time needed could be booked much more efficiently.

3. **Process efficiency in patient records**

   Before we engaged ADAPT, not every patient would get scanned at the initial doctor consultation with a pediatric dentist, and the staff had to wait for the doctor to determine what to do next because scans at that time were primarily used as digital impressions for orthodontic appliances and diagnostic records once there was an agreement to start orthodontic treatment. This created ambiguity and a bottleneck in our patient records process, which increased our patient wait times.

Therefore, an action plan to generate demand from our new patient consults was created, but to be successful, we would need to make the consultation workflow more efficient, identify prospective patients earlier in the process, and improve our utilization of doctor time to handle the streamlined workflow.

Process changes guided by the ADAPT program

1.0 The impact of implementing the iTero™ scanner into the front-end of our consultation workflow

Our pediatric patients are first seen by the pediatric dentists where iTero intraoral scans are taken at the time of the patient exam. The scan is used to screen for potential bite problems, dental problems, and gingival problems. Once iTero scans are examined by the pediatric dentist, the patients might be referred for an evaluation with an orthodontist when the iTero scans are shared with an orthodontist.

Having an iTero scan taken at the pediatric dentist before seeing the orthodontist provides consistency in image quality, allows for doctors to communicate clinical findings with the patients and parents visually, and allows orthodontists to triage patients improving appointment efficiency and driving new patient case starts.

1.1. Appointment triaging of new patient consults

Eliminating a decision bottleneck when determining a patient's need for orthodontic treatment streamlined our consultation workflow and increased our scheduling efficiency, because the type of appointment needed for the initial consultation could be triaged, and patients who did not need orthodontic treatment could be filtered out early.

Previously, patients who were 12 years of age and older (assumed to be in the permanent dentition or close to full eruption) used to be always scanned with an iTero intraoral scanner prior to their consultation with the doctor. However, patients who were younger than 12 (assumed to be in the primary or mixed dentition) were never scanned with iTero and only had their photos and a panoramic radiograph taken. This created an operational efficiency bottleneck at patient scheduling and required a change in our upstream patient intake process.

The change was to implement the iTero scanner into the front-end of our consultation workflow with the pediatric dentist where every patient gets scanned with an iTero scanner irrespective of age, once they had an in-person exam by their pediatric dentist. If there is a need for orthodontic treatment, our pediatric dentists refer the patients to visit our orthodontists and the iTero scans are provided to an orthodontist. This makes the process more scalable by allowing the clinic to see more patients and triaging patients who do not need orthodontic treatment earlier in the process. (Refer to the Bonus section for details.)

1.2 iTero™ scanning provides consistent images

Taking an intraoral scan at the time of the patient exam by the pediatric dentists as part of the new patient intake process instead of after a problem is identified generates a consistent process that provides high-quality and standardized images across the practice resulting in more information for the patient consultation. Furthermore, the orthodontist's review of the scan also determines the amount of time needed for the initial consultation, which prevents staff from scheduling appointments longer than necessary.

1.3 iTero scanning allows for visual communication of clinical findings

With the Invisalign® Outcome Simulator on the iTero scanner, our doctors are able to efficiently communicate their clinical findings visually, and how the patient's teeth could look post-treatment, which helps families make well-informed decisions before starting treatment.[1] The success we experienced was also attributed to our entire team getting trained and being willing to adopt a digital workflow to enhance the customer's experience.

2.0 Changes to scheduling process to increase practice efficiency

Another finding from the ADAPT assessment was that our chair time and labor allocations could be optimized even more. Since the number of new patients available for orthodontic consultation was not a constraint for us, changing how the new patient exam is scheduled and staffed was our greatest opportunity to impact productivity and practice growth.

2.1 Historical patient exam scheduling

Historically, one hour of chair time (with 10 minutes of doctor time) was allocated for each new orthodontic consultation. An 8-hour work schedule was therefore limited to 8 new patient exams a day per chair unless the exams were overlapped (which created other problems with our office workflow).

2.2 Improved patient exam scheduling

Many of our patients are initially seen for crowding and spacing concerns prior to having their restorative work completed by the pediatric dentist, so a full one-hour orthodontic consultation is not needed until after their pediatric dental treatment has been completed.

To improve our scheduling efficiency, a full one-hour consultation is now only scheduled if the patient needs orthodontic treatment and is ready to start. All other types of consultations can be scheduled for 15 minutes of chair time (with 3-5 minutes of doctor time). Provided that the patient has had an in-person exam from their pediatric dentist and the scans are shared with an orthodontist, the orthodontist can review scans remotely; and in order to minimize disruptions with work and school, orthodontic consultation discussions of pre-screened patients can also be virtual.

2.3. Operational impact of improved scheduling process

The impact of modifying our scheduling process has been significant. The number of consults that can now be completed in a typical workday has quadrupled, but the doctor-time has only increased by 1.2 to 2-fold (e.g., 3-5 minutes of total doctor time for each pre-screened consultation vs. 10-15 minutes of total doctor time per the traditional consultation).

The "scan up-front" adjustment to our operational process at the consultation appointment with the pediatric dentist also has the potential to add tremendous value to the practice's future revenues by increasing the recall patient pool (i.e., those not yet ready or able to start orthodontic treatment). Our pediatric clinic patients can also be scanned during their pediatric dental appointments, and their scans can be reviewed by an orthodontist without needing to visit the clinic a second time.

Additionally, once the patient has had an in-person exam from their pediatric dentist and had their scans taken, the practice workflow can continue uninterrupted even if the clinicians are away from the office. The orthodontist can review scans remotely, communicate the treatment plan to the treatment coordinator, and have additional appointments set up for later.

This workflow is extremely convenient for the parents, who appreciate not having to take their kids out of school, drive across town, find parking, and then sit in the waiting room for a separate appointment with the orthodontist.

Practice impact as measured by key performance indicators

1. Increase in production and collections

The ADAPT process uses measurable outcomes as way to gauge progress, and the impact of this new workflow to our practice metrics has been significant. During the Covid-19 pandemic, even with a city mandate that reduced the maximum number of individuals allowed in the office at any given time, our adoption of this new workflow increased production in 2021 by 6 percent, and our collections increased by 10 percent compared to 2019, when we were operating at full capacity (Chart 1).

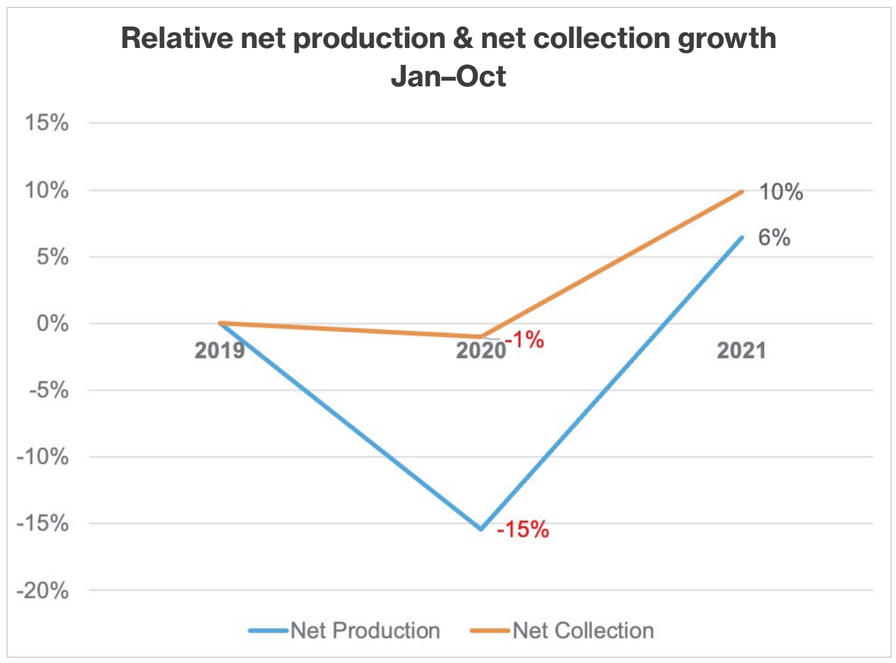


Chart 1: Net production and net collections 2019-2021.

[1] The Invisalign treatment outcome simulator software currently does not support primary or mixed dentition.

2. Growth in production per hour

By October 2021, the practice had increased the number of its new patients such that our production in dollars per doctor per hour grew to 33 percent above 2019 (pre-Covid-19 pandemic) levels (Chart 2). The improvement was 58 percent above 2020 levels and reflects the impact of expanding our capacity and cutting down on unnecessarily long consults.

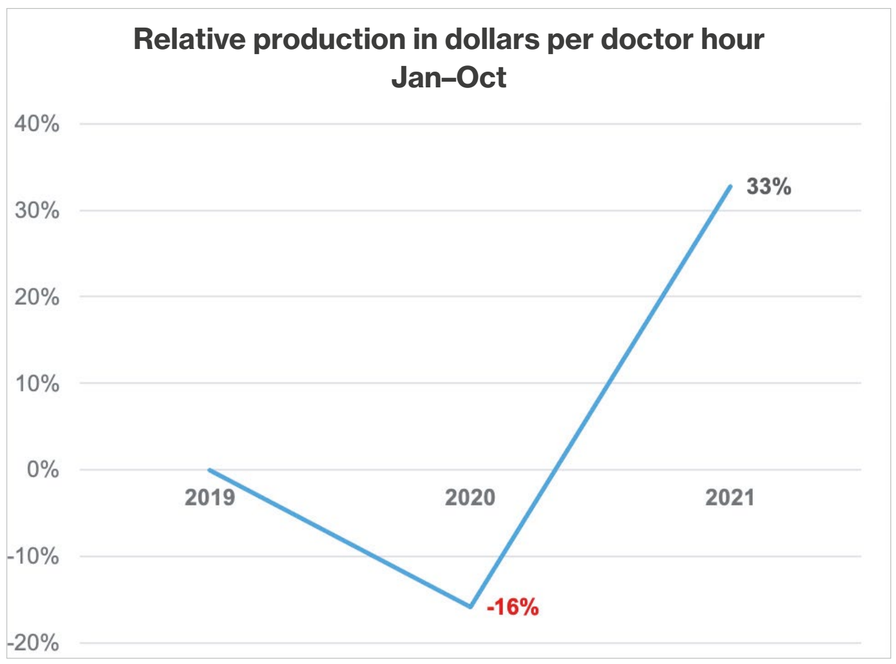


Chart 2: Production in 2019-2021, measured in dollars per doctor hour.

3. Increase in total exams and patient case starts

Ultimately, we were able to see more exams and start more patients in fewer hours. We also overcame a 30 percent and 43 percent decline experienced in 2020, in starts and exams, respectively, and ended up with a 4 percent and 3 percent increase in 2021 compared to 2019 levels (Chart 3).

Within a year, we also reversed the net-production-to-net-collection ratio from -3.8 percent to a healthy 6 percent, which meant that the practice was growing again after experiencing a significant contraction in 2020.

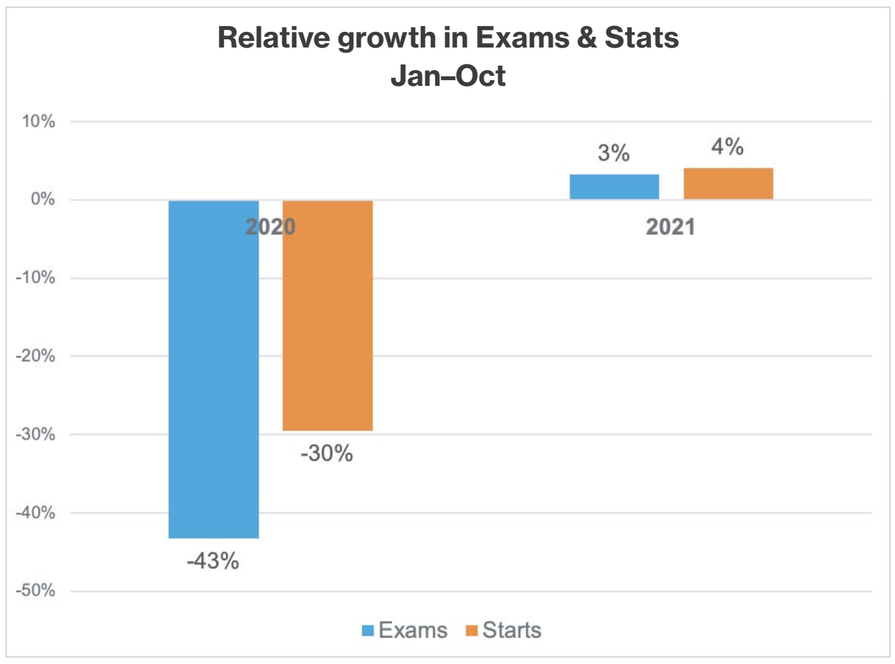


Chart 3: Relative growth in Exams and Starts using 2019 as the baseline.

Conclusion

In summary, the impact of the iTero™ scanner workflow that we implemented as part of our ADAPT plan of action is that our appointment scheduling has become much more flexible and convenient for the patient. The scans can be taken by our staff at any time after an initial in-person exam by the pediatric dentist, and once the 3-D color image data has been collected and shared with an orthodontist, the orthodontist can follow up to discuss the findings with the patient at a convenient time by leveraging in-person and virtual consults. This protocol has reduced wait times especially on our busier clinic days, and it has helped patients flow through the office faster and much more smoothly than before, but without reducing the quality of the consult.

When city-wide mandates during the COVID-19 pandemic limited the number of people allowed in the clinic, we were able to shift away from the traditional in-person consultation model and provide hybrid consultations by leveraging a patient scan taken during an in-person visit to the doctor with follow-up calls. As a result, our case starts increased during this time period. Our customer satisfaction has also improved due to the increased appointment flexibility and convenience, and greater productivity in the clinic has opened up more personal time for the clinicians to teach or spend time with family.

Pediatric patient case report

Clinical Example of an iTero™ scanner empowered orthodontic-pedodontic treatment: iTero scans and Phase 1 orthodontic treatment with Invisalign® First aligners in our practice

Patient:

Age of the patient:
7 years, 11 months old

Gender: Male

Chief concern: The front tooth was “backwards”.

- Previous pediatric dental history of a retained upper left primary central incisor (due to lingual eruption of the permanent incisor) and significant caries (restored with stainless steel crowns)

Diagnosis:

Dental

- Class I molar relationship with mild crowding in the early mixed dentition
- Anterior crossbite of the permanent upper left central incisor

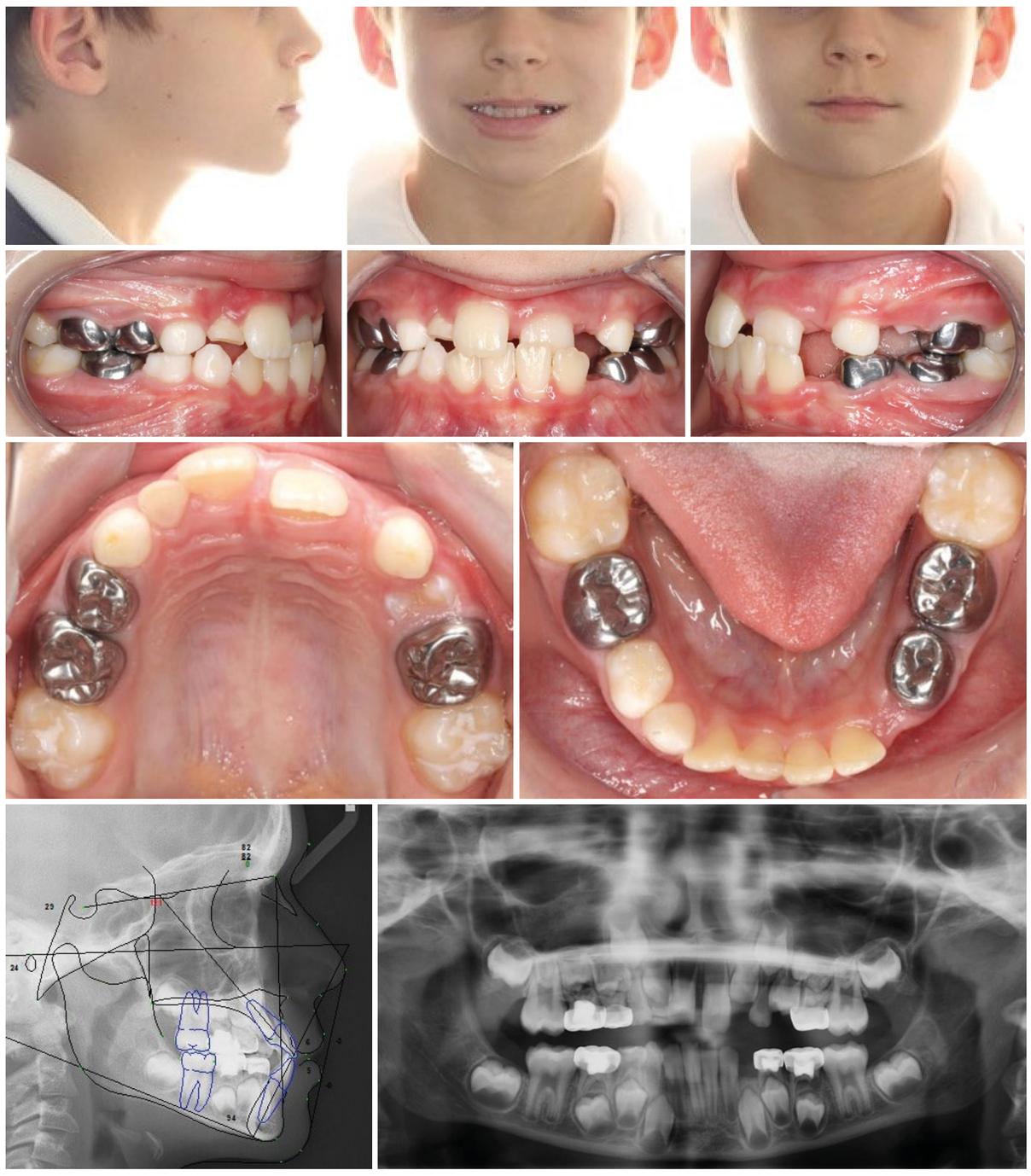
Skeletal

- Mandibular prognathic
- Reduced facial convexity (straight profile)
- Upper incisor proclination

Pediatric dental considerations

- Given the patient’s significant caries experience (previously treated under general anesthesia), the ability to brush and floss normally during orthodontic treatment was critical. A fixed appliance treatment option would have required banding due to the numerous stainless steel crowns present, which would have made oral hygiene even more challenging. The Invisalign First Phase 1 treatment option was much more suitable for the patient’s dental situation.

Clinical photos and radiographs:



Initial iTero scans:

Pediatric patient case report

Invisalign® features used:

- Conventional 4mm attachments on the permanent first molars for maximum aligner retention (no attachments on the stainless-steel crowns)
- Lingual bite ramps in the upper aligners to temporarily open the bite
- Staging: Expand the permanent molars first

Invisalign treatment plan (ClinCheck® set-up):

End of Phase I treatment:

Age of patient: 8 years, 8 months
(9 years, 1 month at the time of final records)

Phase 1 treatment time: 15 months

Number of aligners used:

- Upper: 32 + 22
- Lower: 23 + 16

Aligner change interval (days per aligner): Initially 7 days and reduced to 5 days after 8 weeks (the aligners would become loose after a week of wear, so the frequency of aligner changes was increased)

Auxiliaries used: None.

Appointment scheduling: Average of 10 aligners per visit every 8 weeks

Total number of visits from aligner delivery to retainer delivery: 7 visits

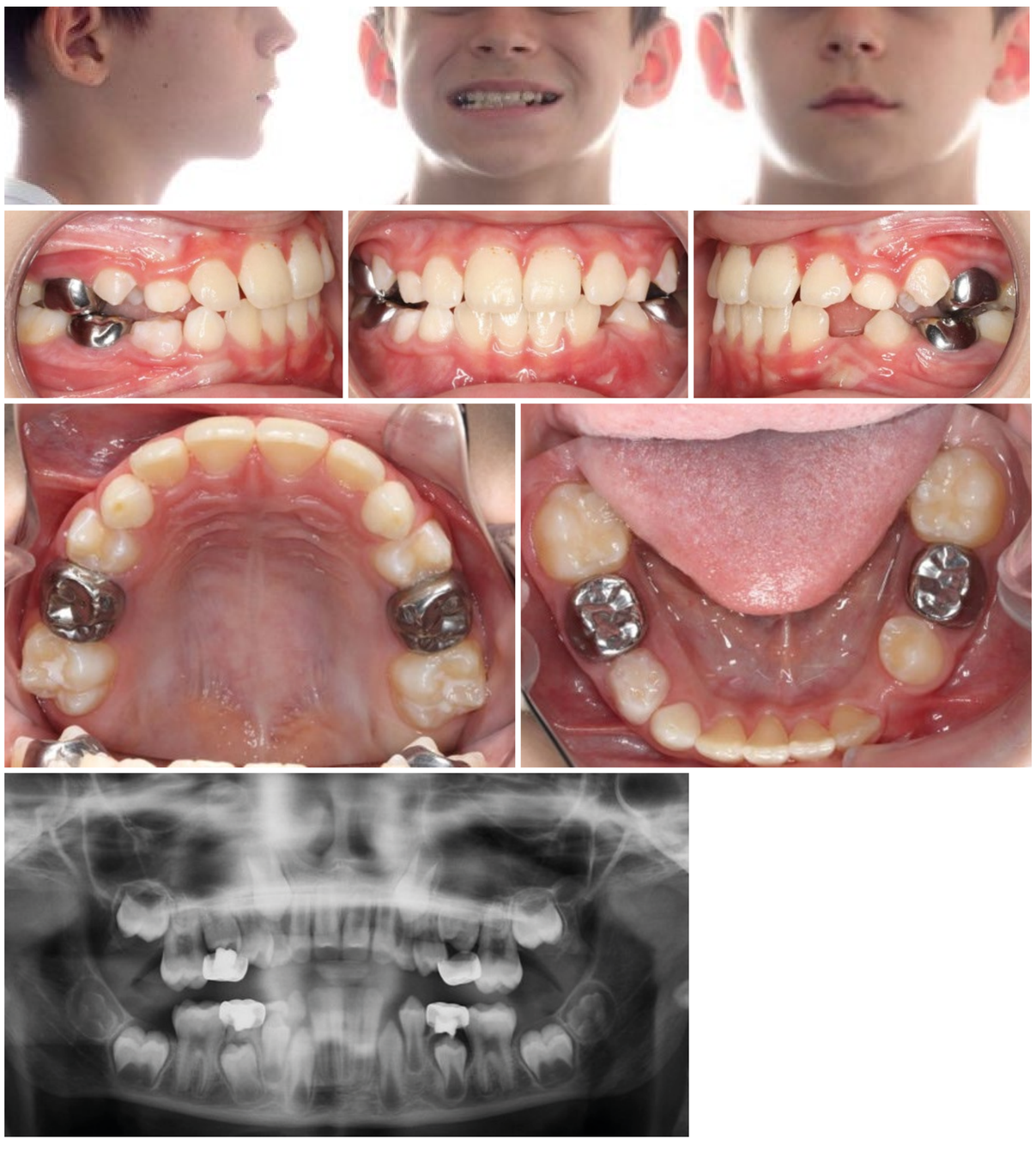
Number of emergency visits: None.

Pediatric dental care during/after orthodontic treatment: Routine check-up visits.

Retention

- Upper: Hawley with Adams clasps on the upper 6's.
- Lower: None (The pre-treatment crowding was minimal and the lower E's were present, so the risk of the L6s mesially tipping was non-existent. The dentition will likely transition naturally into the permanent dentition without incident.)
- Protocol: Full-time wear for 6 months and then night-time wear until the retainer no-longer fits due to the eruption of the permanent teeth.

Progress photos:



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Clinical discussion

Phase 1 orthodontic treatments in our practice are primarily for functional improvements, with a limited window of time available to treat the patient before the teeth begin to transition from primary to permanent. Ideally, any crossbites and functional shifts will be corrected no later than a year before the late mixed dentition phase begins. When the parents learn that the corrections in the first phase of treatment are primarily functional and not just esthetic, they are more accepting of a 2-phase approach. This is where patient communications using the iTero™ scans are very helpful, because we can show the parents areas that are not always obvious when the patient smiles. We will also tell them that if all the functional goals are achieved after Phase 1, then the goal of Phase 2 treatment is more for esthetics, and therefore becomes optional.

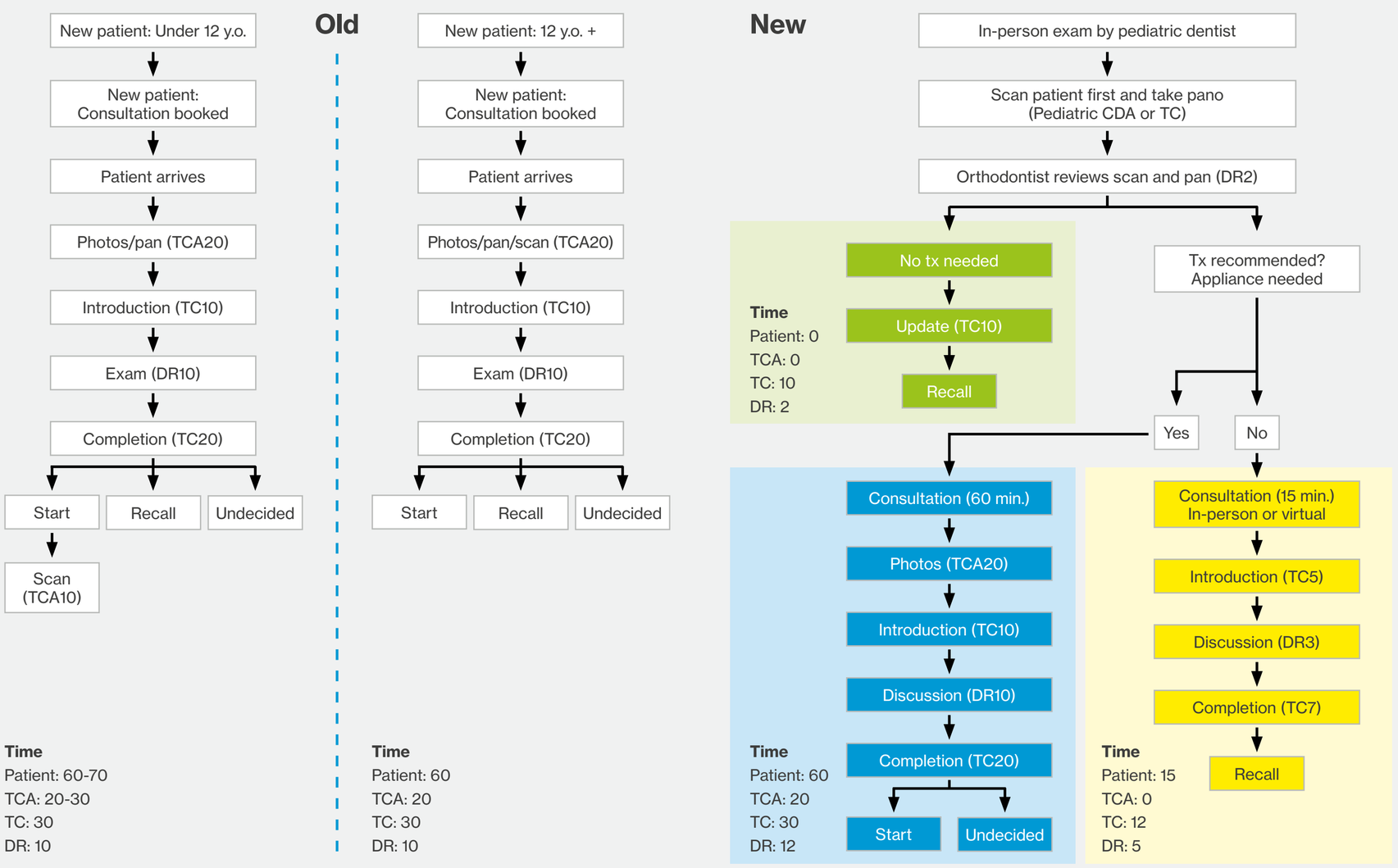
To avoid treatment fatigue during Phase 1, the primary treatment goal should be achieved as quickly as possible while the patients are engaged. During the consultation visit, the patient and parent should also be shown alternative treatment appliances to Invisalign® First aligners, so that they can better appreciate being able to eat, brush and floss normally during aligner treatment compared to traditional orthodontic appliances.

To help motivate younger patients to maintain good oral hygiene throughout their aligner treatment, we will also show them clinical photos of dental caries, so they understand the consequences of not brushing well. We will also describe poor brushing conditions as a “greenhouse” for bacteria, so that they develop a mental picture of the potential problem.

The bigger opportunity for our dental group is for every 7- to 8-year-old pediatric patient in our clinics to be scanned with the iTero scanner by our staff, and for the patients to receive a call from the doctor afterwards. Our hybrid consultation model with the iTero scan taken up front gives us a path forward without compromising the consistency of the data needed to provide quality care. Doing this would build an amazing recall program where every patient’s orthodontic and dental condition is monitored on a regular basis, so that we can intercept any orthodontic problems identified and keep them from becoming bigger problems that are harder to treat later.

Bonus section: Workflow process for maximizing doctor efficiency in our orthodontic-pedodontic office with the iTero™ scanner

Scanning patients in the pediatric dental practice during their exam and using the scans to pre-diagnose and have orthodontic conversations with parents over the phone or via video chat has allowed us to see more patients and have more orthodontic starts than ever before, even when the city of Vancouver limited the number of people allowed on to the premises due to COVID-19 and the number of new patient exam slots in our office was reduced by 50%. We were still able to grow while providing the same or better quality of care.



TC = Treatment coordinator, **TCA** = Treatment coordinator assistant, **DR** = Doctor, **CDA** = Certified dental assistant, **(#)** = number of minutes allocated

In our new consultation model, patients that do not need treatment are triaged and very little doctor time is allocated (2 minutes each). Clinic time is also not utilized for these patients (except for the scan). For patients where treatment is recommended but the patient is not ready to start that day (hence no appliances are needed for that appointment), the amount of doctor time is only 5 minutes and the patient only requires 15 minutes of clinic time. Only patients who need orthodontic treatment and are ready to move forward with appliances that day will require the full 60-minute time slot in the clinic, and with slightly more doctor time (12 minutes instead of 10). The time savings from screening out patients who do not need treatment or who are not ready to start more than makes up for the trade-off of needing slightly more doctor time for those ready to move forward. The throughput is increased substantially with this process without creating additional bottlenecks in the workflow.

External publications

List of external publications evaluating the iTero™ scanner

- Digital vs. conventional implant prosthetic workflows: a cost/time analysis
- Patient-centered outcomes comparing digital and conventional implant impression procedures
- Time-Efficiency Analysis Comparing Digital and Conventional workflows for Implant Crowns
- Accuracy of full-arch digital impressions: an in vitro and in vivo comparison
- A new method to measure the accuracy of intraoral scanners along the complete dental arch: A pilot study
- Randomized controlled clinical trial of digital and conventional workflows for the fabrication of zirconia-ceramic fixed partial dentures.
- Trueness of 12 intraoral scanners in the full-arch implant impression: a comparative in vitro study
- Diagnostic validity of early proximal caries detection using near-infrared imaging technology on 3D range data of posterior teeth
- In Vitro Comparison of Three Intraoral Scanners for Implant – Supported Dental Prostheses
- Intraoral scanning reduces procedure time and improves patient comfort in fixed prosthodontics and implant dentistry: a systematic review
- Reflected near-infrared light versus bite-wing radiography for the detection of proximal caries

List of external publications evaluating the iTero™ scanner

Below is a list of external articles evaluating the iTero™ scanner, the following pages focus on the 11 articles highlighted below.

	Publication	Topic	Author	Reference	Conclusion
1	Digital vs. conventional implant prosthetic workflows: a cost/time analysis.	Efficiency	Tim Joda, Urs Brägger	Clin. Oral Impl. Res. 26, 2015, 1430–1435 doi: 10.1111/clr.12476	The digital workflow was more efficient than the well-established conventional pathway.
2	Patient-centered outcomes comparing digital and conventional implant impression procedures: a randomized crossover trial.	Efficiency	Tim Joda, Urs Brägger	Clin. Oral Impl. Res., 00, 2015, 1–5. doi: 10.1111/clr.12600.	The digital technique emerges as the most preferred one according to patientcentered outcomes and was more time-effective compared to conventional impressions.
3	Time-Efficiency Analysis Comparing Digital and Conventional Workflows for Implant Crowns: A Prospective Clinical Crossover Trial.	Efficiency	Tim Joda, Urs Brägger	The International journal of oral & maxillofacial implants. 30. 1047-1053. DOI :10.11607/jomi.3963.	The digital workflow seems to be more time-efficient than the established conventional production pathway for fixed implant-supported crowns. Both clinical chair time and laboratory manufacturing steps could be effectively shortened with the digital process.
4	Accuracy of full-arch digital impressions: an in vitro and in vivo comparison.	Full-arch, accuracy	Keul C, et al.	Clin Oral Investig. 2019 May 27.	Within the limitations of this study, the iTero™ scan seems to be a valid alternative to conventional impressions for full arches
5	A new method to measure the accuracy of intraoral scanners along the complete dental arch: A pilot study.	Full-arch, accuracy	Iturrate M, et al.	J Adv Prosthodont. 2019 Dec;11(6): 331- 340.	iTero Element™ was more accurate than the 3shape Trios 3 scanner and 3M True Definition. Importantly, the proposed methodology is considered reliable for analyzing accuracy in any dental arch length and valid for assessing both trueness and precision in an in vivo study.
6	Randomized controlled clinical trial of digital and conventional workflows for the fabrication of zirconia-ceramic fixed partial dentures. Part III: Marginal and internal fit.	Marginal fit	Benic GI, et al.	J Prosthet Dent. 2019 Mar;121(3): 426-431.	In terms of frameworks presented similar or better fit than the conventionally fabricated metal frameworks. In the occlusal regions, the conventionally fabricated metal frameworks achieved a more favorable fit than the CAD-CAM zirconia frameworks.
7	Trueness of 12 intraoral scanners in the full-arch implant impression: a comparative in vitro study	Full-arch, accuracy	Francesco Guido et al.	BMC Oral Health. 2020; 20 (1): 263.	Different levels of trueness were found among the Intraoral scanners evaluated in this study. Further studies are needed to confirm these results.
8	Diagnostic validity of early proximal caries detection using near-infrared imaging technology on 3D range data of posterior teeth	NIRI, caries diagnostics	Friederike Litzenburge, et al.	Clin Oral Investig . 2022 Jan;26(1): 543-553.	The iTero Element 5D imaging system scanner achieved diagnostic results comparable to those of BWR. NIRR with and without the trilateral information can detect initial defects in the enamel with higher sensitivity than BWR
9	In Vitro Comparison of Three Intraoral Scanners for Implant—Supported Dental Prostheses	Full-arch, accuracy	Costa V, et al.	Dent J (Basel). 2022 Jun 15;10(6):112.	iTero™ intraoral scanner was found to be the most accurate (26.00 µm), followed by the Medit scanner (35.90 µm) and Planmeca PlanScan scanner (57.30 µm)
10	Intraoral scanning reduces procedure time and improves patient comfort in fixed prosthodontics and implant dentistry: a systematic review	Efficiency, patient comfort	Siqueira R, et al.	Clin Oral Investig. 2021 Dec;25(12): 6517-6531.	Intraoral scanner is faster than conventional impressions, independent of the size of the scanned area
11	Reflected near-infrared light versus bite-wing radiography for the detection of proximal caries: A multicenter prospective clinical study conducted in private practices	NIRI, caries diagnostics	Metzger Z, et al.	J Dent. 2022 Jan;116:103861.	NILR had higher sensitivity than BWR in the detection of early enamel lesions and comparable sensitivity to BWR in detecting lesions that involved the DEJ

List of external publications evaluating the iTero™ scanner

	Publication	Topic	Author	Reference	Conclusion
12	The effect different substrates have on the trueness and precision of eight different intraoral scanners.	Substrates	Dutton E, et al.	J Esthet Restor Dent. 2019 Sep 30.	Substrate type affects the trueness and precision of a scan. Active Triangulation scanners are more sensitive to substrate differences than their parallel confocal counterparts. Some scanners scan certain substrates better, but in general the new generation of scanners outperforms the old, across all substrates.
13	Comparison of two intraoral scanners based on three-dimensional surface analysis.	Accuracy	Lee KM, et al.	Prog Orthod. 2018 Feb 12;19(1):6.	Although there were some deviations in visible inspection, there was no statistical significance between the two intraoral scanners.
14	Intraoral digital scans-Part 1: Influence of ambient scanning light conditions on the accuracy (trueness and precision) of different intraoral scanners.	Light conditions	Revilla-León M, et al.	J Prosthet Dent. 2019 Dec 18.	Ambient lighting conditions influenced the accuracy (trueness and precision) of the Intraoral scanners tested. The recommended lighting conditions depend on the Intraoral scanner selected. For iTero Element™ scanner, chair and room light conditions resulted in better accuracy mean values. For CEREC Omnicam scanner, zero light resulted in better accuracy, and for 3shape Trios 3 scanner, room light resulted in better accuracy.
15	Trueness of digital intraoral impression in reproducing multiple implant position.	Implants, trueness	Kim RJ, et al.	PLoS One. 2019 Nov 19;14(11):e0222070.	Within the limitations of the present study, all the Intraoral scanners exhibited increasing deviation with an increasing distance from the start position of scanning. The direction and magnitude of deviation differed among jaw regions and Intraoral scanners. All the Intraoral scanners were similar for unilateral arch scanning, while i500 scanner, and Trios 3 scanner outperformed the other Intraoral scanners for partially edentulous scanning. The accuracy of Intraoral scanners requires additional improvement.
16	Trueness and precision of 5 intraoral scanners for scanning edentulous and dentate complete-arch mandibular casts: A comparative in vitro study.	Edentulous, precision, trueness	Braian M, et al.	J Prosthet Dent. 2019 Aug;122(2): 129- 136.e2.	Significant differences were found in scanning edentulous and dentate scans for short arches and complete arches. Trueness for complete-arch scans were <193 µm for edentulous scans and <150 µm for dentate scans. Trueness for short-arch scans were <103 µm for edentulous scans and <56 µm for dentate scans.
17	Trueness and Precision of Three-Dimensional Digitizing Intraoral Devices.	Edentulous, precision, trueness	Mutwalli H, et al	Int J Dent. 2018 Nov 26;2018:5189761.	Within the limitations of this in vitro study, the results suggest significant differences between Intraoral scanner devices when scanning fully edentulous arch with multiple implants. ,e main observation was the low precision for all intraoral scanners, suggesting that the intraoral scanning devices are unreliable for scanning fully edentulous arch with multiple implants. Two scanners, however, 3shape Trios 3 mono scanner and iTero Element scanner showed fair trueness.
18	Local accuracy of actual intraoral scanning systems for single-tooth preparations in vitro.	Single tooth, accuracy	Zimmer-mann M, et al.	J Am Dent Assoc. 2020 Feb;151(2): 127- 135.	Intraoral scanner systems use different behaviors in terms of local accuracy. Preparation MA shows higher deviations than preparation SU for all test groups. Trueness and precision values for both MA and SU of single-unit preparations are equal or close to CO impressions for several Intraoral scanner systems
19	Investigation of the Accuracy of Four Intraoral Scanners in Mandibular Full-Arch Digital Implant Impression: A Comparative In Vitro Study	Full-arch, accuracy	Adolfo Di Fiore, et al.	Int J Environ Res Public Health. 2022 Apr 13;19(8):4719	1. The 3D position analysis showed that all Intraoral scanners, including the iTero Element scanner, were able to execute digital impressions for a full arch, according to the clinically desirable value of the position errors reported in the literature (150 µm). 2. The 3D distance analysis showed that the CEREC Primescan scanner, iTero™ scanner presented regression close and almost parallel to the x-axis, which meant that the systematic errors sources were negligible.
20	Effect of pulp chamber depth on the accuracy of endocrown scans made with different intraoral scanners versus an industrial scanner: An in vitro study	Endocrowns, accuracy	Bahar Gurpinar, et al.	J Prosthet Dent. 2022 Mar;127(3):430-437.	1. iTero™ scanner is the second most accurate scanner for endocrowns after the CEREC Primescan scanner. 2. Increasing the pulpal chamber extension depth of endocrown preparations can reduce scanning accuracy.
21	Comparison of the acquisition accuracy and digitizing noise of 9 intraoral and extraoral scanners: An objective method	Digitizing noise	Lucien Dupagne, et al.	J Prosthet Dent. 2021 Mar 26:S0022-3913(21)00076-7.	Primescan scanner, iTero Element™ 5D imaging system, CS3600 scanner, and 3Shape Trios 3 scanner showed minimally significant differences. Conclusions Significant differences were found among the intraoral scanners for small-scale scans. The objective methodology of using a gauge block provided coherent and repeatable results.
22	Comparison of conventional, photogrammetry, and intraoral scanning accuracy of complete-arch implant impression procedures evaluated with a coordinate measuring machine	Full-arch, accuracy	Marta Revilla-León, et al.	J Prosthet Dent. 2021 Mar;125(3):470-478.	The 2 Intraoral scanners - iTero Element scanner and 3Shape Trios 3 scanner, tested provided a reliable digitizing procedure as no significant differences were found between the linear discrepancy compared with the conventional impression technique.

List of external publications evaluating the iTero™ scanner

	Publication	Topic	Author	Reference	Conclusion
23	Accuracy of Digital Impressions Obtained Using Six Intraoral Scanners in Partially Edentulous Dentitions and the Effect of Scanning Sequence	Partially edentulous, accuracy	Burcu Diker, et al.	Int J Prosthodont. 2021 Jan-Feb;34(1):101-108.	The accuracy of partially edentulous models was affected by the scanning sequence when using Virtuo vivo scanner, Emerald scanner, Primescan scanner, and iTero™ scanner. the effect of scanning sequence on the accuracy of digital impressions. Based on the results of the present study, scanner and scanning sequence have an important role in the success of digital scanning. it could be considered that deviation on the digital impression may affect the accuracy of RPD frameworks and, consequently, the success of the dentures in the digital workflow.
24	Effect of scan pattern on complete-arch scans with 4 digital scanners	Full-arch, accuracy	Jason Latham, et al.	J Prosthet Dent. 2020 Jan;123(1):85-95.	1. Scan pattern affected the trueness, precision, and speed of digital scanners, and differences were found when different scanners were compared by using the same scan pattern. 2. The iTero Element™ scanner, Planmeca PlanScan scanner, and 3Shape Trios 3 scanner were close to equivalent regarding trueness and precision.
25	Full-arch accuracy of five intraoral scanners: In vivo analysis of trueness and precision	Full-arch, accuracy	Miran Kwon, et al.	Korean J Orthod. 2021 Mar 25;51(2):95-104.	Regarding trueness, Omnicam scanner showed greater dimensional errors followed by i500 scanner, CS3600 scanner, iTero™ scanner, and 3Shape Trios 3 scanner. CS3600 scanner showed greater errors followed by Omnicam scanner, i500 scanner, iTero™ scanner, and 3Shape Trios 3 scanner in the linear distance from the canine to the molar in the same quadrant. Thus, the dimensional accuracy of intraoral scan data may differ significantly according to the type of scanner, with the amount of error in terms of trueness being clinically significant.
26	Accuracy of the Intraoral Scanner for Detection of Tooth Wear	Patient monitoring	Mitrirat-tanakul S, et al.	Int Dent J. 2022 Aug 2:S0020-6539(22)00116-2.	From this study, as the iTero™ intraoral scanner has shown high sensitivity, accuracy, and PPV.

Article Summary of:

"Digital vs. conventional implant prosthetic workflows: a cost/time analysis"

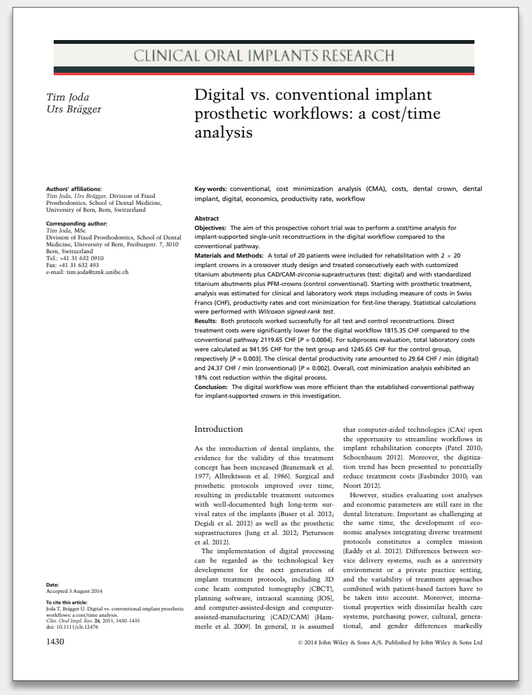
Objectives:

Prospective cohort trial to perform a cost/time analysis for implant-supported single-unit reconstructions in the digital workflow compared to the conventional pathway.

Materials and Methods:

- 20 patients
- Rehabilitation with 2 x 20 implant crowns
- Crossover study design
- Test: customized titanium abutments plus CAD/CAM-zirconia-suprastructures
- Control: standardized titanium abutments plus PFM-crowns
- Starting with prosthetic treatment, analysis was estimated for clinical and laboratory work steps including measure of costs in Swiss Francs (CHF), productivity rates and cost minimization for first-line therapy.
- Statistical calculations with Wilcoxon signed-rank test

Article:



CLINICAL ORAL IMPLANTS RESEARCH

Tim Joda
Urs Brägger

Digital vs. conventional implant prosthetic workflows: a cost/time analysis

Authors' affiliations:
Tim Joda, Urs Brägger, Division of Fixed Prosthodontics, School of Dental Medicine, University of Bern, Bern, Switzerland

Corresponding author:
Tim Joda, MSc
Division of Fixed Prosthodontics, School of Dental Medicine, University of Bern, Freiburgstr. 7, 3010 Bern, Switzerland
Tel.: +41 31 632 0910
Fax: +41 31 632 493
e-mail: tim.joda@zmk.unibe.ch

Key words: conventional, cost minimization analysis (CMA), costs, dental crown, dental implant, digital, economics, productivity rate, workflow

Abstract
Objectives: The aim of this prospective cohort trial was to perform a cost/time analysis for implant-supported single-unit reconstructions in the digital workflow compared to the conventional pathway.
Materials and Methods: A total of 20 patients were included for rehabilitation with 2 × 20 implant crowns in a crossover study design and treated consecutively each with customized titanium abutments plus CAD/CAM-zirconia-suprastructures (test: digital) and with standardized titanium abutments plus PFM-crowns (control conventional). Starting with prosthetic treatment, analysis was estimated for clinical and laboratory work steps including measure of costs in Swiss Francs (CHF), productivity rates and cost minimization for first-line therapy. Statistical calculations were performed with *Wilcoxon signed-rank test*.
Results: Both protocols worked sucessfully for all test and control reconstructions. Direct treatment costs were significantly lower for the digital workflow 1815.35 CHF compared to the conventional pathway 2119.65 CHF ($P = 0.0004$). For subprocess evaluation, total laboratory costs were calculated as 941.95 CHF for the test group and 1245.65 CHF for the control group, respectively ($P = 0.003$). The clinical dental productivity rate amounted to 29.64 CHF / min (digital) and 24.37 CHF / min (conventional) ($P = 0.002$). Overall, cost minimization analysis exhibited an 18% cost reduction within the digital process.
Conclusion: The digital workflow was more efficient than the established conventional pathway for implant-supported crowns in this investigation.

Introduction

As the introduction of dental implants, the evidence for the validity of this treatment concept has been increased [Branemark et al. 1977; Albrektsson et al. 1986]. Surgical and prosthetic protocols improved over time, resulting in predictable treatment outcomes with well-documented high long-term survival rates of the implants [Buser et al. 2012; Degidi et al. 2012] as well as the prosthetic suprastructures [Jung et al. 2012; Pjetursson et al. 2012].

The implementation of digital processing can be regarded as the technological key development for the next generation of implant treatment protocols, including 3D cone beam computed tomography (CBCT), planning software, intraoral scanning (IOS), and computer-assisted-design and computer-assisted-manufacturing (CAD/CAM) [Hamerle et al. 2009]. In general, it is assumed that computer-aided technologies (CAx) open the opportunity to streamline workflows in implant rehabilitation concepts (Patel 2010; Schoenbaum 2012). Moreover, the digitization trend has been presented to potentially reduce treatment costs (Fasbinder 2010; van Noort 2012).

However, studies evaluating cost analyses and economic parameters are still rare in the dental literature. Important as challenging at the same time, the development of economic analyses integrating diverse treatment protocols constitutes a complex mission (Eaddy et al. 2012). Differences between service delivery systems, such as a university environment or a private practice setting, and the variability of treatment approaches combined with patient-based factors have to be taken into account. Moreover, international properties with dissimilar health care systems, purchasing power, cultural, generational, and gender differences markedly

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"Digital vs. conventional implant prosthetic workflows: a cost/time analysis"

Results:

Overall, cost minimization analysis exhibited an 18% cost reduction within the digital process.

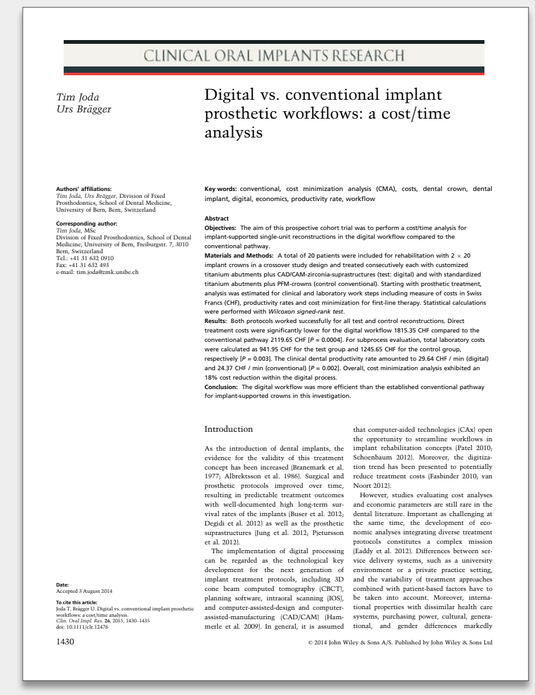
Both protocols worked successfully for all test and control reconstructions.

	Digital Workflow	Conventional Workflow	Statistic
Direct treatment costs	1815.35 CHF	2119.65 CHF	Significant [P = 0.0004]
Total laboratory costs	941.95 CHF	1245.65 CHF	Significant [P = 0.0003]
The clinical dental productivity rate	29.64 CHF / min	24.37 CHF / min	[P = 0.0002]

Conclusion:

The digital workflow was more efficient than the well-established conventional pathway.

Article:



CLINICAL ORAL IMPLANTS RESEARCH

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Digital vs. conventional implant prosthetic workflows: a cost/time analysis

Authors' affiliations:
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Corresponding author:
Tim Joda, MSc
Division of Fixed Prosthodontics, School of Dental Medicine, University of Bern, Freibuegstr. 7, 3010 Bern, Switzerland
Tel.: +41 31 632 0910
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e-mail: tim.joda@zmk.unibe.ch

Key words: conventional, cost minimization analysis (CMA), costs, dental crown, dental implant, digital, economics, productivity rate, workflow

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However, studies evaluating cost analyses and economic parameters are still rare in the dental literature. Important as challenging at the same time, the development of economic analyses integrating diverse treatment protocols constitutes a complex mission [Eaddy et al. 2012]. Differences between service delivery systems, such as a university environment or a private practice setting, and the variability of treatment approaches combined with patient-based factors have to be taken into account. Moreover, international properties with dissimilar health care systems, purchasing power, cultural, generational, and gender differences markedly

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Clin. Oral Impl. Res. 26, 2015, 1430–1435 doi: 10.1111/clr.12476

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Article Summary of:

"Patient-centered outcomes comparing digital and conventional implant impression procedures: a randomized crossover trial"

Objectives:

The aim of this randomized controlled trial was to compare patient-centered outcomes during digital and conventional implant impressions.

Materials and Methods:

Intraoral scanning (IOS) [test] as well as classical polyether impressions [control] were both performed on

- 20 patients
- single-tooth replacement with implant-supported crowns
- Crossover study design
- Test: Patients' perception and satisfaction on the level of convenience-related factors were assessed with visual analogue scale (VAS) questionnaires.

In addition, clinical work time was separately recorded for test and control procedures.

- Statistical analyses with Wilcoxon signed-rank tests and corrected for multiple testing by the method of Holm.

Results:

On VAS (visual analogue scale) ranging from 0 to 100, patients scored a mean convenience level of 78.6 (SD ± 14.0) in favor of Intraoral scanner compared to conventional impressions with 53.6(SD ± 15.4) [P = 0.0001]. All included patients would prefer the digital workflow if in the future they could choose between the two techniques. Secondary, Intraoral scanner was significantly faster with 14.8 min (SD ± 2.2) compared to the conventional approach with 17.9 min (SD ± 1.1) [P = 0.0001].

Article:

CLINICAL ORAL IMPLANTS RESEARCH

Tim Joda
Urs Brägger

Patient-centered outcomes comparing digital and conventional implant impression procedures: a randomized crossover trial

Authors' affiliation:
Tim Joda, Urs Brägger, Division of Fixed Prosthodontics, School of Dental Medicine, University of Bern, Bern, Switzerland

Corresponding author:
Dr. med. dent. *Tim Joda*, MSc
Division of Fixed Prosthodontics
School of Dental Medicine
University of Bern
Freiburgstr. 7, 3010 Bern
Switzerland
Tel.: +41 31 632 09 10
Fax: +41 31 632 49 31
e-mail: tim.joda@zmk.unibe.ch

Key words: crossover, dental implant, digital, impression, patient satisfaction, randomized-controlled trial

Abstract

Objectives: The aim of this randomized controlled trial was to compare patient-centered outcomes during digital and conventional implant impressions.

Material and methods: In a crossover study design, intraoral scanning (IOS) [test] as well as classical polyether impressions [control] were both performed on 20 patients for single-tooth replacement with implant-supported crowns. The sequential distribution of either starting with the test or the control procedure was randomly selected. Patients' perception and satisfaction on the level of convenience-related factors were assessed with visual analogue scale (VAS) questionnaires. In addition, clinical work time was separately recorded for test and control procedures. Statistical analyses were performed with *Wilcoxon* signed-rank tests and corrected for multiple testing by the method of *Holm*.

Results: On VAS ranging from 0 to 100, patients scored a mean convenience level of 78.6 (SD ± 14.0) in favor of IOS compared to conventional impressions with 53.6 (SD ± 15.4) [*P* = 0.0001]. All included patients would prefer the digital workflow if in the future they could choose between the two techniques. Secondary, IOS was significantly faster with 14.8 min (SD ± 2.2) compared to the conventional approach with 17.9 min (SD ± 1.1) (*P* = 0.0001).

Conclusion: Based on the findings of this investigation, both impression protocols worked successfully for all study participants capturing the 3D implant positions. However, the digital technique emerges as the most preferred one according to patient-centered outcomes and was more time-effective compared to conventional impressions.

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Healthcare-related validation should be associated with objective criteria to assess treatment efficiency. The various stakeholders representing patients, the healthcare providers, the industry or third-party players concentrate on different endpoints (Anderson 1998).

Treatment outcomes in implant therapy can be distinguished into four subgroups: (i) longevity and survival, (ii) physiological impact, (iii) psychological effect, (iv) economic factors (Guyatt et al. 1996). This classification includes categories of primary relevance to patients but also outcomes of their indirect concern, though maybe of greater interest to the clinician. Therefore, the clinicians' as well as the patients' appraisals should be taken into account for efficiency assessment of implant treatment (Cosgrove et al. 1989).

However, studies are limited to dental implant survival and clinical/radiographically surrogate parameters (den Hartog et al. 2008). In contrast, patient-centered outcomes of implant treatment protocols have been unattended for years and are only gradually integrated into clinical trials (Pommer et al. 2011). Scientific information on patient satisfaction levels as well as the investigation of psychological and social effects following implant therapy is still rare in the current literature (Abduo & Lyons 2013). Most studies reported on edentulous patients with implant-supported removable prostheses

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Article Summary of:

“Patient-centered outcomes comparing digital and conventional implant impression procedures: a randomized crossover trial”

Questions on patient satisfaction with digital and conventional impression procedures and mean scores of the results.

VAS (visual analogue scale): unsatisfactory 0 – 100 excellent

12 Questions (2 x 6)	Digital Impression	Conventional impression
What is your opinion on the treatment time required for the impression procedure?	Mean 79.2; SD ± 12.1 median 83.0; range 50–95	Mean 57.6; SD ± 15.6 median 59.5; range 17–95
How convenient was the impression procedure for you?	Mean 78.6; SD ± 14.0median 84.0; range 35–90	Mean 53.6; SD ± 15.4 median 53.5; range 15–85
Was there a bad oral taste present and/or after the impression procedure?	Mean 10.9; SD ± 9.5 median 6.5; range 0–36	Mean 71.3; SD ± 15.7 median 77.5; range 25–87
Was there a bad oral taste present and/or after the impression procedure?	Mean 10.9; SD ± 9.5 median 6.5; range 0–36	Mean 71.3; SD ± 15.7 median 77.5; range 25–87
Did you experience a nausea sensation during impression procedure?	Mean 12.2; SD ± 11.4 median 7.0; range 0–51	Mean 68.7; SD ± 18.0 median 74.0; range 10–93
Did you experience pain during impression procedure?	Mean 13.9; SD ± 10.3median 13.0; range 0–36	Mean 44.6; SD ± 20.7 median 45.0; range 5–77

Conclusion:

The digital technique emerges as the most preferred one according to patient-centered outcomes and was more time-effective compared to conventional impressions. Within the limitations of this clinical crossover study, the following conclusions can be summarized:

- The digital workflow was significantly accepted as the most preferred and time effective implant impression procedure compared to the conventional technique with regard to the patients’ perception and satisfaction.
- With regard to treatment comfort, the digital impression protocol with Intraoral scanners was more patient-friendly than the conventional approach when it was performed by an experienced team of dentist/dental assistance.
- Both workflows worked clinically successful restoring single-tooth gaps with implant-supported crowns.

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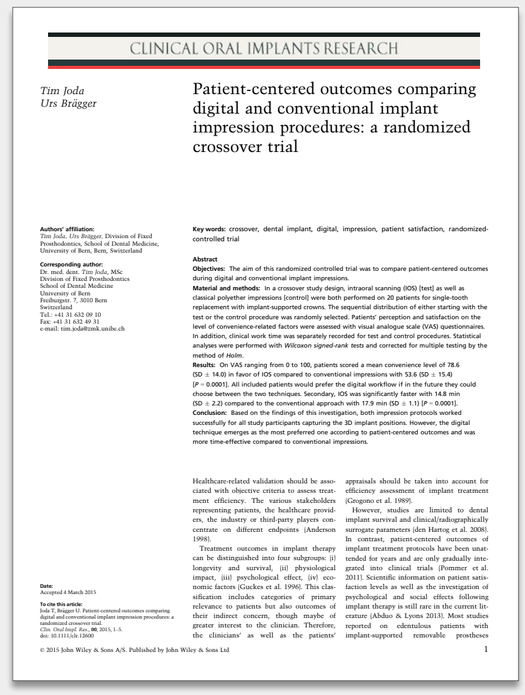

CLINICAL ORAL IMPLANTS RESEARCH

Tim Joda
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Patient-centered outcomes comparing digital and conventional implant impression procedures: a randomized crossover trial

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Article Summary of:

“Time-Efficiency Analysis Comparing Digital and Conventional Workflows for Implant Crowns: A Prospective Clinical Crossover Trial”

iTero™

Objectives:

To compare time-efficiency in the production of implant crowns using a digital workflow versus the conventional pathway.

Materials and Methods:

- 20 patients
- single-tooth replacements in posterior sites
- Crossover study design
- Test: Each patient received
  - for those in the test group, using digital workflow: a customized titanium abutment plus a computer-aided design/computer-assisted manufacture (CAD/CAM) zirconia suprastructure
  - for those in the control group, using a conventional pathway: a standardized titanium abutment plus a porcelain- fused- to-metal crown
- The start of the implant prosthetic treatment was established as the baseline.
- Time-efficiency analysis was defined as the primary outcome, and was measured for every single clinical and laboratory work step in minutes.
- Statistical calculations with Wilcoxon rank sum test

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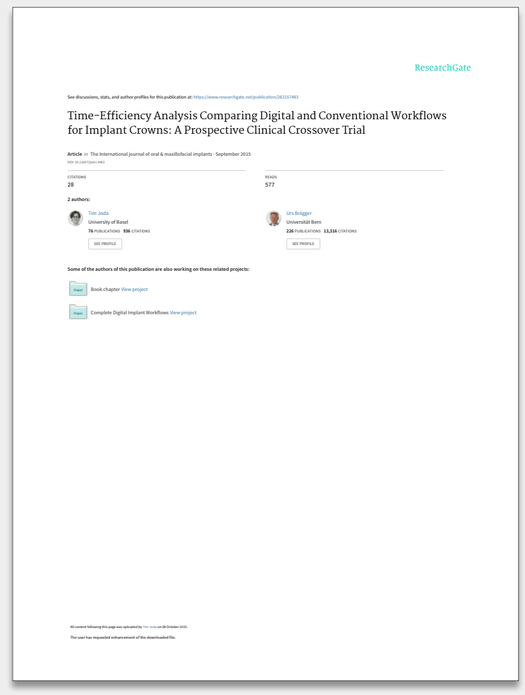

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Time-Efficiency Analysis Comparing Digital and Conventional Workflows for Implant Crowns: A Prospective Clinical Crossover Trial

Article in The International journal of oral & maxillofacial implants · September 2015

DOI: 10.11607/jomi.3963

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Article Summary of:

“Time-Efficiency Analysis Comparing Digital and Conventional Workflows for Implant Crowns: A Prospective Clinical Crossover Trial”

iTero™

Results:

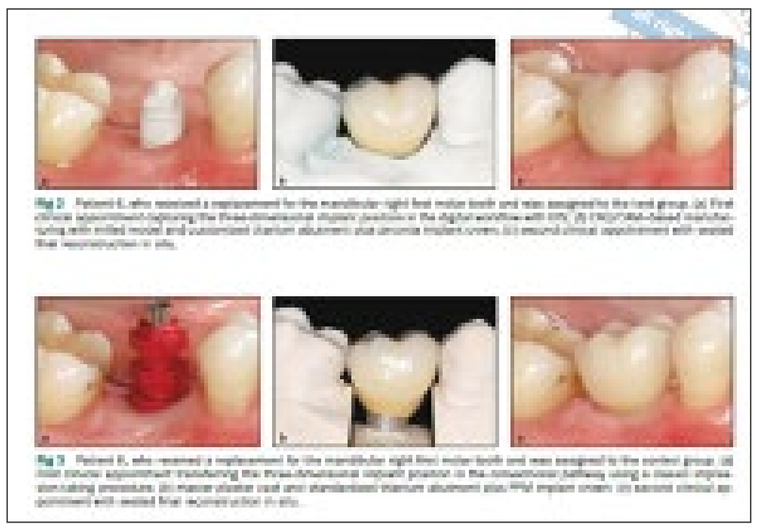
All crowns could be provided within two clinical appointments, independent of the manufacturing process.

The mean total production time, as the sum of clinical plus laboratory work steps, was significantly different.

The mean ± standard deviation (SD) time was 185.4 ± 17.9 minutes for the digital workflow process and 223.0 ± 26.2 minutes for the conventional pathway (P = .0001).

Therefore, digital processing for overall treatment was 16% faster.

Detailed analysis for the clinical treatment revealed a significantly reduced mean ± SD chair time of 27.3 ± 3.4 minutes for the test group compared with 33.2 ± 4.9 minutes for the control group (P = .0001). Similar results were found for the mean laboratory work time, with a significant decrease of 158.1 ± 17.2 minutes for the test group vs 189.8 ± 25.3 minutes for the control group (P = .0001).



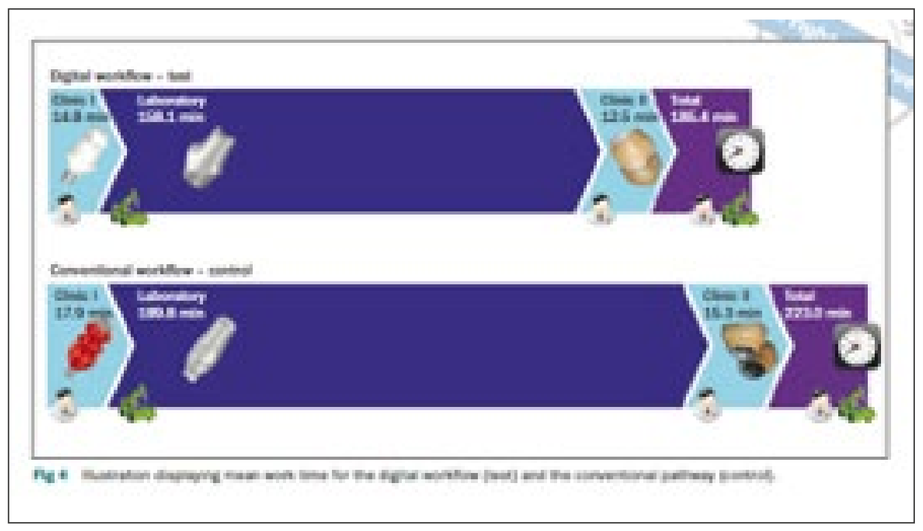
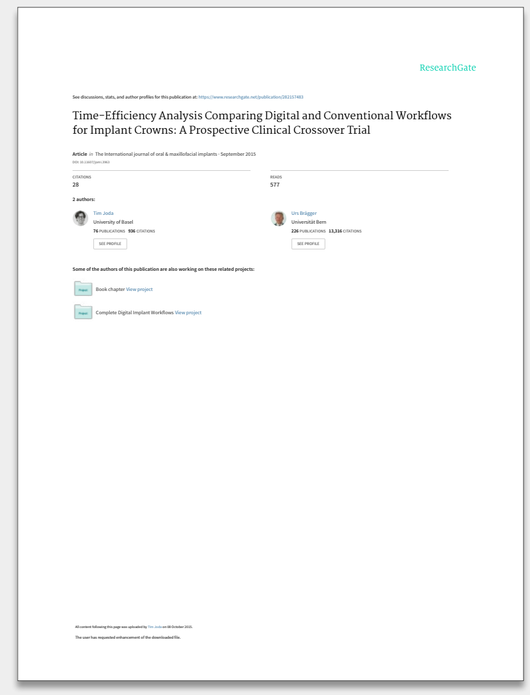


Fig 4 Illustration displaying mean work time for the digital workflow (test) and the conventional pathway (control).

Conclusion:

This investigation shows that the digital workflow seems to be more time-efficient than the established conventional production pathway for fixed implant-supported crowns. Both clinical chair time and laboratory manufacturing steps could be effectively shortened with the digital process of intraoral scanning plus CAD/CAM technology.

Article:



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Article Summary of:

“Accuracy of full-arch digital impressions:
an in vitro and in vivo comparison.”

Objectives:

Comparison of full-arch digital impressions to conventional impressions in vitro and in vivo.

Materials and Methods:

Reference structure: A straight metal bar fixed between the second upper molars in the mouth of a voluntary patient and a corresponding polymer model.

The following digitalization methods were applied:

- The maxilla was digitized in vivo 12 times with the iTero Element™ scanner (P-SCAN);
- The maxilla was captured in vivo 12 times by conventional impression and the impression was digitized by a desktop scanner (P-IMP);
- The impressions were poured and the 12 referring gypsum master-casts were scanned with the same desktop scanner (P-CAST)
- The polymer model was digitized in vitro 12 times with the iTero Element scanner (M-SCAN);
- The polymer model was captured in vitro 2 times by conventional impression and the impression was digitized by a desktop scanner (M-IMP);
- The impressions were poured and the 12 referring gypsum master-casts were scanned with the same desktop scanner (M-CAST).

Datasets were exported and metrically analyzed (Geomagic Control X) to determine three dimensional length aberration and angular distortion versus the reference structure Mann-Whitney U test was implemented to detect differences ($p < 0.05$).

Article:

Clinical Oral Investigations
https://doi.org/10.1007/s00784-019-02965-2

ORIGINAL ARTICLE

Accuracy of full-arch digital impressions: an in vitro and in vivo comparison

Christine Keul[1] · Jan-Frederik Güth[1]

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Abstract
Objectives Comparison of full-arch digital impressions to conventional impressions in vitro and in vivo.
Materials and methods A straight metal bar was fixed between the second upper molars as a reference structure in the mouth of a voluntary patient and a corresponding polymer model. The following digitalization methods were applied: (1) the maxilla was digitized in vivo 12 times with the iTero Element (P-SCAN); (2) the maxilla was captured in vivo 12 times by conventional impression and the impression was digitized by a desktop scanner (P-IMP); (3) the impressions were poured and the 12 referring gypsum master-casts were scanned with the same desktop scanner (P-CAST); (4) the polymer model was digitized in vitro 12 times with the iTero Element (M-SCAN); (5) the polymer model was captured in vitro 12 times by conventional impression and the impression was digitized by a desktop scanner (M-IMP); (6) the impressions were poured and the 12 referring gypsum master-casts were scanned with the same desktop scanner (M-CAST). Datasets were exported and metrically analyzed (Geomagic Control X) to determine three-dimensional length aberration and angular distortion versus the reference structure. Mann–Whitney *U* test was implemented to detect differences ($p < 0.05$).
Results For multiple accuracy parameters, P-SCAN and M-SCAN showed similar or superior results compared to the other digitalization methods. The following length deviations were found: M-SCAN (~ 55 to 80 µm), M-IMP (110 to 329 µm), M-CAST (88 to 178 µm), P-SCAN (~ 67 to 76 µm), P-IMP (125–320 µm), and P-CAST (92–285 µm).
Conclusions Within the limitations of this study, the iTero-scan seems to be a valid alternative to conventional impressions for full arches.
Clinical relevance Intraoral scanners are more and more used in daily routine; however, little is known about their accuracy when it comes to full-arch scans. Under optimum conditions, the direct digitalization using the iTero Element intraoral scanning device results in the same and for single parameters (arch width and arch distortion) even in higher accuracy than the indirect digitalization of the impression or the gypsum cast using a desktop scanner.

Keywords Digital impression · Accuracy · Full-arch impression · iTero Element · Metrology analysis

Introduction

Intraoral scanning supplements more and more the well-established conventional impressions using elastomers and the subsequent indirect digitalization of the impressions itself or the resulting casts. Therefore it can be meanwhile considered as a common entry to dental computer-aided design/computer-aided manufacturing (CAD/CAM) processes [1]. Virtual models are the basis for all steps in the digital workflow that enables a wide range of innovative diagnosis and rehabilitation options for a patient-centered treatment [2–4].

The available intraoral digitalization systems are working on optical measuring principles [5, 6] to digitize the intraoral structures directly in the patient’s mouth [7, 8]. This avoids different working steps, like the selection of the proper impression tray, application of the adequate impression technique, disinfection, transport, and fabrication of dental gypsum casts. Besides the understandable enthusiasm for intraoral

✉ Christine Keul
Christine.keul@med.uni-muenchen.de

[1] Department of Prosthodontics, LMU Munich, Goethestraße 70, 80336 Munich, Germany

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Authors:
Christine Keul,
Jan-Frederik Güth

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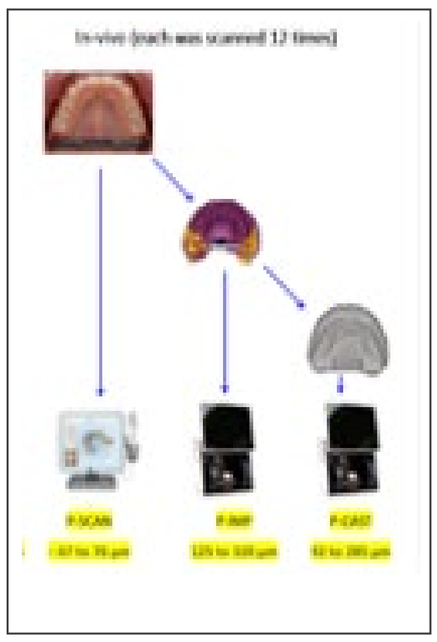
Article Summary of:

"Accuracy of full-arch digital impressions: an in vitro and in vivo comparison."

iTero™

Results:

For multiple accuracy parameters, P-SCAN (iTero scan) and M-SCAN (iTero™ scan of polymer model) showed similar or superior results compared to the other digitalization methods.



CLINICAL RELEVANCE:

Intraoral scanners are more and more used in daily routine; however, little is known about their accuracy when it comes to full-arch scans. Under optimum conditions, the direct digitalization using the iTero Element™ intraoral scanner results in the same and for single parameters (arch width and arch distortion) even in higher accuracy than the indirect digitalization of the impression or the gypsum cast using a desktop scanner.

The following length deviations were found:

	Substrate	Captured with	Digitized with	
M-SCAN	Polymer model	iTero	N/A	-55 to 80 µm
M-IMP	Polymer model	Conventional impression	Desktop scanner	110 to 329 µm
M-CAST	Polymer model	Casted conventional impression	Desktop scanner	88 to 178 µm
P-SCAN	Maxilla	iTero	N/A	- 67 to 76 µm
P-IMP	Maxilla	Conventional impression	Desktop scanner	125-320 µm
P-CAST	Maxilla	Casted conventional impression	Desktop scanner	92-285 µm

Conclusion:

Within the limitations of this study, the iTero™ scan seems to be a valid alternative to conventional impressions for full arches

Article:

Clinical Oral Investigations
https://doi.org/10.1007/s00784-019-02965-2

ORIGINAL ARTICLE

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Accuracy of full-arch digital impressions: an in vitro and in vivo comparison

Christine Keul[1] · Jan-Frederik Güth[1]

Received: 11 January 2019 / Accepted: 16 May 2019

Abstract
Objectives Comparison of full-arch digital impressions to conventional impressions in vitro and in vivo.
Materials and methods A straight metal bar was fixed between the second upper molars as a reference structure in the mouth of a voluntary patient and a corresponding polymer model. The following digitalization methods were applied: (1) the maxilla was digitized in vivo 12 times with the iTero Element (P-SCAN); (2) the maxilla was captured in vivo 12 times by conventional impression and the impression was digitized by a desktop scanner (P-IMP); (3) the impressions were poured and the 12 referring gypsum master-casts were scanned with the same desktop scanner (P-CAST); (4) the polymer model was digitized in vitro 12 times with the iTero Element (M-SCAN); (5) the polymer model was captured in vitro 12 times by conventional impression and the impression was digitized by a desktop scanner (M-IMP); (6) the impressions were poured and the 12 referring gypsum master-casts were scanned with the same desktop scanner (M-CAST). Datasets were exported and metrically analyzed (Geomagic Control X) to determine three-dimensional length aberration and angular distortion versus the reference structure. Mann–Whitney *U* test was implemented to detect differences ($p < 0.05$).
Results For multiple accuracy parameters, P-SCAN and M-SCAN showed similar or superior results compared to the other digitalization methods. The following length deviations were found: M-SCAN (− 55 to 80 µm), M-IMP (110 to 329 µm), M-CAST (88 to 178 µm), P-SCAN (− 67 to 76 µm), P-IMP (125–320 µm), and P-CAST (92–285 µm).
Conclusions Within the limitations of this study, the iTero-scan seems to be a valid alternative to conventional impressions for full arches.
Clinical relevance Intraoral scanners are more and more used in daily routine; however, little is known about their accuracy when it comes to full-arch scans. Under optimum conditions, the direct digitalization using the iTero Element intraoral scanning device results in the same and for single parameters (arch width and arch distortion) even in higher accuracy than the indirect digitalization of the impression or the gypsum cast using a desktop scanner.

Keywords Digital impression · Accuracy · Full-arch impression · iTero Element · Metrology analysis

Introduction

Intraoral scanning supplements more and more the well-established conventional impressions using elastomers and the subsequent indirect digitalization of the impressions itself or the resulting casts. Therefore it can be meanwhile considered as a common entry to dental computer-aided design/computer-aided manufacturing (CAD/CAM) processes [1]. Virtual models are the basis for all steps in the digital workflow that enables a wide range of innovative diagnosis and rehabilitation options for a patient-centered treatment [2–4].

The available intraoral digitalization systems are working on optical measuring principles [5, 6] to digitize the intraoral structures directly in the patient's mouth [7, 8]. This avoids different working steps, like the selection of the proper impression tray, application of the adequate impression technique, disinfection, transport, and fabrication of dental gypsum casts. Besides the understandable enthusiasm for intraoral

✉ Christine Keul
Christine.keul@med.uni-muenchen.de

1 Department of Prosthodontics, LMU Munich, Goethestraße 70, 80336 Munich, Germany

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"A new method to measure the accuracy of intraoral scanners along the complete dental arch: A pilot study."

iTero™

Purpose:

The purpose of this study is to assess the accuracy of three intraoral scanners along the complete dental arch and evaluate the feasibility of the assessment methodology for further in vivo analysis.

Materials and Methods:

A specific measurement pattern was fabricated and measured using a coordinate measuring machine for the assessment of control distances and angles. Afterwards, the pattern was placed and fixed in replica of an upper jaw for their subsequent scans (10 times) using 3 intraoral scanners, namely iTero Element™ scanner, 3shape Trios 3 scanner, and 3M True Definition scanner. 4 reference distances and 5 angles were measured and compared with the controls. Trueness and precision were assessed for each Intraoral scanner: trueness, as the deviation of the measures from the control ones, while precision, as the dispersion of measurements in each reference parameter. These measurements were carried out using software for analyzing 3-dimensional data. Data analysis software was used for statistical and measurements analysis (a=.05).

Results:

Significant differences (P<.05) were found depending on the intraoral scanner used. Best trueness values were achieved with iTero Element scanner (mean from 10 ± 7 μm to 91 ± 63 μm) while the worst values were obtained with 3shapeTrios 3 scanner (mean from 42 ± 23 μm to 174 ± 77 μm). Trueness analysis in angle measurements, as well as precision analysis, did not show conclusive results.

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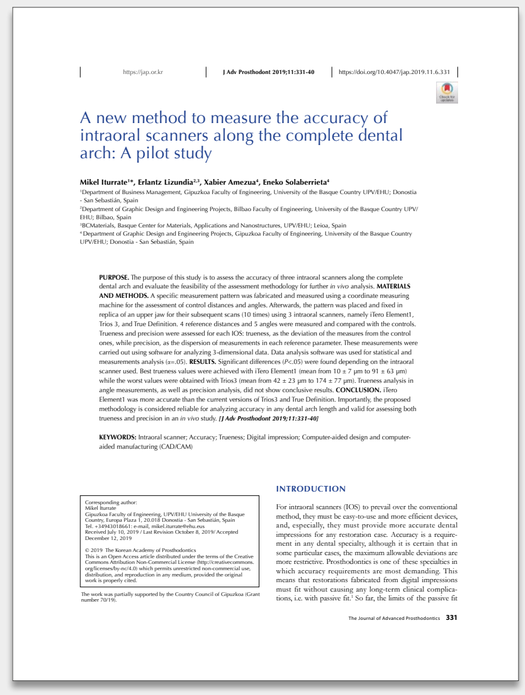

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A new method to measure the accuracy of intraoral scanners along the complete dental arch: A pilot study

Mikel Iturrate[1*], Erlantz Lizundia[2,3], Xabier Amezua[4], Eneko Solaberrieta[4]

[1]Department of Business Management, Gipuzkoa Faculty of Engineering, University of the Basque Country UPV/EHU; Donostia - San Sebastián, Spain
[2]Department of Graphic Design and Engineering Projects, Bilbao Faculty of Engineering, University of the Basque Country UPV/EHU; Bilbao, Spain
[3]BCMaterials, Basque Center for Materials, Applications and Nanostructures, UPV/EHU; Leioa, Spain
[4]Department of Graphic Design and Engineering Projects, Gipuzkoa Faculty of Engineering, University of the Basque Country UPV/EHU; Donostia - San Sebastián, Spain

PURPOSE. The purpose of this study is to assess the accuracy of three intraoral scannees along the complete dental arch and evaluate the feasibility of the assessment methodology for further *in vivo* analysis. **MATERIALS AND METHODS.** A specific measurement pattern was fabricated and measured using a coordinate measuring machine for the assessment of control distances and angles. Afterwards, the pattern was placed and fixed in replica of an upper jaw for their subsequent scans (10 times) using 3 intraoral scanners, namely iTero Element1 , Trios 3, and True Definition. 4 reference distances and 5 angles were measured and compared with the controls. Trueness and precision were assessed for each IOS: trueness, as the deviation of the measures from the control ones, while precision, as the dispersion of measurements in each reference parameter. These measurements were carried out using software for analyzing 3-dimensional data. Data analysis software was used for statistical and measurements analysis (a=.05). **RESULTS.** Significant differences (P<.05) were found depending on the intraoral scanner used. Best trueness values were achieved with iTero Element1 (mean from 10 ± 7 μm to 91 ± 63 μm) while the worst values were obtained with Trios3 (mean from 42 ± 23 μm to 174 ± 77 μm). Trueness analysis in angle measurements, as well as precision analysis, did not show conclusive results. **CONCLUSION.** iTero Element1 was more accurate than the current versions of Trios3 and True Definition. Importantly, the proposed methodology is considered reliable for analyzing accuracy in any dental arch length and valid for assessing both trueness and precision in an *in vivo* study. *[J Adv Prosthodont 2019;11:331-40]*

KEYWORDS: Intraoral scanner; Accuracy; Trueness; Digital impression; Computer-aided design and computer-aided manufacturing (CAD/CAM)

Corresponding author:
Mikel Iturrate
Gipuzkoa Faculty of Engineering, UPV/EHU University of the Basque Country, Europa Plaza 1, 20.018 Donostia - San Sebastián, Spain
Tel. +34943018661 e-mail. mikel.iturrate@ehu.eus
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The work was partially supported by the Country Council of Gipuzkoa (Grant number 70/19).

INTRODUCTION

For intraoral scanners (IOS) to prevail over the conventional method, they must be easy-to-use and more efficient devices, and, especially, they must provide more accurate dental impressions for any restoration case. Accuracy is a requirement in any dental specialty, although it is certain that in some particular cases, the maximum allowable deviations are more restrictive. Prosthodontics is one of these specialties in which accuracy requirements are most demanding. This means that restorations fabricated from digital impressions must fit without causing any long-term clinical complications, i.e. with passive fit.[1] So far, the limits of the passive fit

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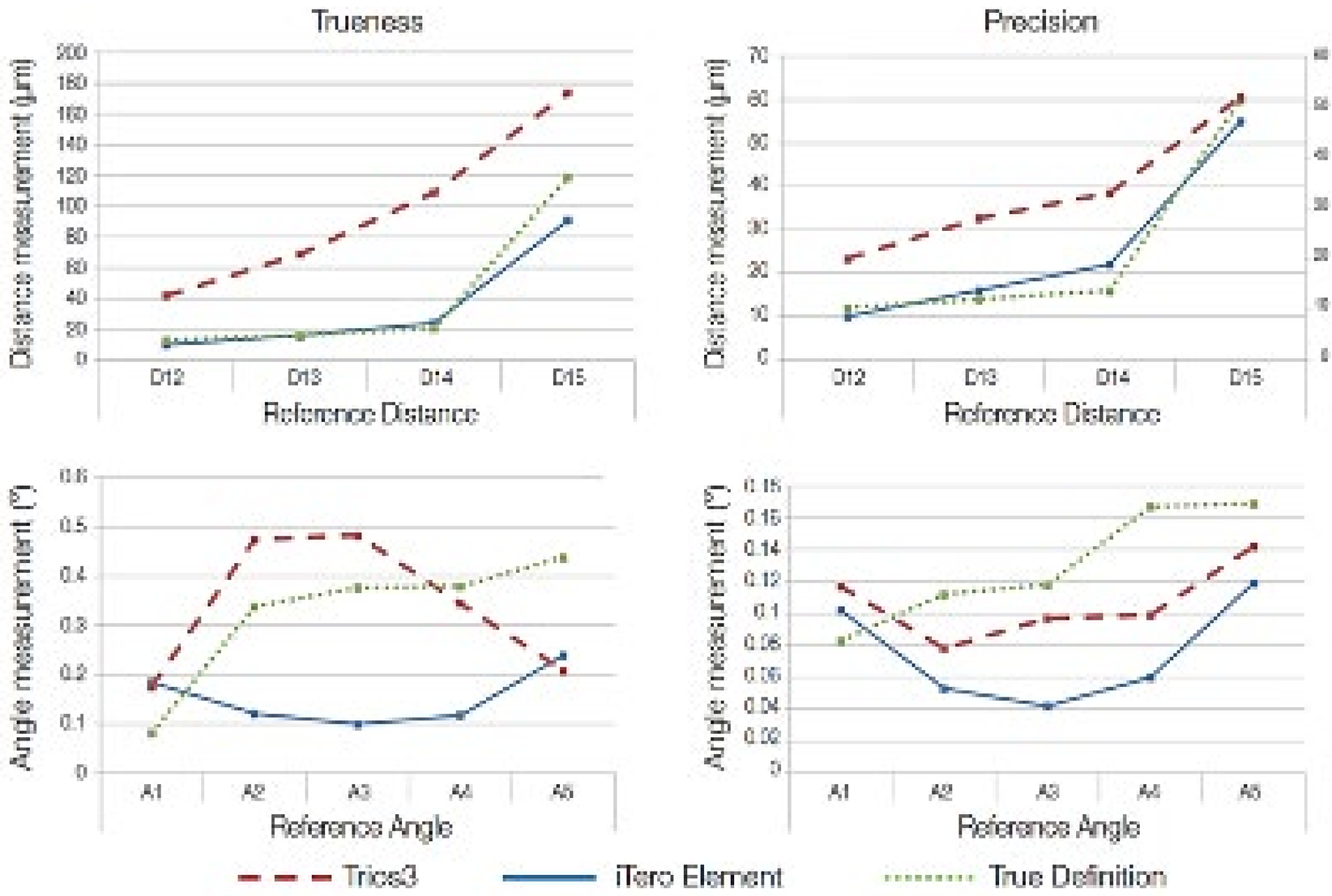

Conclusion:

iTero Element was more accurate than the 3shape Trios 3 scanner and 3M True Definition scanner. Importantly, the proposed methodology is considered reliable for analyzing accuracy in any dental arch length and valid for assessing both trueness and precision in an in vivo study.

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Mikel Iturrate[1*], Erlantz Lizundia[2,3], Xabier Amezua[4], Eneko Solaberrieta[4]

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KEYWORDS: Intraoral scanner; Accuracy; Trueness; Digital impression; Computer-aided design and computer-aided manufacturing (CAD/CAM)

Corresponding author:
Mikel Iturrate
Gipuzkoa Faculty of Engineering, UPV/EHU University of the Basque Country, Europa Plaza 1, 20018 Donostia - San Sebastián, Spain
Tel. +34943018661: e-mail, mikel.iturrate@ehu.eus
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"Randomized controlled clinical trial of digital and conventional workflows for the fabrication of zirconia-ceramic fixed partial dentures. Part III: Marginal and internal fit"

iTero™

Objectives:

The purpose of the third part of this clinical study was to test whether the fit of zirconia 3-unit frameworks for fixed partial dentures fabricated with fully digital workflows differed from that of metal frameworks fabricated with the conventional workflow.

Materials and Methods:

- 10 patients
- 4 fixed-partial-denture frameworks were fabricated for the same abutment teeth
- Digital workflows were applied for the fabrication of 3 zirconia frameworks with Lava, iTero™ scanner, and Cerec infiniDent systems
- Conventional workflow included a polyether impression, manual waxing, the lost-wax technique, and the casting of a metal framework.
- Test : For each participant
  - 3 FPDs were digitally fabricated, and 1 FPD was conventionally fabricated.
  - The sequence of the FPD assessment was randomly allocated according to a computer-generated list.
  - To reduce operator bias, the investigators generated and evaluated the replicas without being able to distinguish among the digitally fabricated FPDs under investigation.

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CLINICAL RESEARCH

Randomized controlled clinical trial of digital and conventional workflows for the fabrication of zirconia-ceramic fixed partial dentures. Part III: Marginal and internal fit

Goran I. Benic, PD Dr med dent,[a] Irena Sailer, Prof Dr med dent,[b] Marco Zeltner, Dr med dent,[c] Janine N. Gütermann,[d] Mutlu Özcan, Prof(NL) Dr med dent,[e] and Sven Mühlemann, Dr med dent[f]

ABSTRACT

Statement of problem. Trials comparing the overall performances of digital and conventional workflows in restorative dentistry are lacking.

Purpose. The purpose of the third part of this clinical study was to test whether the fit of zirconia 3-unit frameworks for fixed partial dentures fabricated with fully digital workflows differed from that of metal frameworks fabricated with the conventional workflow.

Material and methods. In each of 10 participants, 4 fixed-partial-denture frameworks were fabricated for the same abutment teeth according to a randomly generated sequence. Digital workflows were applied for the fabrication of 3 zirconia frameworks with Lava, iTero, and Cerec infiniDent systems. The conventional workflow included a polyether impression, manual waxing, the lost-wax technique, and the casting of a metal framework. The discrepancies between the frameworks and the abutment teeth were registered using the replica technique with polyvinyl siloxane. The dimensions of the marginal discrepancy ($Discrepancy_{marginal}$) and the internal discrepancy in 4 different regions of interest ($Discrepancy_{Axiobuc}$, $Discrepancy_{Axio}$, $Discrepancy_{Line}$, and $Discrepancy_{occlusal}$) were assessed using a light microscope. Post hoc t tests with Bonferroni correction were applied to detect differences (α=.05).

Results. $Discrepancy_{Provisbuc}$ was 96.1 ±63.7 μm for the iTero, 106.9 ±96.0 μm for the Lava, 112.2 ±76.7 μm for the Cerec infiniDent, and 126.5 ±91.0 μm for the conventional workflow. The difference between the iTero and the conventional workflow was statistically significant (P=.029). $Discrepancy_{occlusal}$ was 153.5 ±66.8 μm for the iTero, 203.3 ±127.9 μm for the Lava, 179.7 ±63.1 μm for the Cerec infiniDent, and 148.8 ±66.8 μm for the conventional workflow. $Discrepancy_{occlusal}$ was significantly lower for the conventional workflow than for the Lava and the Cerec infiniDent workflows (P<.01). The iTero resulted in significantly lower values of $Discrepancy_{occlusal}$ than the Lava and the Cerec infiniDent workflows (P<.01).

Conclusions. In terms of framework fit in the region of the shoulder, digitally fabricated zirconia 3-unit frameworks presented similar or better fit than the conventionally fabricated metal frameworks. In the occlusal regions, the conventionally fabricated metal frameworks achieved a more favorable fit than the CAD-CAM zirconia frameworks. (J Prosthet Dent 2018;■:■-■)

Funding: This work was supported by the Clinic of Fixed and Removable Prosthodontics and Dental Material Science, Center of Dental Medicine, University of Zurich, Switzerland, and by a research grant from the Institut Straumann AG, Basel, Switzerland.

[a]Senior Teaching and Research Assistant, Clinic of Fixed and Removable Prosthodontics and Dental Material Science, Center of Dental Medicine, University of Zurich, Zurich, Switzerland.
[b]Professor, Division of Fixed Prosthodontics and Biomaterials, University Clinics for Dental Medicine, University of Geneva, Geneva, Switzerland.
[c]Senior Teaching and Research Assistant, Clinic of Fixed and Removable Prosthodontics and Dental Material Science, Center of Dental Medicine, University of Zurich, Zurich, Switzerland.
[d]Master of Dental Medicine, Clinic of Fixed and Removable Prosthodontics and Dental Material Science, Center of Dental Medicine, University of Zurich, Zurich, Switzerland.
[e]Professor, Clinic of Fixed and Removable Prosthodontics and Dental Material Science, Center of Dental Medicine, University of Zurich, Zurich, Switzerland.
[f]Senior Teaching and Research Assistant, Clinic of Fixed and Removable Prosthodontics and Dental Material Science, Center of Dental Medicine, University of Zurich, Zurich, Switzerland.

Authors:
Goran I. Benic, Irena Sailer, Marco Zeltner, Janine N. Gütermann, Mutlu Özcan and Sven Mühlemann

Reference:
J Prosthet Dent. 2019 Mar;121(3):426-431

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"Randomized controlled clinical trial of digital and conventional workflows for the fabrication of zirconia-ceramic fixed partial dentures. Part III: Marginal and internal fit"

iTero™

Results:

	Conventional	iTero	Lava	CEREC infiniDent
Discrepancy shoulder	126.5 ±91.0 mm	96.1 ±61.7 mm	106.9 ±96.0 mm	112.2 ±76.7 mm
Discrepancy occlusal	148.8 ±66.8 mm	153.5 ±66.8 mm	203.3 ±127.9 mm	179.7 ±63.1 mm

The difference between the the iTero™ scanner and the conventional workflow was statistically significant (P=.029).

The iTero™ scanner resulted in significantly lower values of Discrepancy occlusal than the Lava and the Cerec infini Dent workflows (P<.01).The difference between iTero and Conventional was not statistically significant.

Conclusion:

In terms of frameworks presented similar or better fit than the conventionally fabricated metal frameworks. In the occlusal regions, the conventionally fabricated metal frameworks achieved a more favorable fit than the CAD-CAM zirconia frameworks.

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CLINICAL RESEARCH

Randomized controlled clinical trial of digital and conventional workflows for the fabrication of zirconia-ceramic fixed partial dentures. Part III: Marginal and internal fit

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The introduction of computer-aided design and computer-aided manufacturing (CAD-CAM) systems to dentistry has led to increased production efficiency and the introduction of new restorative materials, such as zirconia. Zirconia, because of its excellent mechanical characteristics, is a suitable alternative to the traditionally used metal frameworks for posterior fixed partial dentures (FPDs).[1-4]

An essential aspect of any restorative workflow is the marginal and internal fit of the resulting prosthesis. Poorly fitting margins are associated with a risk of caries through increased plaque accumulation and microleakage.[5,6] Internal fit can influence the mechanical stability of the ceramic restoration, and an increased internal discrepancy can

ABSTRACT

Statement of problem. Trials comparing the overall performances of digital and conventional workflows in restorative dentistry are lacking.

Purpose. The purpose of the third part of this clinical study was to test whether the fit of zirconia 3-unit frameworks for fixed partial dentures fabricated with fully digital workflows differed from that of metal frameworks fabricated with the conventional workflow.

Material and methods. In each of 10 participants, 4 fixed-partial-denture frameworks were fabricated for the same abutment teeth according to a randomly generated sequence. Digital workflows were applied for the fabrication of 3 zirconia frameworks with Lava, iTero, and Cerec infiniDent systems. The conventional workflow included a polyether impression, manual waxing, the lost-wax technique, and the casting of a metal framework. The discrepancies between the frameworks and the abutment teeth were registered using the replica technique with polyvinyl siloxane. The dimensions of the marginal discrepancy ($Discrepancy_{marginal}$) and the internal discrepancy in 4 different regions of interest ($Discrepancy_{shoulder}$, $Discrepancy_{axial}$, $Discrepancy_{cusp}$, and $Discrepancy_{occlusal}$) were assessed using a light microscope. Post hoc *t* tests with Bonferroni correction were applied to detect differences (α=.05).

Results. $Discrepancy_{shoulder}$ was 96.1 ±61.7 μm for the iTero, 106.9 ±96.0 μm for the Lava, 112.2 ±76.7 μm for the Cerec infiniDent, and 126.5 ±91.0 μm for the conventional workflow. The difference between the iTero and the conventional workflow was statistically significant ($P_{shoulder}$=.029). $Discrepancy_{occlusal}$ was 153.5 ±66.8 μm for the iTero, 203.3 ±127.9 μm for the Lava, 179.7 ±63.1 μm for the Cerec infiniDent, and 148.8 ±66.8 μm for the conventional workflow. $Discrepancy_{occlusal}$ was significantly lower for the conventional workflow than for the Lava and the Cerec infiniDent workflows ($P_{occlusal}$<.01). The iTero resulted in significantly lower values of $Discrepancy_{occlusal}$ than the Lava and the Cerec infiniDent workflows ($P_{occlusal}$<.01).

Conclusions. In terms of framework fit in the region of the shoulder, digitally fabricated zirconia 3-unit frameworks presented similar or better fit than the conventionally fabricated metal frameworks. In the occlusal regions, the conventionally fabricated metal frameworks achieved a more favorable fit than the CAD-CAM zirconia frameworks. (J Prosthet Dent 2018;■:■■■)

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"Trueness of 12 intraoral scanners in the full-arch implant impression: a comparative in vitro study"

iTero™

Objectives:

The aim of this in vitro study was to assess and compare the trueness of 12 different Intraoral scanners in FA implant impression.

Materials and Methods:

- A stone-cast model of a totally edentulous maxilla with 6 implant analogues and scanbodies (SBs) was scanned with a desktop scanner (Freedom UHD®) to capture a reference model (RM), and with 12 Intraoral scanners :
  - ITERO ELEMENTS 5D®;
  - PRIMESCAN® and OMNICAM®;
  - CS 3700® and CS 3600®;
  - TRIOS3®; i-500®;
  - EMERALD S® and EMERALD® VIRTUO VIVO® and DWIO®;
  - RUNEYES QUICKSCAN®.
- Ten scans were taken using each Intraoral scanner, and each was compared to the RM, to evaluate trueness.
- A mesh/mesh method and a nurbs/nurbs method were used to evaluate the overall trueness of the scans;
- Linear and cross distances between the SBs were used to evaluate the local trueness of the scans.
- The analysis was performed using reverse engineering software (Studio®, Geomagics Magics®,Materialise).
- A statistical evaluation was performed.

In this in vitro study, a type IV gypsum model was used. This model represented a totally edentulous maxilla with 6 implant analogues in positions #11, #14, #16, #21, #24 and #26 (right and left central incisors, first premolars and first molars) and high-precision non-reflective polyether-ether-ketone (PEEK) SBs (Megagen®, Daegu, South Korea) screwed on

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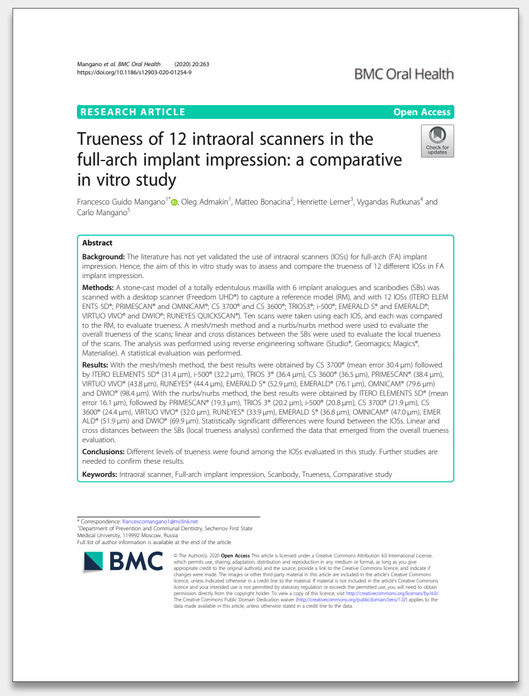

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https://doi.org/10.1186/s12903-020-01254-9

BMC Oral Health

RESEARCH ARTICLE Open Access

Trueness of 12 intraoral scanners in the full-arch implant impression: a comparative in vitro study

Francesco Guido Mangano[1*], Oleg Admakin[1], Matteo Bonacina[2], Henriette Lerner[3], Vygandas Rutkunas[4] and Carlo Mangano[5]

Abstract

Background: The literature has not yet validated the use of intraoral scanners (IOSs) for full-arch (FA) implant impression. Hence, the aim of this in vitro study was to assess and compare the trueness of 12 different IOSs in FA implant impression.

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Conclusions: Different levels of trueness were found among the IOSs evaluated in this study. Further studies are needed to confirm these results.

Keywords: Intraoral scanner, Full-arch implant impression, Scanbody, Trueness, Comparative study

* Correspondence: francescomangano1@mclink.net
[1]Department of Prevention and Communal Dentistry, Sechenov First State Medical University, 119992 Moscow, Russia
Full list of author information is available at the end of the article

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Article Summary of:

"Trueness of 12 intraoral scanners in the full-arch implant impression: a comparative in vitro study"

Results:

Two methods of comparison were used:

1 - Mesh/mesh evaluation method

2 - Nurbs/nurbs evaluation method

Ranking (starting from best)	Mesh/Mesh Method	Nurbs/Nurbs Method
1	CS 3700® (mean error 30.4 µm)	ITERO ELEMENTS 5D® (mean error 16.1 µm)
2	ITERO ELEMENTS 5D® (31.4 µm),	PRIMESCAN® (19.3 µm),
3	i-500® (32.2 µm),	TRIOS 3® (20.2 µm),
4	TRIOS 3® (36.4 µm),	i-500® (20.8 µm),
5	CS 3600® (36.5 µm),	CS 3700® (21.9 µm),
6	PRIMESCAN® (38.4 µm),	CS3600® (24.4 µm),
7	VIRTUO VIVO® (43.8 µm),	VIRTUO VIVO® (32.0 µm),
8	RUNEYES® (44.4 µm),	RUNEYES® (33.9 µm),
9	EMERALD S® (52.9 µm),	EMERALD S® (36.8 µm),
10	EMERALD® (76.1 µm),	OMNICAM® (47.0 µm),
11	OMNICAM® (79.6 µm)	EMERALD® (51.9 µm)
12	DWIO® (98.4 µm).	DWIO® (69.9 µm).

Statistically significant differences were found between the Intraoral scanners. Linear and cross distances between the SBs (local trueness analysis) confirmed the data that emerged from the overall trueness evaluation.

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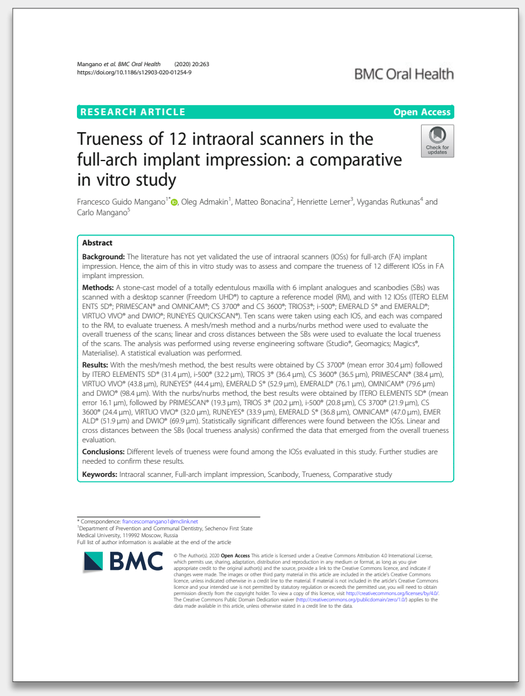

Mangano et al. BMC Oral Health (2020) 20:263
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BMC Oral Health

RESEARCH ARTICLE Open Access

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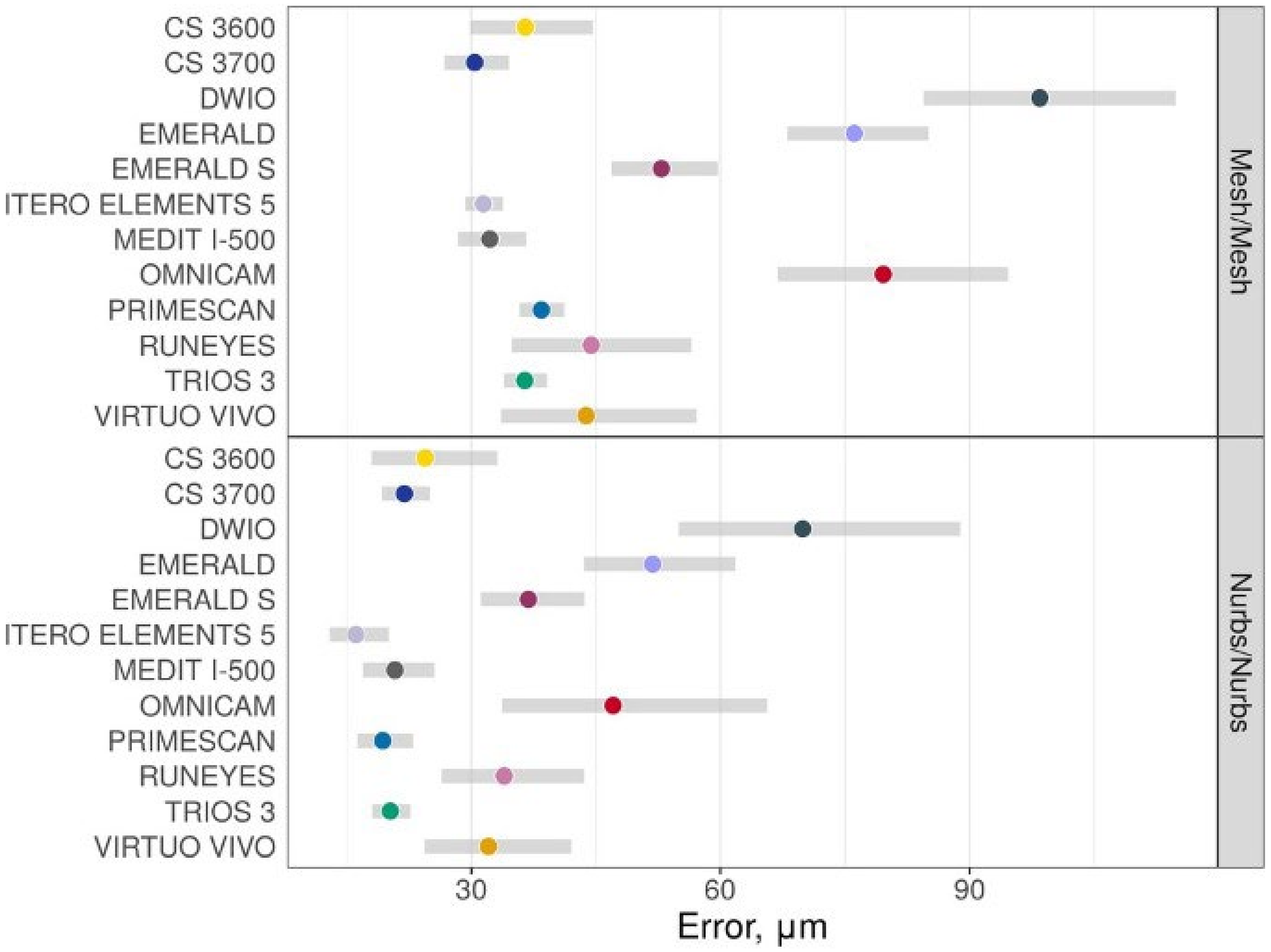

Fig. 3 Estimated mean errors (in µm, with 95% CIs) for mesh/mesh and nurbs/nurbs evaluations

Conclusion:

Different levels of trueness were found among the Intraoral scanners evaluated in this study. Further studies are needed to confirm these results.

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iTero™

Executive summary

- This study analysed potential of early proximal caries detection using 3D range data of teeth consisting of near-infrared reflection(NIRR) images.
- iTero Element™ 5D imaging system with the iTero NIRI technology mode activated can detect initial defects in the enamel with higher sensitivity than BWR, but it cannot, in contrast to BWR, support a reliable recommendation for or against invasive therapy when the EDJ is exceeded.
- Unlike other devices for caries diagnosis that use 850 nm LEDs as an infrared light source, the iTero Element 5D imaging system does not show any reflection artefacts caused by a smooth dental surface.
- Images acquired with the iTero NIRI technology scanner present light scattered in depth mainly at dentin and irregularities in enamel, without being superimposed by superficial specular reflections.
- The novel approach to entirely measure the dental arch from different directions can be an attractive option for the development of future diagnostic applications. It would be possible to calculate the complete surface texture for the entire 3D data set from the multitude of individual images.

Aim of the study

The aim of this study was to compare the diagnostic performance of the iTero Element 5D imaging system for the detection of early proximal caries with that of bitewings.

Materials and Methods

- Two hundred fifty extracted permanent molars and premolars were selected from a pool of extracted teeth of anonymous patients.
- The samples were cleaned of any residues using manual scalers and assigned a unique identification number (ID).
- Using a lock-and-key fixation method, the teeth were divided into pairs, the tooth pairs were arranged to mimic the natural proximal contact area as closely as possible.
- Coupled sample pairs were fixed on a metal plate and then scanned with the iTero Element 5D imaging system with the iTero NIRI technology.
- The tooth pairs were radiographed without proximal contact for this study, to avoid hindering the evaluation of the radiographs by overlapping in the area of the proximal contacts and to enable the best possible radiographic diagnosis. All radiographs were taken using a Heliodent DS Dental X-ray unit (Sirona, Bensheim, Germany, 60 kV, 7 mA, 200 mm FHA cone, 0.08 s) and a digital charged-coupled device (CCD) sensor (Intra-Oral II CCD sensor, Sirona, Bensheim, Germany, sensor size 30.93×40.96×7.0 mm).

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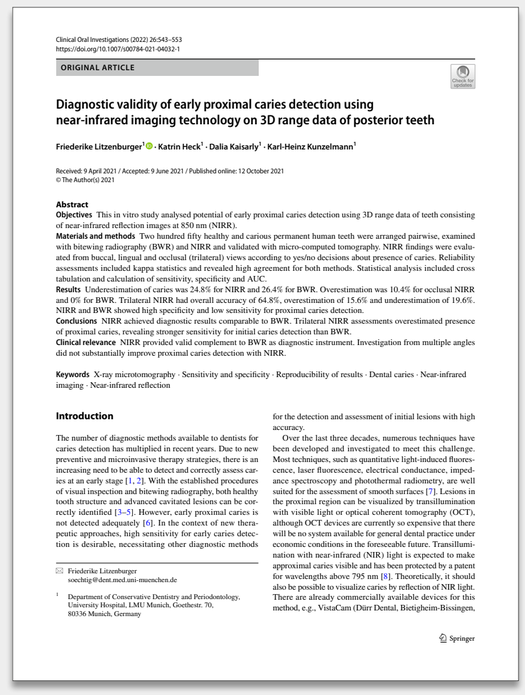

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ORIGINAL ARTICLE

Diagnostic validity of early proximal caries detection using near-infrared imaging technology on 3D range data of posterior teeth

Friederike Litzenburger[1] · Katrin Heck[1] · Dalia Kaisarly[1] · Karl-Heinz Kunzelmann[1]

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Abstract
Objectives This in vitro study analysed potential of early proximal caries detection using 3D range data of teeth consisting of near-infrared reflection images at 850 nm (NIRR).
Materials and methods Two hundred fifty healthy and carious permanent human teeth were arranged pairwise, examined with bitewing radiography (BWR) and NIRR and validated with micro-computed tomography. NIRR findings were evaluated from buccal, lingual and occlusal (trilateral) views according to yes/no decisions about presence of caries. Reliability assessments included kappa statistics and revealed high agreement for both methods. Statistical analysis included cross tabulation and calculation of sensitivity, specificity and AUC.
Results Underestimation of caries was 24.8% for NIRR and 26.4% for BWR. Overestimation was 10.4% for occlusal NIRR and 0% for BWR. Trilateral NIRR had overall accuracy of 64.8%, overestimation of 15.6% and underestimation of 19.6%. NIRR and BWR showed high specificity and low sensitivity for proximal caries detection.
Conclusions NIRR achieved diagnostic results comparable to BWR. Trilateral NIRR assessments overestimated presence of proximal caries, revealing stronger sensitivity for initial caries detection than BWR.
Clinical relevance NIRR provided valid complement to BWR as diagnostic instrument. Investigation from multiple angles did not substantially improve proximal caries detection with NIRR.

Keywords X-ray microtomography · Sensitivity and specificity · Reproducibility of results · Dental caries · Near-infrared imaging · Near-infrared reflection

Introduction

The number of diagnostic methods available to dentists for caries detection has multiplied in recent years. Due to new preventive and microinvasive therapy strategies, there is an increasing need to be able to detect and correctly assess caries at an early stage [1, 2]. With the established procedures of visual inspection and bitewing radiography, both healthy tooth structure and advanced cavitated lesions can be correctly identified [3–5]. However, early proximal caries is not detected adequately [6]. In the context of new therapeutic approaches, high sensitivity for early caries detection is desirable, necessitating other diagnostic methods for the detection and assessment of initial lesions with high accuracy.

Over the last three decades, numerous techniques have been developed and investigated to meet this challenge. Most techniques, such as quantitative light-induced fluorescence, laser fluorescence, electrical conductance, impedance spectroscopy and photothermal radiometry, are well suited for the assessment of smooth surfaces [7]. Lesions in the proximal region can be visualized by transillumination with visible light or optical coherent tomography (OCT), although OCT devices are currently so expensive that there will be no system available for general dental practice under economic conditions in the foreseeable future. Transillumination with near-infrared (NIR) light is expected to make approximal caries visible and has been protected by a patent for wavelengths above 795 nm [8]. Theoretically, it should also be possible to visualize caries by reflection of NIR light. There are already commercially available devices for this method, e.g., VistaCam (Dürr Dental, Bietigheim-Bissingen,

✉ Friederike Litzenburger
soechtig@dent.med.uni-muenchen.de

[1] Department of Conservative Dentistry and Periodontology, University Hospital, LMU Munich, Goethestr. 70, 80336 Munich, Germany

Authors:
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Materials and Methods

Fig. 1 – The application of the three-dimensional near-infrared reflection scanner is visualized by a monitor with the appropriate software (a). The tooth is illuminated either with a white LED (b) or a red laser (c)

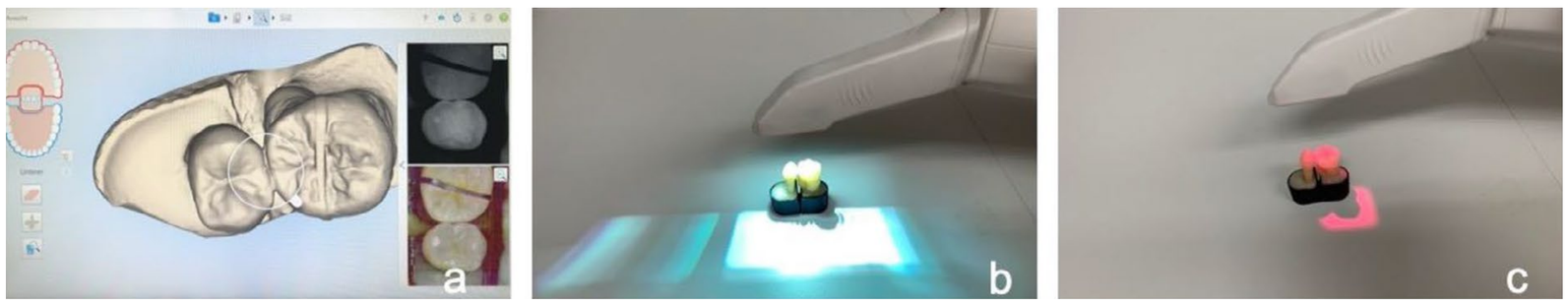


Fig. 2 – The teeth were fixed with composite material in three dimensionally printed specimen holders. (a) Maleholder, (b) female holder and (c) two specimens connected by amagnetic female-male key-lockjoint

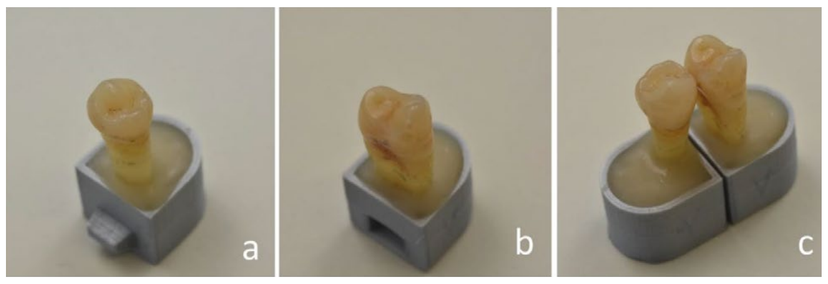
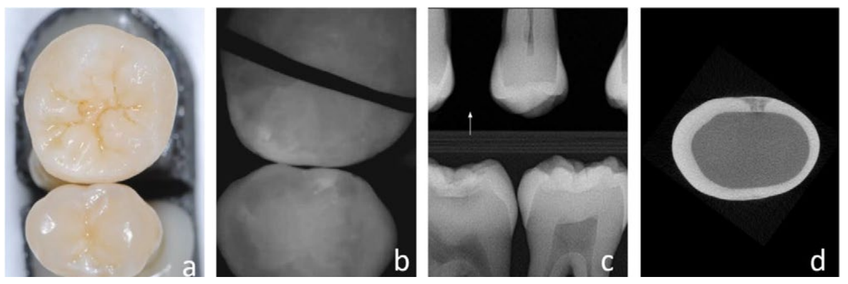


Fig. 3 – A non-cavitated caries lesion in a premolar that is visually undetectable (a). The caries lesion is visible with NIRR (white spot) and the black line marks the tooth that is not in the region of interest (b). The lesion was undetectable using X-rays and the arrow marks the side of interest (c). Micro-computed tomography reveals the presence of an initial dentin lesion (d)



Results

Table 1 – Cross-table for the ratings of three-dimensional near-infrared reflection scans at 850 nm from the occlusal viewpoint (NIRR occlusal) and from trilateral evaluation (NIRR trilateral) as well as from digital bitewing radiography (BWR) and micro-computed tomography (µCT) using the Marthaler classification (score 0 to 4) and describing findings that were not assessable (na).

		BWR						NIRR occlusal		NIRR trilateral		
		0	1	2	3	4	na	0	1	0	1	Total
µCT	0	154	0	0	0	0	4	132	26	119	39	158
	1	19	0	0	0	0	0	14	5	12	7	19
	2	23	2	2	1	0	1	19	10	16	13	29
	3	24	4	7	6	0	1	27	15	19	23	42
	4	0	0	1	0	1	0	2	0	2	0	2
	Total	220	6	10	7	1	6	194	56	168	82	250

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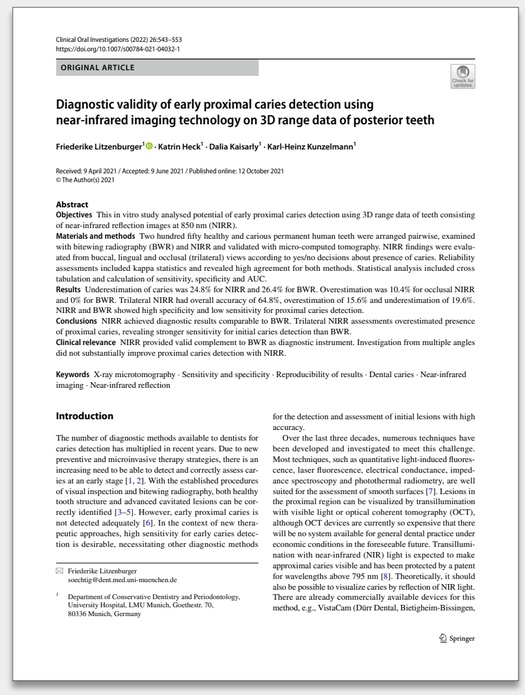

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✉ Friederike Litzenburger
soechtig@dent.med.uni-muenchen.de

[1] Department of Conservative Dentistry and Periodontology, University Hospital, LMU Munich, Goethestr. 70, 80336 Munich, Germany

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Results

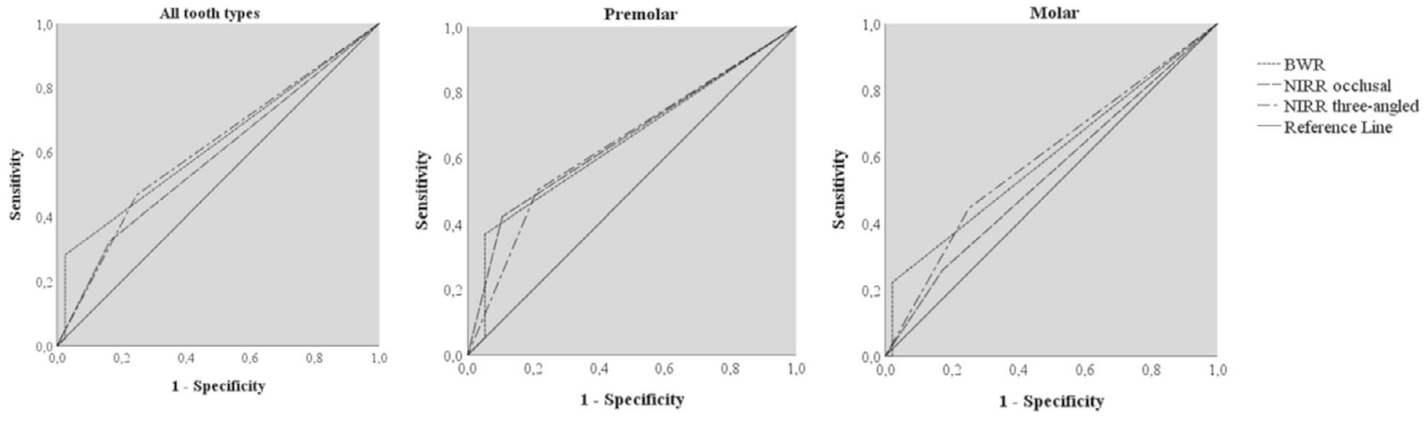
Table 2 – Inter- and intra-examiner reliability (linear weighted K values) for ratings of three-dimensional near-infrared reflection scans at 850 nm from the occlusal viewpoint (NIRR occlusal) and from trilateral evaluation (NIRR trilateral) as well as from digital bitewing radiography (BWR) with 0.95 confidence intervals (CI)

		Inter-examiner	Intra-examiner	
		Examiner 1 vs. Examiner 2	Examiner 1	Examiner 2
NIRR occlusal	κ	0.97	0.82	0.76
	Lower 0.95 CI	0.93	0.74	0.66
	Upper 0.95 CI	1.00	0.91	0.86
NIRR trilateral	κ	0.96	0.69	0.65
	Lower 0.95 CI	0.92	0.59	0.55
	Upper 0.95 CI	0.99	0.79	0.75
BWR	κ	0.85	0.90	0.91
	Lower 0.95 CI	0.76	0.85	0.85
	Upper 0.95 CI	0.93	0.96	0.97

Table 3 – Sensitivity, specificity, false-positive (FP) value, false-negative (FN) value and area under the receiver operating characteristic curve (AUC) for evaluation of three-dimensional near-infrared reflection scans at 850 nm from the occlusal viewpoint (NIRR occlusal)

		Sensitivity	Specificity	FP	FN	AUC
NIRR occlusal	All samples	0.33 (0.23–0.42)	0.84 (0.78–0.89)	0.16 (0.11–0.22)	0.67 (0.57–0.74)	0.58 (0.51–0.66)
	Premolars	0.42 (0.26–0.58)	0.89 (0.76–1.03)	0.11 (−0.03–0.24)	0.58 (0.42–0.73)	0.66 (0.51–0.80)
	Molars	0.26 (0.14–0.38)	0.83 (0.76–0.89)	0.17 (0.11–0.24)	0.74 (0.62–0.81)	0.54 (0.45–0.64)
NIRR trilateral	All samples	0.47 (0.37–0.57)	0.75 (0.69–0.82)	0.25 (0.18–0.31)	0.53 (0.43–0.61)	0.61 (0.54–0.68)
	Premolars	0.50 (0.34–0.66)	0.79 (0.61–0.97)	0.21 (0.03–0.39)	0.50 (0.34–0.67)	0.65 (0.50–0.79)
	Molars	0.44 (0.31–0.58)	0.75 (0.68–0.82)	0.25 (0.18–0.32)	0.56 (0.42–0.64)	0.60 (0.51–0.69)
BWR	All samples	0.27 (0.17–0.36)	1.00 (1.00–1.00)	0.00 (0.00–0.00)	0.73 (0.64–0.80)	0.63 (0.55–0.70)
	Premolars	0.33 (0.18–0.49)	1.00 (1.00–1.00)	0.00 (0.00–0.00)	0.67 (0.51–0.81)	0.65 (0.50–0.80)
	Molars	0.22 (0.11–0.33)	1.00 (1.00–.100)	0.00 (0.00–0.00)	0.78 (0.67–0.84)	0.60 (0.50–0.69)

Fig. 4 – Receiver operating characteristic curves (ROCs) for carious lesions for all tooth types and separated into premolar and molar groups. The graphs show equal area under the ROCs for near-infrared reflection assessment from the occlusal viewpoint (NIRR occlusal), from three angles (NIRR trilateral) and for evaluation of bitewing radiography (BWR) ($p < 0.05$)



Article:

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ORIGINAL ARTICLE

Diagnostic validity of early proximal caries detection using near-infrared imaging technology on 3D range data of posterior teeth

Friederike Litzenburger[1] · Katrin Heck[1] · Dalia Kaisarly[1] · Karl-Heinz Kunzelmann[1]

Received: 9 April 2021 / Accepted: 9 June 2021 / Published online: 12 October 2021
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Abstract
Objectives This in vitro study analysed potential of early proximal caries detection using 3D range data of teeth consisting of near-infrared reflection images at 850 nm (NIRR).
Materials and methods Two hundred fifty healthy and carious permanent human teeth were arranged pairwise, examined with bitewing radiography (BWR) and NIRR and validated with micro-computed tomography. NIRR findings were evaluated from buccal, lingual and occlusal (trilateral) views according to yes/no decisions about presence of caries. Reliability assessments included kappa statistics and revealed high agreement for both methods. Statistical analysis included cross tabulation and calculation of sensitivity, specificity and AUC.
Results Underestimation of caries was 24.8% for NIRR and 26.4% for BWR. Overestimation was 10.4% for occlusal NIRR and 0% for BWR. Trilateral NIRR had overall accuracy of 64.8%, overestimation of 15.6% and underestimation of 19.6%. NIRR and BWR showed high specificity and low sensitivity for proximal caries detection.
Conclusions NIRR achieved diagnostic results comparable to BWR. Trilateral NIRR assessments overestimated presence of proximal caries, revealing stronger sensitivity for initial caries detection than BWR.
Clinical relevance NIRR provided valid complement to BWR as diagnostic instrument. Investigation from multiple angles did not substantially improve proximal caries detection with NIRR.

Keywords X-ray microtomography · Sensitivity and specificity · Reproducibility of results · Dental caries · Near-infrared imaging · Near-infrared reflection

Introduction

The number of diagnostic methods available to dentists for caries detection has multiplied in recent years. Due to new preventive and microinvasive therapy strategies, there is an increasing need to be able to detect and correctly assess caries at an early stage [1, 2]. With the established procedures of visual inspection and bitewing radiography, both healthy tooth structure and advanced cavitated lesions can be correctly identified [3–5]. However, early proximal caries is not detected adequately [6]. In the context of new therapeutic approaches, high sensitivity for early caries detection is desirable, necessitating other diagnostic methods for the detection and assessment of initial lesions with high accuracy.

Over the last three decades, numerous techniques have been developed and investigated to meet this challenge. Most techniques, such as quantitative light-induced fluorescence, laser fluorescence, electrical conductance, impedance spectroscopy and photothermal radiometry, are well suited for the assessment of smooth surfaces [7]. Lesions in the proximal region can be visualized by transillumination with visible light or optical coherent tomography (OCT), although OCT devices are currently so expensive that there will be no system available for general dental practice under economic conditions in the foreseeable future. Transillumination with near-infrared (NIR) light is expected to make approximal caries visible and has been protected by a patent for wavelengths above 795 nm [8]. Theoretically, it should also be possible to visualize caries by reflection of NIR light. There are already commercially available devices for this method, e.g., VistaCam (Dürr Dental, Bietigheim-Bissingen,

✉ Friederike Litzenburger
soechig@dent.med.uni-muenchen.de

[1] Department of Conservative Dentistry and Periodontology, University Hospital, LMU Munich, Goethestr. 70, 80336 Munich, Germany

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iTero™

Conclusion:

- The iTero Element™ 5D imaging system achieved diagnostic results comparable to those of BWR. NIRR with and without the trilateral information can detect initial defects in the enamel with higher sensitivity than BWR, but it cannot, in contrast to BWR, support a reliable recommendation for or against invasive therapy when the EDJ is exceeded.
- Enamel cracks do not result in a therapeutic consequence, this observation is of secondary clinical importance.
- Unlike other NIRR devices for caries diagnosis that use 850 nm LEDs as a light source, the iTero Element 5D imaging system does not show any reflection artefacts caused by a smooth dental surface.
- Images acquired from the NIRR scanner present light scattered in depth mainly at dentin and irregularities in enamel, without being superimposed by superficial specular reflections, as has been observed for other NIRR diagnostic devices.
- The novel approach to entirely measure the dental arch from different directions can be an attractive option for the development of future diagnostic applications.
- It would be possible to calculate the complete surface texture for the entire 3D data set from the multitude of individual images.

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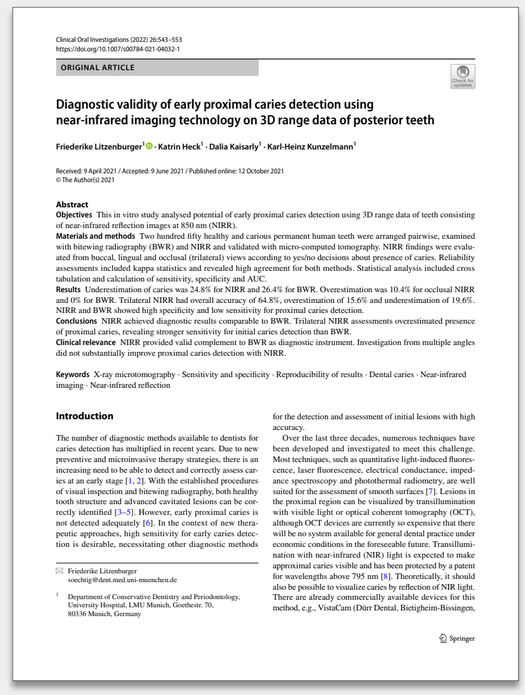

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"In Vitro Comparison of Three Intraoral Scanners for Implant—Supported Dental Prostheses"

iTero™

Executive summary

Comparison study of three intraoral scanners used in oral implant rehabilitation: Planmeca Planscan scanner, Medit i500 scanner, iTero Element™ Plus series.

- iTero scanner shows the best results, which confirmed a high stability pattern in this comparison of the quality of the different readings randomized to specific clinical situations.
- iTero™ scanner was found to be the most accurate (26.00 µm), followed by the Medit scanner (35.90 µm) and Planmeca Planscan scanner (57.30 µm).
- Trueness was slightly better for total rehabilitation than for partial rehabilitation iTero™ scanner, reflecting the great progress made by the latest generation of intraoral scanners.

Aim of the study

The aim of this study was to evaluate the accuracy of three intraoral scanners used in oral implant rehabilitation, using an extraoral scanner as a reference and varying the scanning area.

Planmeca PlanScan

iTero Element Plus Series

Medit i500 scanner

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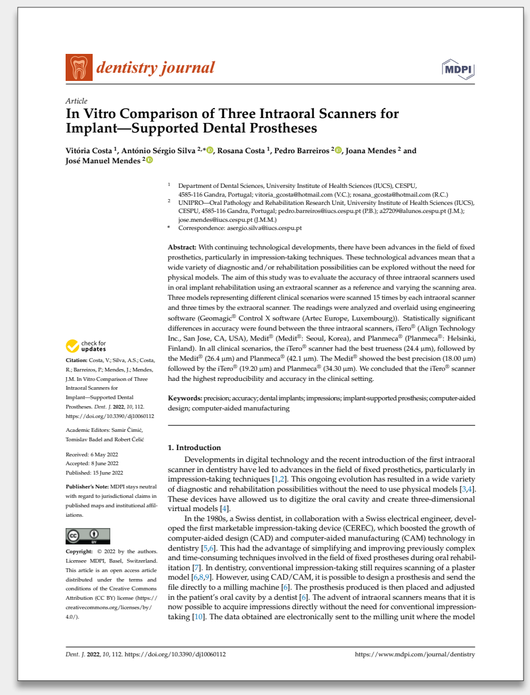

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[1] Department of Dental Sciences, University Institute of Health Sciences (IUCS), CESPU, 4585-116 Gandra, Portugal; vitoria_gcosta@hotmail.com (V.C.); rosana_gcosta@hotmail.com (R.C.)
[2] UNIPRO—Oral Pathology and Rehabilitation Research Unit, University Institute of Health Sciences (IUCS), CESPU, 4585-116 Gandra, Portugal; pedro.barreiros@iucs.cespu.pt (P.B.); a22709@alunos.cespu.pt (J.M.); jose.mendes@iucs.cespu.pt (J.M.M.)
* Correspondence: asergio.silva@iucs.cespu.pt

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Keywords: precision; accuracy; dental implants; impressions; implant-supported prosthesis; computer-aided design; computer-aided manufacturing

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In the 1980s, a Swiss dentist, in collaboration with a Swiss electrical engineer, developed the first marketable impression-taking device (CEREC), which boosted the growth of computer-aided design (CAD) and computer-aided manufacturing (CAM) technology in dentistry [5,6]. This had the advantage of simplifying and improving previously complex and time-consuming techniques involved in the field of fixed prostheses during oral rehabilitation [7]. In dentistry, conventional impression-taking still requires scanning of a plaster model [6,8,9]. However, using CAD/CAM, it is possible to design a prosthesis and send the file directly to a milling machine [6]. The prosthesis produced is then placed and adjusted in the patient's oral cavity by a dentist [6]. The advent of intraoral scanners means that it is now possible to acquire impressions directly without the need for conventional impression-taking [10]. The data obtained are electronically sent to the milling unit where the model

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Materials and Methods

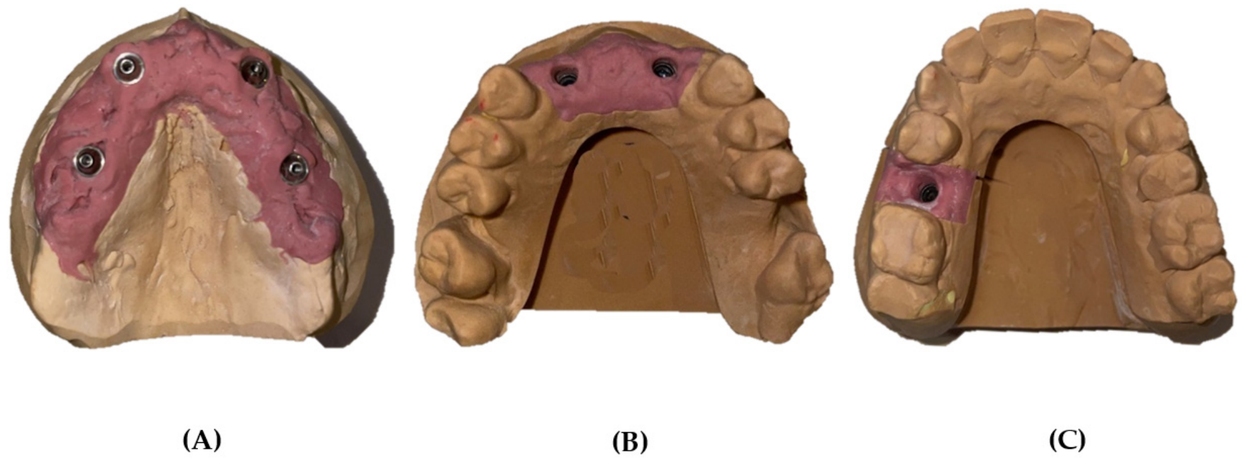
Table 1 – Information about the intraoral scanner systems.

System	Manufacturer	Scanning Technology	Scan Protocol	Acquisition	Powder Application	Export
iTero- Element Plus Series	Align Technology	Parallel confocal microscopy	OPB	Video Sequence	No	STL/OBJ/PLY
i500	Medit	Triangulation technique	OPB	Video Sequence	No	STL/OBJ/PLY
Planscan	Planmecca	Confocal microscopy and optical coherence tomography	OPB	Video Sequence	No	STL/OBJ/PLY

O = Occlusal; P = Palatal; B = Bucal.

Three representative plaster models made in the laboratory. (A) Completely edentulous jaw rehabilitated with four implants. (B) Partially edentulous jaw rehabilitated with two implants. (C) Partially edentulous jaw rehabilitated with one implant. Three ZrGEN-MegaGen AANISR4013, four ZrGEN-MegaGen, and AMUASR4013 scan bodies were used in the respective analogs to enable scanning and location of the implants.

Figure 1 – Three representative plaster models made in the laboratory. (A) Completely edentulous jaw rehabilitated with four implants. (B) Partially edentulous jaw rehabilitated with two implants. (C) Partially edentulous jaw rehabilitated with one implant.



The models were fixed to the rotating base that was moved so that the model could be read at various angles. This procedure was repeated three times for each model. The images obtained were named and saved in an STL file for subsequent analysis. Subsequently, the readings were entered into Geomagic® Control X software (version 2018. 1.1; Artec Europe, Luxembourg), where the structures were superposed to select a reference dataset.These models were used as a guide for measurement of the veracity of all intraoral scanner.

Figure 2 – S600 ARTI extraoral scanner used in the laboratory.

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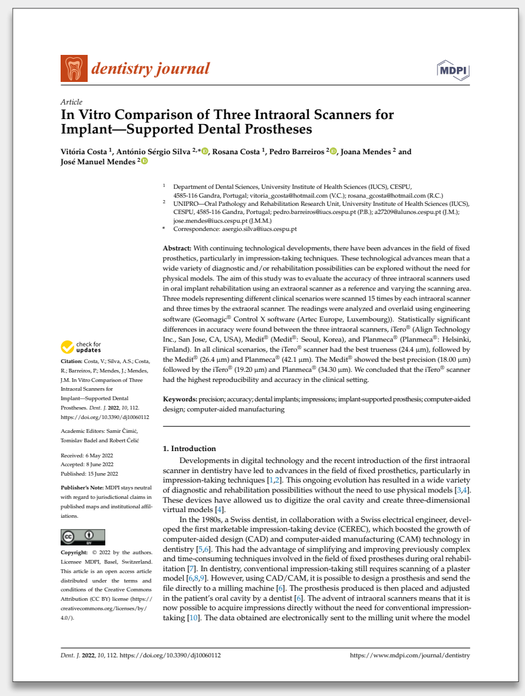

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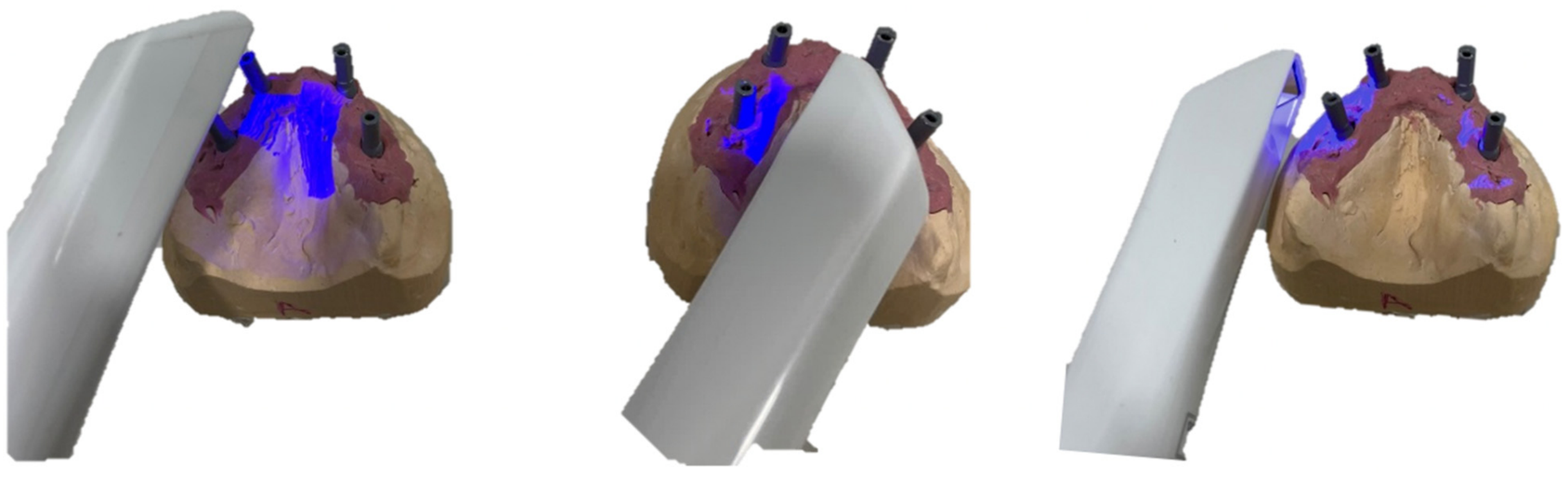
Scanning technique

1: **iTero Element™ Plus Series:** The iTero Element Plus Series is a device that does not require opacification and features color scanning. The acquisition method of this device is based on parallel confocal microscopy. The scanning procedure with iTero started from the occlusal surface, rolling to palatal and buccal surface.

2: **Medit i500 scanner:** Using the triangulation technique to acquire 3D images. The image is based on a color video enabling the distinction between teeth, soft tissue and tartar. It does not require the use of powder for scanning. This allows data to be exported in several formats (STL/OBJ/PLY), giving the operator freedom of choice. The scanning strategy for the Medit scanner group was performed by zigzag movement, from occlusal to palatal and buccal surface.

3: **Planmeca PlanScan scanner:** Based on the principle of confocal microscopy and optical coherence tomography, this system uses a blue light with real-time and color streaming video. No opacification is required for scanning. This open system facilitates the conversion of acquired files into STL readable by all CAD systems. The scanning technique from Planmeca Planscan started first from the occlusal, rotating to the palatal and then rotating across the distal proximal to reach the buccal side.

Figure 3 – Scanning technique used by intraoral scanners.



To evaluate the accuracy of these devices, the models were scanned 15 times per scanner with a 10-min interval to allow for cooling, resulting in a total of 135 virtual 3D mod.

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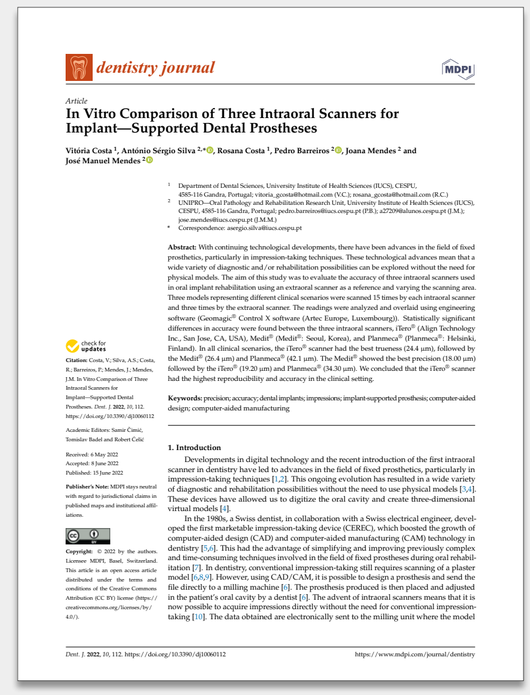

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Results

The color maps indicated the displacements between overlapped structures. The same colorimetric parameters were set for the different models; the maximum deviation ranged from 100 µm to–100 µm, with the best results ranging between 30 µm and −30 µm (green; Figures 4 and 5).

Figure 4 – Colorimetric maps comparing the trueness of three intraoral scanning.

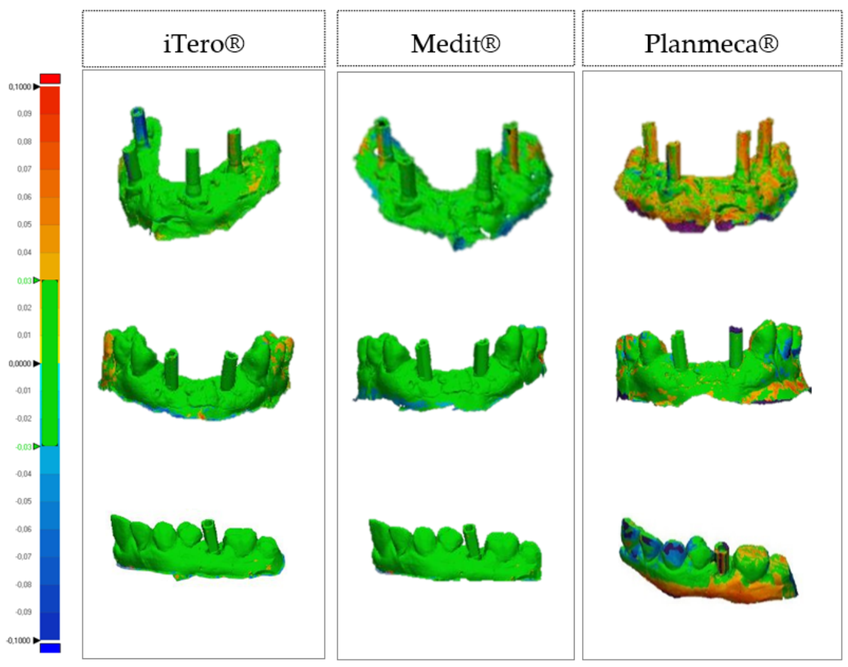
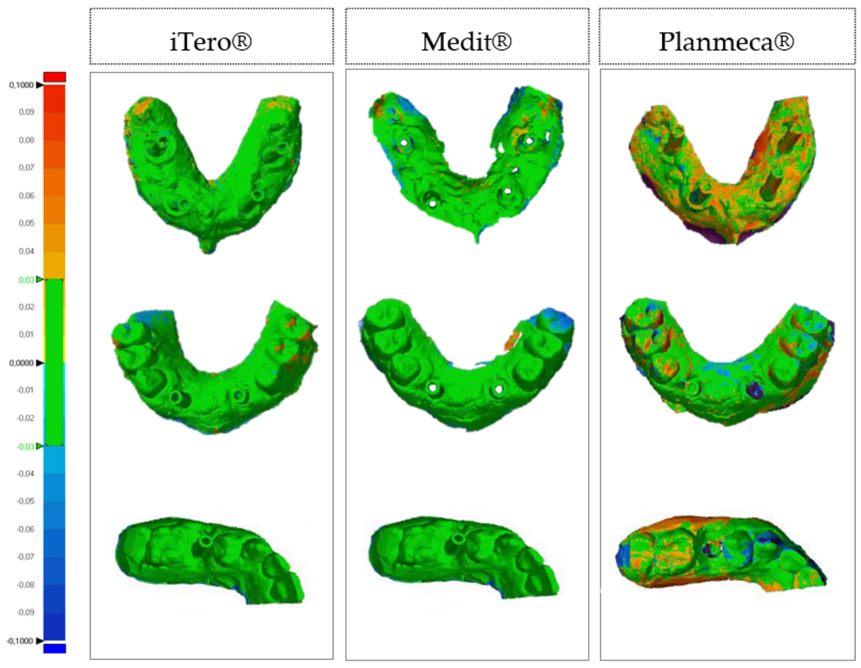


Figure 5 – Colorimetric maps comparing the precision of three intraoral scanning models.



In this study, the trueness values were lower (iTero™ scanner, 24.40 µm) in representative situations of fully edentulous patients rehabilitated with four implants than those in single implant rehabilitations (iTero™ scanner, 24.90 µm). Contrary to what some authors have reported, they found an increase in error with an increase in the area scanned.

Table 2 – Comparison of root mean square values for trueness according to type and model of scanner by two-way analysis of variance.

				Two-Way Analysis of Variance		
	Model A	**Model B**	**Model C**	**Scanner**	**Model**	**Interaction**
iTero®	0.0244 (0.0017)	0.0244 (0.0047)	0.0249 (0.0012)	$F_{(2,126)} = 675.53$ $p < 0.001$ $\eta^2 = 0.92$	$F_{(2,126)} = 58.13$ $p < 0.001$ $\eta^2 = 0.48$	$F_{(4,126)} = 17.77$ $p < 0.001$ $\eta^2 = 0.36$
Medit®	0.0379 (0.0028)	0.0329 (0.0041)	0.0264 (0.0030)			
Planmeca®	0.0507 (0.0028)	0.0469 (0.0017)	0.0421 (0.0019)			

Data are presented as the mean and standard deviation in millimeters. $p < 0.001$, statistically significant difference between scanners and between brands, Tukey's test.

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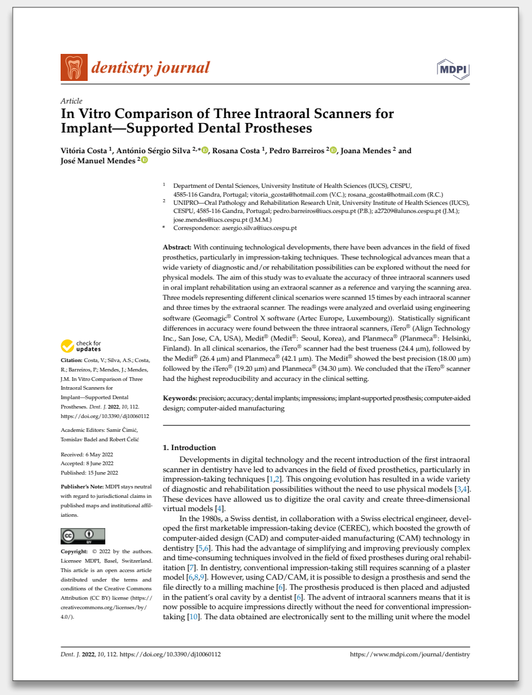

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Article

In Vitro Comparison of Three Intraoral Scanners for Implant—Supported Dental Prostheses

Vitória Costa [1], António Sérgio Silva [2,*], Rosana Costa [1], Pedro Barreiros [2], Joana Mendes [2] and José Manuel Mendes [2]

[1] Department of Dental Sciences, University Institute of Health Sciences (IUCS), CESPU, 4585-116 Gandra, Portugal; vitoria_gcosta@hotmail.com (V.C.); rosana_gcosta@hotmail.com (R.C.)
[2] UNIPRO—Oral Pathology and Rehabilitation Research Unit, University Institute of Health Sciences (IUCS), CESPU, 4585-116 Gandra, Portugal; pedro.barreiros@iucs.cespu.pt (P.B.); a27209@alunos.cespu.pt (J.M.); jose.mendes@iucs.cespu.pt (J.M.M.)
* Correspondence: asergio.silva@iucs.cespu.pt

Abstract: With continuing technological developments, there have been advances in the field of fixed prosthetics, particularly in impression-taking techniques. These technological advances mean that a wide variety of diagnostic and/or rehabilitation possibilities can be explored without the need for physical models. The aim of this study was to evaluate the accuracy of three intraoral scanners used in oral implant rehabilitation using an extraoral scanner as a reference and varying the scanning area. Three models representing different clinical scenarios were scanned 15 times by each intraoral scanner and three times by the extraoral scanner. The readings were analyzed and overlaid using engineering software (Geomagic® Control X software (Artec Europe, Luxembourg)). Statistically significant differences in accuracy were found between the three intraoral scanners, iTero® (Align Technology Inc., San Jose, CA, USA), Medit® (Medit®; Seoul, Korea), and Planmeca® (Planmeca®; Helsinki, Finland). In all clinical scenarios, the iTero® scanner had the best trueness (24.4 µm), followed by the Medit® (26.4 µm) and Planmeca® (42.1 µm). The Medit® showed the best precision (18.00 µm) followed by the iTero® (19.20 µm) and Planmeca® (34.30 µm). We concluded that the iTero® scanner had the highest reproducibility and accuracy in the clinical setting.

Keywords: precision; accuracy; dental implants; impressions; implant-supported prosthesis; computer-aided design; computer-aided manufacturing

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Citation: Costa, V.; Silva, A.S.; Costa, R.; Barreiros, P.; Mendes, J.; Mendes, J.M. In Vitro Comparison of Three Intraoral Scanners for Implant—Supported Dental Prostheses. *Dent. J.* **2022**, *10*, 112. https://doi.org/10.3390/dj10060112

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1. Introduction

Developments in digital technology and the recent introduction of the first intraoral scanner in dentistry have led to advances in the field of fixed prosthetics, particularly in impression-taking techniques [1,2]. This ongoing evolution has resulted in a wide variety of diagnostic and rehabilitation possibilities without the need to use physical models [3,4]. These devices have allowed us to digitize the oral cavity and create three-dimensional virtual models [4].

In the 1980s, a Swiss dentist, in collaboration with a Swiss electrical engineer, developed the first marketable impression-taking device (CEREC), which boosted the growth of computer-aided design (CAD) and computer-aided manufacturing (CAM) technology in dentistry [5,6]. This had the advantage of simplifying and improving previously complex and time-consuming techniques involved in the field of fixed prostheses during oral rehabilitation [7]. In dentistry, conventional impression-taking still requires scanning of a plaster model [6,8,9]. However, using CAD/CAM, it is possible to design a prosthesis and send the file directly to a milling machine [6]. The prosthesis produced is then placed and adjusted in the patient's oral cavity by a dentist [6]. The advent of intraoral scanners means that it is now possible to acquire impressions directly without the need for conventional impression-taking [10]. The data obtained are electronically sent to the milling unit where the model

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Results

We obtained statistically significant differences in precision between the different scanners and models. For oral rehabilitation with one implant, Medit scanner had the lowest precision value at 18.00 µm, followed by the iTero™ scanner (19.2 µm) and Planmeca PlanScan scanner (34.3 µm).

Table 3 – Comparison of root mean square values for trueness according to type and model of scanner by two-way analysis of variance.

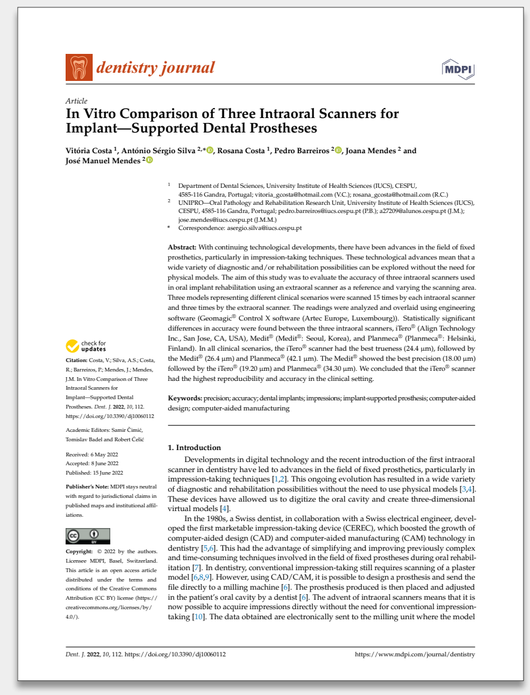
				Two-Way Analysis of Variance		
	Model A	**Model B**	**Model C**	**Scanner**	**Model**	**Interaction**
iTero®	0.0260 (0.0039)	0.0250 (0.0025)	0.0192 (0.0042)	$F_{(2,117)} = 593.52$ $p < 0.001$ $\eta^2 = 0.91$	$F_{(2,117)} = 218.95$ $p < 0.001$ $\eta^2 = 0.79$	$F_{(4,117)} = 24.01$ $p < 0.001$ $\eta^2 = 0.45$
Medit®	0.0359 (0.0052)	0.0268 (0.0052)	0.0180 (0.0020)			
Planmeca®	0.0573 (0.0034)	0.0530 (0.0018)	0.0343 (0.0027)			

Data are presented as the mean and standard deviation in millimeters. $p < 0.001$, statistically significant difference between scanners and between brands, Tukey's test.

Conclusion:

- iTero™ scanner was found to be the most accurate (26.00 µm), followed by the Medit scanner (35.90 µm) and Planmeca PlanScan scanner (57.30 µm).
- iTero scanner shows the best results, which confirmed a high stability pattern in this comparison of the quality of the different readings randomized to specific clinical situations. Trueness was slightly better for total rehabilitation than for partial rehabilitation (iTero™ scanner), reflecting the great progress made by the latest generation of intraoral scanners.

Article:



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Article

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Article Summary of:

"Intraoral scanning reduces procedure time and improves patient comfort in fixed prosthodontics and implant dentistry: a systematic review"

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Executive summary

- Intraoral scanner is faster than conventional impressions, independent of the size of the scanned area.
- Intraoral scanner can improve the patient experience in the dental office measured by overall preference and comfort.
- Intraoral scanner as part of a digital workflow can provide reliable prosthodontic outcomes.
- In this study iTero Element™ scanner shows the highest results in patient comfort among the scanners tested.
- A recently published study showed that digital impressions are more efficient and cost-effective than standard impressions.

About the study

The present study is a systematic review. It was conducted with the primary objective of assessing whether intraoral scanning can reduce working times and improve patient-reported outcomes compared to conventional impressions. The secondary objective of this review was to determine whether the Intraoral scanner procedure was effective, based on prosthodontic outcomes. The review included 17 research papers with data from 430 intraoral scans and 370 conventional impressions performed on 437 patients.

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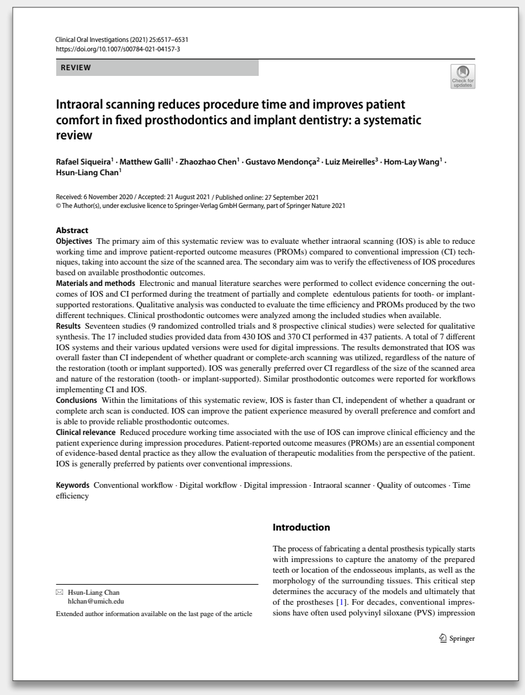

Clinical Oral Investigations (2021) 25:6517–6531
https://doi.org/10.1007/s00784-021-04157-3

REVIEW

Intraoral scanning reduces procedure time and improves patient comfort in fixed prosthodontics and implant dentistry: a systematic review

Rafael Siqueira[1] · Matthew Galli[1] · Zhaozhao Chen[1] · Gustavo Mendonça[2] · Luiz Meirelles[3] · Hom-Lay Wang[1] · Hsun-Liang Chan[1]

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Abstract

Objectives The primary aim of this systematic review was to evaluate whether intraoral scanning (IOS) is able to reduce working time and improve patient-reported outcome measures (PROMs) compared to conventional impression (CI) techniques, taking into account the size of the scanned area. The secondary aim was to verify the effectiveness of IOS procedures based on available prosthodontic outcomes.

Materials and methods Electronic and manual literature searches were performed to collect evidence concerning the outcomes of IOS and CI performed during the treatment of partially and complete edentulous patients for tooth- or implant-supported restorations. Qualitative analysis was conducted to evaluate the time efficiency and PROMs produced by the two different techniques. Clinical prosthodontic outcomes were analyzed among the included studies when available.

Results Seventeen studies (9 randomized controlled trials and 8 prospective clinical studies) were selected for qualitative synthesis. The 17 included studies provided data from 430 IOS and 370 CI performed in 437 patients. A total of 7 different IOS systems and their various updated versions were used for digital impressions. The results demonstrated that IOS was overall faster than CI independent of whether quadrant or complete-arch scanning was utilized, regardless of the nature of the restoration (tooth or implant supported). IOS was generally preferred over CI regardless of the size of the scanned area and nature of the restoration (tooth- or implant-supported). Similar prosthodontic outcomes were reported for workflows implementing CI and IOS.

Conclusions Within the limitations of this systematic review, IOS is faster than CI, independent of whether a quadrant or complete arch scan is conducted. IOS can improve the patient experience measured by overall preference and comfort and is able to provide reliable prosthodontic outcomes.

Clinical relevance Reduced procedure working time associated with the use of IOS can improve clinical efficiency and the patient experience during impression procedures. Patient-reported outcome measures (PROMs) are an essential component of evidence-based dental practice as they allow the evaluation of therapeutic modalities from the perspective of the patient. IOS is generally preferred by patients over conventional impressions.

Keywords Conventional workflow · Digital workflow · Digital impression · Intraoral scanner · Quality of outcomes · Time efficiency

Introduction

The process of fabricating a dental prosthesis typically starts with impressions to capture the anatomy of the prepared teeth or location of the endosseous implants, as well as the morphology of the surrounding tissues. This critical step determines the accuracy of the models and ultimately that of the prostheses [1]. For decades, conventional impressions have often used polyvinyl siloxane (PVS) impression

✉ Hsun-Liang Chan
hlchan@umich.edu

Extended author information available on the last page of the article

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Authors:

Siqueira R, Galli M, Chen Z, Mendonça G, Meirelles L, Wang HL, Chan HL

Reference:

Clin Oral Investig. 2021 Dec;25(12):6517-6531.

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Article Summary of:

“Reflected near-infrared light versus bite-wing radiography for the detection of proximal caries”

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Executive summary

- The non-inferiority hypothesis of NILR compared to BWR in detecting proximal caries was approved.
- A team of observers experienced in NILR imaging evaluated the two methods with higher accuracy and agreement levels compared to individual dentists in their clinical settings, who were less experienced with the NILR method.
- NILR had higher sensitivity than BWR in the detection of early enamel lesions and comparable sensitivity to BWR in detecting lesions that involved the DEJ.
- Matching between the NILR findings and the clinical direct observation was found in 34/35 lesions that were limited to the enamel and in 23/24 of the lesions with DEJ involvement. This represents a sensitivity of 97% and 96%, respectively.

Aim of the study

The aim of the clinical study was to compare the detection of proximal caries with near-infrared light reflection (NILR) versus bitewing radiography (BWR).

Introduction

Near infrared light imaging (NILR) to aid in early caries detection

- When using NILR technology, teeth are illuminated with the near-infrared light and the reflection is registered and presented as a grayscale image. Within this image, sound enamel, which is transparent to light, appears dark and the carious lesion, which scatters and reflects the near-infrared light, appears brighter on the dark background of the surrounding enamel.

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Reflected near-infrared light versus bite-wing radiography for the detection of proximal caries: A multicenter prospective clinical study conducted in private practices

Zvi Metzger [a,*], Dana G. Colson [b], Peggy Bown [c], Timo Weihard [d], Ingo Baresel [e], Tim Nolting [f]

[a] Departments of Oral Biology and Endodontology, The Goldschleger School of Dental Medicine, Tel Aviv University, Tel Aviv, Israel
[b] Private practice, Toronto, ON, Canada
[c] Private practice, Saint John, NB, Canada
[d] Private practice, Hildesrath, Germany
[e] Private practice, Cuxhaven, Germany
[f] Private practice, Freudenberg, Germany

ARTICLE INFO

Keywords:
Bitewing radiography
Caries detection
Intraoral scan
Near-infrared
Near-infrared light reflection
Proximal caries

ABSTRACT

Objectives: The aim of the present prospective multicenter clinical study was to compare the detection of proximal caries with near-infrared light reflection (NILR) versus bitewing radiography (BWR).
Materials and methods: Intraoral scans were performed on 100 patients in five dental clinics using an intraoral scanner (iTero Element 5D, Align Technology, Tempe, AZ, USA) that includes a near-infrared light source (850 nm) and sensor. Reflected near-infrared light images of posterior teeth were used by the individual dentists to detect proximal caries and the results were compared to the BWRs. In a total of 3499 proximal surfaces of molars and premolars which were examined, 223 carious lesions were detected by BWR, while NILR detected 549 carious lesions. Caries detection using both methods was also done by an expert team of five dentists, highly experienced in NILR image interpretation, who used the same sets of clinically-obtained data. Sensitivity, specificity, and accuracy were calculated for caries detection by both the dentists and the expert team. Fifty-nine of the detected carious lesions were clinically treated and the observations during caries excavation were compared with those done with NILR and BWR. Statistical analysis to compare between NILR and BWR diagnosis was performed using non-parametric two-sided McNemar's Chi-Square test with the significance level set at $p < 0.05$. Kappa coefficients were calculated to assess the level of agreement between the two caries detection methods.
Results: Accuracy of NILR detection of early enamel lesions was 88% and that of carious lesions involving the dentino-enamel junction (DEJ) was 97%. Accuracy was found to be higher at 96% and 99%, respectively, when the same data were examined by the expert team. Direct observation during caries-excavation treatment suggested that NILR detected early enamel lesions that were not detectable with BWR alone.
Conclusions: Within the limitations of the present study, NILR was more sensitive than BWR in detecting early enamel lesions and comparable to BWR in detecting lesions that involved the DEJ.
Clinical relevance: Reflected near-infrared light images that are generated simultaneously with 3D intra-oral scanning may be used reliably for detection, screening, and monitoring of proximal caries, thus potentially minimizing the traditional use of ionizing radiation.

1. Introduction

Diagnosis of early carious lesions in pits and fissures is based mainly on visual-tactile detection of the lesions. Such methods are not effective when early lesions in proximal surfaces of molars and premolars are considered [1]. Bitewing radiography (BWR) has been used for many decades as the standard of care for the detection of early proximal lesions, yet this traditional method has its limitations. A meta-analysis

* Corresponding author.
E-mail addresses: metzger.zvi@gmail.com (Z. Metzger), danacolson@me.com (D.G. Colson), peggy@smilesbybown.com (P. Bown), timo.weihard@gmx.de (T. Weihard), ingo.baresel@t-online.de (I. Baresel), nolting@drnolting.de (T. Nolting).

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Reference:
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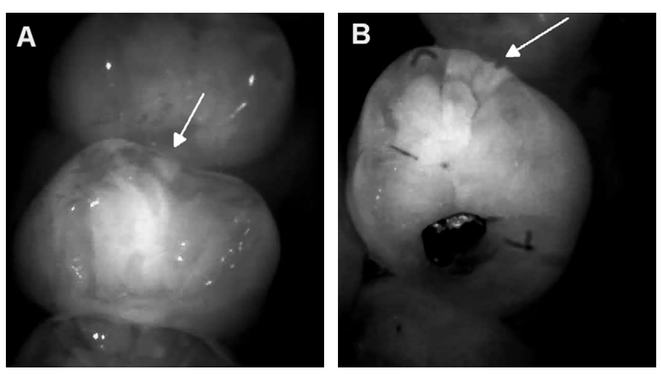
Figure 1 – Screenshot of the “View mode” of the iTero Element 5D scanner. When the simulated loupe is positioned over a given area of the color 3D model, the corresponding 2D NILR gray-tone image is presented next to the color 3D image of the same teeth.

Figure 2 – Mesial surface of tooth #15 with a carious lesion detected by NILR. The lesion (arrow) is of triangular shape and does not reach the DEJ and was recorded as an early enamel lesion. B. Mesial surface of tooth #16 with a carious lesion detected by NILR. The lesion is trapezoid in shape (arrow) reaching the DEJ and was recorded as a lesion involving the DEJ.



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"Reflected near-infrared light versus bite-wing radiography for the detection of proximal caries"

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Materials and methods

- 100 patients were included in the study (n = 20 per each clinic).
- The actual sample size that was used in the study was 3499 non-treated proximal surfaces of molars and premolars. Previously restored surfaces, non-proximal surfaces and anterior teeth were excluded from the present study analysis.
- Clinical examination and BWRs used during this study were those that are used as the standard of care in the diagnosis of proximal caries in each of the participating clinics.
- Full scans of the maxillary and mandibular arches of each subject using the iTero Element™ 5D imaging system were obtained. The resulting 3D scans included a NILR image in gray scale, which was automatically presented next to the 3D image of a given tooth/pair of teeth.
- The interpretation of the NILR and BWR images was done by each of the individual dentists and by the expert team.
- To minimize bias, NILR or BWR images were interpreted by the dentist in alternating order: either the NILR image first and the BWR second or vice versa. In each case, the operator assessed and documented the findings of the first diagnostic method (BWR or NILR imaging) before performing the second method.
- For each subject, the dentist graded carious lesions in the BWR and the NILR scan according to American Dental Association (ADA) staging guidelines for BWR.
- The data that was clinically acquired by the dentists was transferred for parallel evaluation by the expert team as anonymized, unmatched NILR scan and BWR datasets.
- The expert team consisted of five dentists who had been recruited and trained by the sponsor (Align Technology, Tempe, AZ, USA) for research and development purposes. They had 2 years of experience in evaluating thousands of NILR images of carious lesions, prior to the present study
- Analysis of sensitivity, specificity, and accuracy was done independently of a similar analysis of the data as interpreted by the individual dentists
- Sensitivity, specificity, and accuracy values were calculated for NILR scan vs. BWR, which was referred to as "ground truth"
- The non-parametric two-sided McNemar's Chi-Square test was used for paired nominal data. This test enables the comparison of the detection proportions between the two methods.

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"Reflected near-infrared light versus bite-wing radiography for the detection of proximal caries"

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Study design[1]

Multicenter study

- 5 sites in Canada and Germany
- 100 patients, 3499 proximal surfaces included

Real-world evidence

- More relevant to daily clinical practice
- Broad inclusion: patients not pre-selected
- Study taking place under true clinical conditions

Phase I and phase II

- Phase I: NIRI vs. BWX
- Phase II: NIRI and BWX vs. caries excavation

1. Metzger, Z., Colson, D. G., Bown, P., Weihard, T., Baresel, I., & Nolting, T. (2021). Reflected near-infrared light versus bite-wing radiography for the detection of proximal caries: a multicenter prospective clinical study conducted in private practices. Journal of dentistry, 103861. Advance online publication. https://doi.org/10.1016/j.jdent.2021.103861 (Accessed: 31 October 2021).

Multicenter study[1]

- **15 sites in Canada and Germany**
  (Doctor/Trial Site):
  – Dr. Dana Colson, Canada
  – Dr. Peggy Bown, Canada
  – Dr. Tim Nolting, Germany
  – Dr. Ingo Baresel, Germany
  – Dr. Timo Weihard, Germany
- **Advantage[2]**
  – Quicker recruitment of patients
  – Larger sample sizes for more generalizable findings

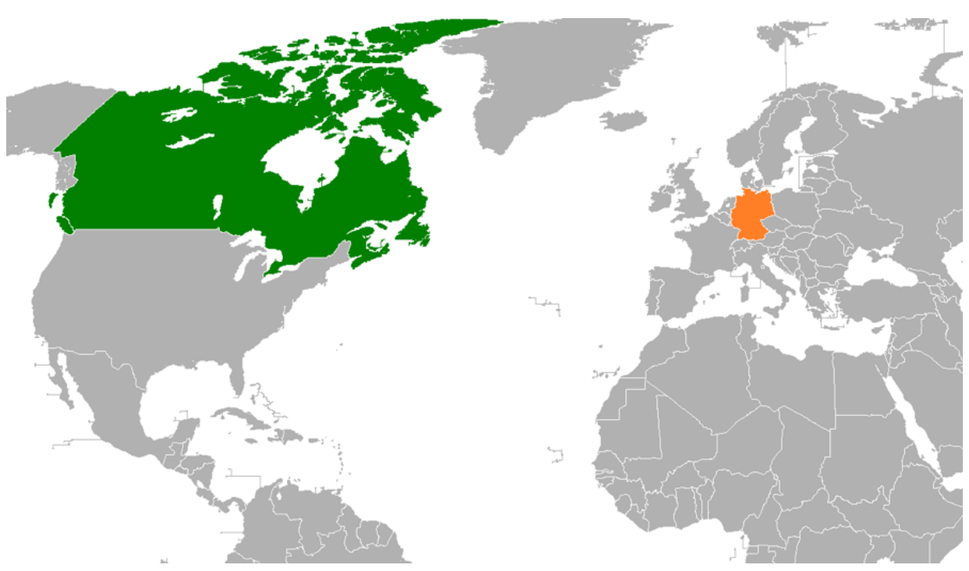

Figure 3 – Source: Wikipedia (2021) Canada-Germany relations. Available at: https://en.wikipedia.org/wiki/Canada%E2%80%93Germany_relations

1. Blumenstein BA, James KE, Lind BK, Mitchell HE. Functions and Organization of Coordinating Centers for Multicenter Studies. Controlled Clinical Trials 1995;16: 4S-29S Available at: https://media.tghn.org/articles/trialprotocoltool/SOURCE/Checklist/StudyObjectives/Single%20or%20Multi.html (Accessed: 13 October 2021).
2. Lippi, G., von Meyer, A., Cadamuro, J., Simundic, A. & for the European Federation of Clinical Chemistry and Laboratory Medicine (EFLM) Working Group for Preanalytical Phase (WG-PRE) (2020). PREDICT: a checklist for preventing preanalytical diagnostic errors in clinical trials. Clinical Chemistry and Laboratory Medicine (CCLM), 58(4), 518-526. https://doi.org/10.1515/cclm-2019-1089. (Accessed: 31 October 2021).

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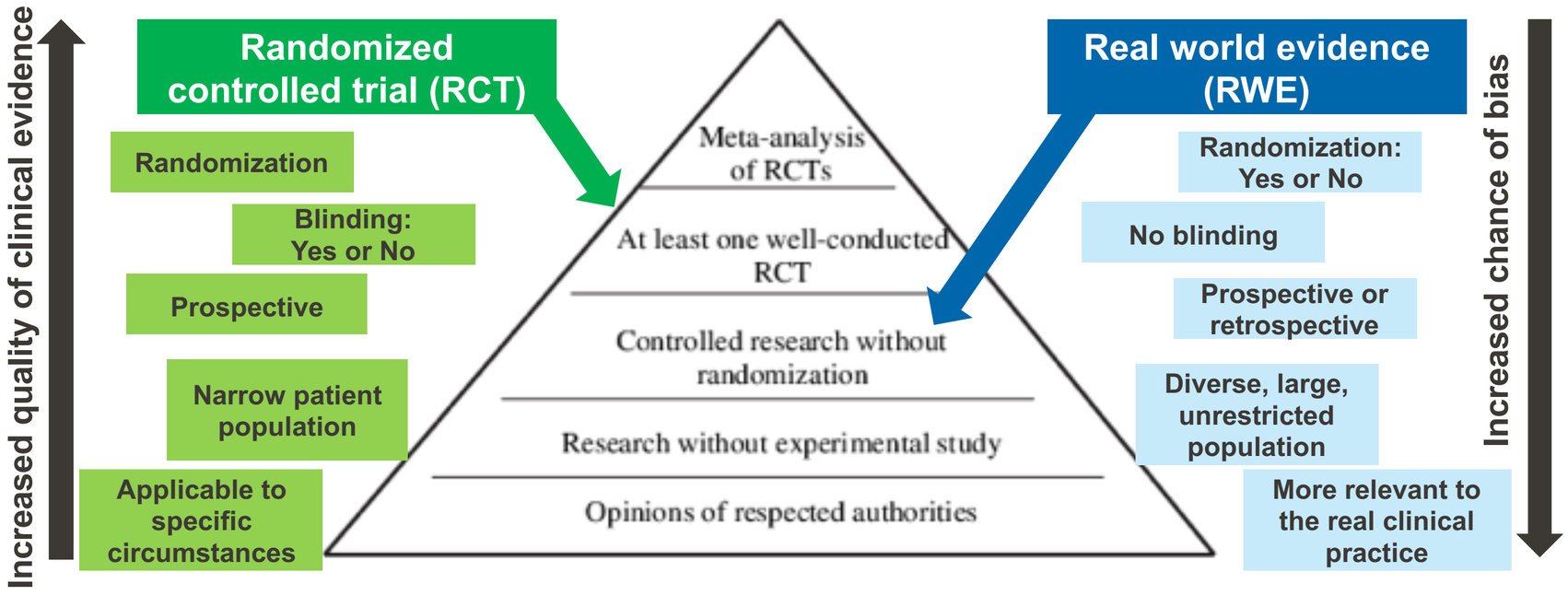
What is real-world evidence (RWE)?

- RWE is defined as "clinical evidence derived from analysis of data collected in non-RCT setting".[1]

Figure 4 – The hierarchy of evidence (source: Mantzoukas, 2012[2])



1. Makady, A., de Boer, A., Hillege, H., Klungel, O., Goettsch, W., & (on behalf of GetReal Work Package 1) (2017). What Is Real-World Data? A Review of Definitions Based on Literature and Stakeholder Interviews. Value in health : the journal of the International Society for Pharmacoeconomics and Outcomes Research, 20(7), 858–865. https://doi.org/10.1016/j.jval.2017.03.008 (Accessed: 01 November 2021).
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Study design[1]

Data acquisition was performed by 5 dentists in their individual clinical settings. This included BWR and NILR scans. A total of 3499 proximal surfaces of molars and premolars were included in the present study.

Caries detection was done

a) by each of the individual dentists and

b) the same images were also examined by a team of 5 dentists who had a vast experience in interpretation of NILR images and provided an agreed-upon interpretation of the same data.

Analysis of sensitivity, specificity and accuracy was performed for the results obtained by both evaluation groups. In 59 of the cases direct observation was possible during caries excavation, thus allowing validation of the diagnosis made using BWR and NILR.

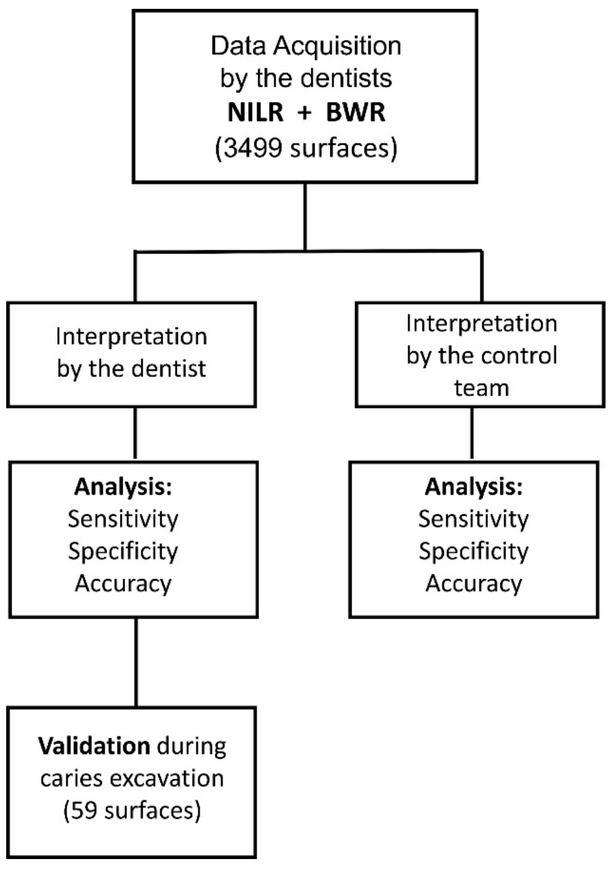

Figure 5 – Flowchart of the experimental design.

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Study design: Phase I and Phase II[1]

Phase I

- Sample: 100 patients
  – 3,499 posterior proximal surfaces
- Comparison: NIRI vs. BWX
- Outcome measure: accuracy

Phase II

- Sample: 59 cases/lesions (carious teeth surfaces)
- Comparison: NIRI and BWX vs. caries excavation
- Outcome measure: sensitivity

Figure 5

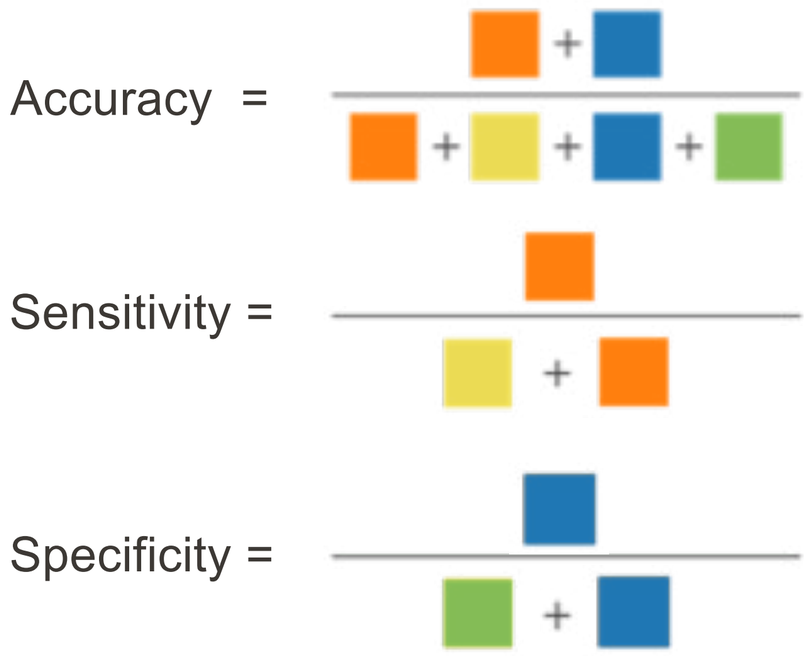
1. Metzger, Z., Colson, D. G., Bown, P., Weihard, T., Baresel, I., & Nolting, T. (2021). Reflected near-infrared light versus bite-wing radiography for the detection of proximal caries: a multicenter prospective clinical study conducted in private practices. Journal of dentistry, 103861. Advance online publication. https://doi.org/10.1016/j.jdent.2021.103861 (Accessed: 31 October 2021).

Accuracy, sensitivity, and specificity

Figure 6

	BWX Positive*	BWX Negative**
NIRI Positive	**Correct** True positive	**Wrong** False positive
NIRI Negative	**Wrong** False negative	**Correct** True negative

Figure 7



- **Sensitivity**: "the percent correctly predicted to have the disease"
- **Accuracy:** "how correct a diagnostic test identifies and excludes a given condition"
- **Specificity:** "the percent correctly predicted to be disease-free"

* Positive: caries present, **Negative: caries absent

1. Parikh, R., Mathai, A., Parikh, S., Chandra Sekhar, G., & Thomas, R. (2008). Understanding and using sensitivity, specificity and predictive values. Indian journal of ophthalmology, 56(1), 45–50. Available at: https://doi.org/10.4103/0301-4738.37595 (Accessed: 13 October 2021).

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Phase I results[1]

When compared to the "ground truth" of BWR, the sensitivity of NILR detection of early enamel caries was 51.6% and the specificity was 90.4%. The sensitivity of NILR detection of carious lesions with DEJ involvement was 84.8% and specificity was 97.1%. The findings represent an accuracy of 88.6% for early enamel lesions and 96.9% for lesions with DEJ involvement. A statistically significant difference was found between the detection ability of NILR and BWR ($p < 0.0001$)

Table 1 – NIRI demonstrated 96% accuracy in detecting dentinal interproximal caries when compared to BWX.

	Accuracy
DEJ* involvement	96,9%
Early enamel lesions	88,6%

Phase I results[1] – Dentist reported results

Table 2 – Numbers of carious (positive) and non-carious (negative) proximal surfaces of posterior teeth, as recorded by five dentists in their clinical environment.

Depth of Lesion	Detection Method	NILR Positive	NILR Negative
Early Enamel	BWR Positive	81	76
	BWR Negative	314	2965
DEJ involvement	BWR Positive	56	10
	BWR Negative	98	3335

Table 3 – Sensitivity, specificity, and accuracy of caries detection by NILR when compared to a "ground truth" of BWR. Evaluation by five individual dentists.

	Early Enamel Lesions	DEJ Involvement
Sensitivity	51.6%	84.8%
Specificity	90.4%	97.1%
Accuracy	88.6%	96.9%
Two-Sided McNemar's Chi-Square test (p-value)	< 0.0001[a]	< 0.0001[a]
Asymptotic Non-Inferiority Test (p-value)	< 0.0001[b]	< 0.0001[b]
One-Sided Binominal test (p-value)	< 0.0001[c]	< 0.0001[c]
Kappa Coefficient	0.24[d]	0.50[e]

* DEJ: dentino-enamel junction

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Phase I results[1] – Dentist reported results

Table 4 – Numbers of carious (positive) and non-carious (negative) proximal surfaces of posterior teeth as detected and recorded by a expert team using the same database as collected and used by the five individual dentists (Table 2).

Type of Lesion		NILR Positive	NILR Negative
Early Enamel	BWR Positive	76	28
	BWR Negative	106	3216
DEJ involvement	BWR Positive	62	8
	BWR Negative	11	3418

Table 5 – Sensitivity, specificity, and accuracy of caries detection by NILR when compared to a "ground truth" of BWR. Evaluation by a expert team, using the same database as collected and used by the 5 dentists (Tables 2,3).

	Early Enamel Lesions	DEJ Involvement
Sensitivity	73.0%	88.5%
Specificity	96.8%	99.6%
Accuracy	96.0%	99.4%
Two-Sided McNemar's Chi-Square test (p-value)	<0.0001[a]	0.65 (>0.05)[b]
Asymptotic Non-Inferiority Test (p-value)	<0.0001[c]	<0.0001[c]
One-Sided Binominal test (p-value)	<0.0001[d]	0.32 (>0.05)[e]
Kappa Coefficient	0.51[f]	0.86[g]

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Reflected near-infrared light versus bite-wing radiography for the detection of proximal caries: A multicenter prospective clinical study conducted in private practices

Zvi Metzger[a,*], Dana G. Colson[b], Peggy Bown[c], Timo Weihard[d], Ingo Baresel[e], Tim Nolting[f]

[a] Departments of Oral Biology and Endodontology, The Goldschleger School of Dental Medicine, Tel Aviv University, Tel Aviv, Israel
[b] Private practice, Toronto, ON, Canada
[c] Private practice, Saint John, NB, Canada
[d] Private practice, Filderstadt, Germany
[e] Private practice, Cuxhaven, Germany
[f] Private practice, Freudenberg, Germany

ARTICLE INFO

Keywords:
Bitewing radiography
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Near-infrared
Near-infrared light reflection
Proximal caries

ABSTRACT

Objectives: The aim of the present prospective multicenter clinical study was to compare the detection of proximal caries with near-infrared light reflection (NILR) versus bitewing radiography (BWR).
Materials and methods: Intraoral scans were performed on 100 patients in five dental clinics using an intraoral scanner (iTero Element 5D, Align Technology, Tempe, AZ, USA) that includes a near-infrared light source (850 nm) and sensor. Reflected near-infrared light images of posterior teeth were used by the individual dentists to detect proximal caries and the results were compared to the BWRs. In a total of 3499 proximal surfaces of molars and premolars which were examined, 223 carious lesions were detected by BWR, while NILR detected 549 carious lesions. Caries detection using both methods was also done by an expert team of five dentists, highly experienced in NILR image interpretation, who used the same sets of clinically-obtained data. Sensitivity, specificity, and accuracy were calculated for caries detection by both the dentists and the expert team. Fifty-nine of the detected carious lesions were clinically treated and the observations during caries excavation were compared with those done with NILR and BWR. Statistical analysis to compare between NILR and BWR diagnosis was performed using non-parametric two-sided McNemar's Chi-Square test with the significance level set at $p < 0.05$. Kappa coefficients were calculated to assess the level of agreement between the two caries detection methods.
Results: Accuracy of NILR detection of early enamel lesions was 88% and that of carious lesions involving the dentino-enamel junction (DEJ) was 97%. Accuracy was found to be higher at 96% and 99%, respectively, when the same data were examined by the expert team. Direct observation during caries-excavation treatment suggested that NILR detected early enamel lesions that were not detectable with BWR alone.
Conclusions: Within the limitations of the present study, NILR was more sensitive than BWR in detecting early enamel lesions and comparable to BWR in detecting lesions that involved the DEJ.
Clinical relevance: Reflected near-infrared light images that are generated simultaneously with 3D intra-oral scanning may be used reliably for detection, screening, and monitoring of proximal caries, thus potentially minimizing the traditional use of ionizing radiation.

1. Introduction

Diagnosis of early carious lesions in pits and fissures is based mainly on visual-tactile detection of the lesions. Such methods are not effective when early lesions in proximal surfaces of molars and premolars are considered [1]. Bitewing radiography (BWR) has been used for many decades as the standard of care for the detection of early proximal lesions, yet this traditional method has its limitations. A meta-analysis

* Corresponding author.
E-mail addresses: metzger.zvi@gmail.com (Z. Metzger), danacolson@me.com (D.G. Colson), peggy@smilesbybown.com (P. Bown), timo.weihard@gmx.de (T. Weihard), ingo.baresel@t-online.de (I. Baresel), noltingt@drnolting.de (T. Nolting).

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1. Metzger, Z., Colson, D. G., Bown, P., Weihard, T., Baresel, I., & Nolting, T. (2021). Reflected near-infrared light versus bite-wing radiography for the detection of proximal caries: a multicenter prospective clinical study conducted in private practices. Journal of dentistry, 103861. Advance online publication. https://doi.org/10.1016/j.jdent.2021.103861 (Accessed: 31 October 2021).

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The iTero™ NIRI technology of the iTero Element 5D imaging system was 66% more sensitive* than bite-wing X-rays (BWX) for proximal lesions detection

Table 6 – NIRI showed 66% higher sensitivity than BWX when compared against the clinical evaluation of posterior proximal lesions observed during caries debridement.

	NIRI sensitivity	BWX sensitivity
All lesions (average)	**96%**	**30%**
DEJ* involvement	97%	54%
Early enamel lesions	96%	14%

* DEJ: dentino-enamel junction

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Conclusion:

- The non-inferiority hypothesis of NILR compared to BWR in detecting proximal caries was approved
- NILR had higher sensitivity than BWR in the detection of early enamel lesions and comparable sensitivity to BWR in detecting lesions that involved the DEJ

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* Corresponding author.
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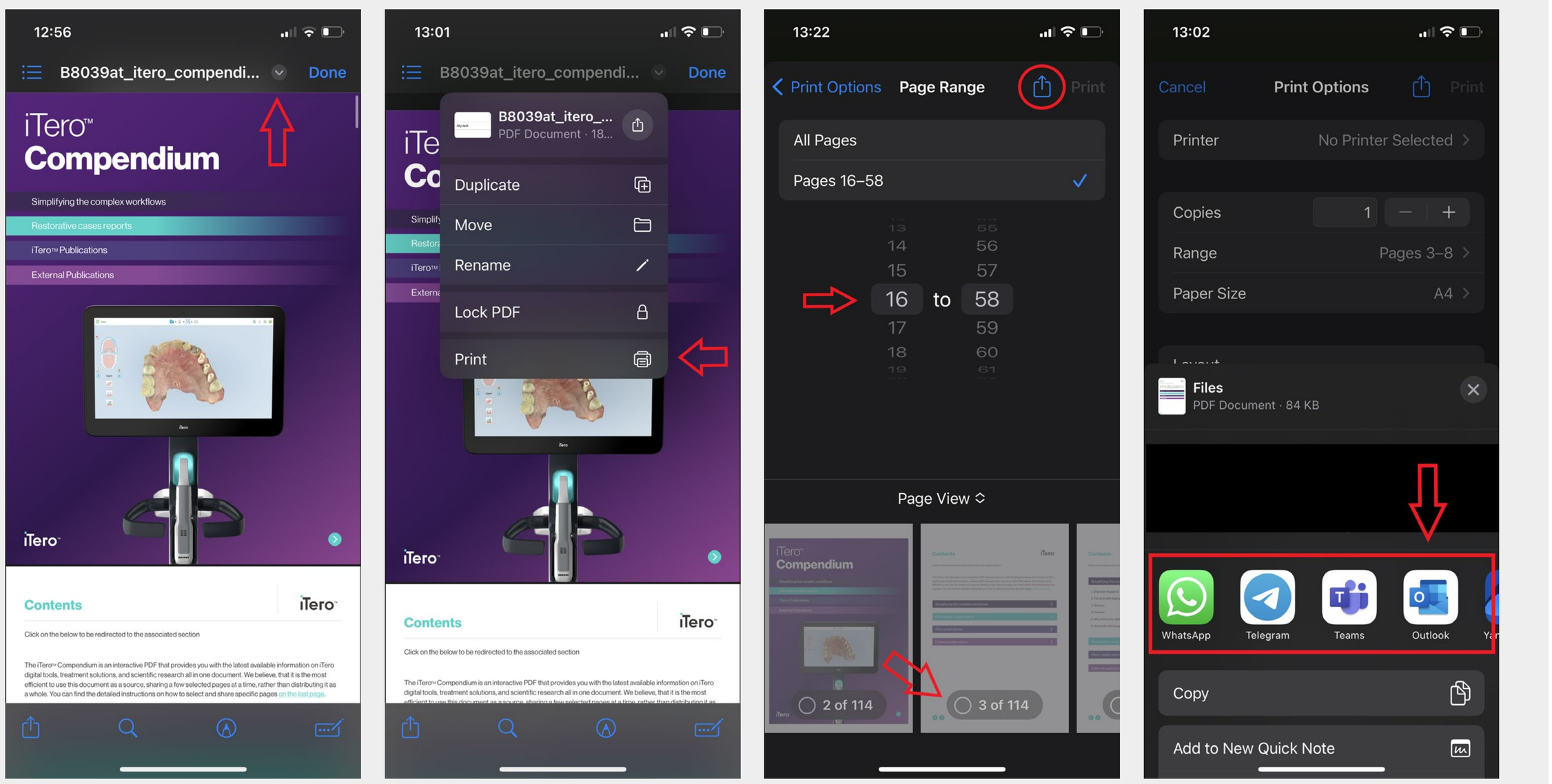

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