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Expert Opinion Article

Digital Impressions Redefined: The Role of Intraoral Scanners in Modern Prosthodontics

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Abstract
Background
Intraoral scanners have revolutionized the field of dentistry by providing a more efficient, accurate and patient-friendly alternative to traditional dental impressions. This article explore the advancements in intraoral scanning technology and its impact on digital impressions and restorations.

Discussion
It highlights the revolutionary effect these technologies have on modern dentistry, emphasizing the benefits they offer in terms of precision, effectiveness, patient experience, collaboration, integration with CAD/CAM technology and general practice success. The use of intraoral scanners into workflows in dental practices, with a focus on how these devices might improve communication between dental practitioners and laboratories and streamline procedures.
Summary
An intraoral scanner is a digital dental tool that captures precise 3D images of a patient's teeth and gums. It enhances diagnostic accuracy, improves treatment planning, and streamlines workflows, replacing traditional impressions with faster, more comfortable, and efficient scanning methods.
Conclusion
An intraoral scanners has shed light on the significant advancements and benefits that these devices bring to the field of dentistry. By improving accuracy, reducing turnaround times, and enhancing patient comfort, intraoral scanners have revolutionized the way dental professionals capture impressions and collaborate with laboratories.

Keywords: Intraoral scanners, Accuracy, Time efficiency

INTRODUCTION

Intraoral scanners (IOS) have revolutionized prosthodontics by offering a digital alternative to traditional impression techniques. These cutting-edge devices capture highly accurate three-dimensional (3D) images of the oral cavity, streamlining workflows and enhancing patient experience. Unlike conventional impressions, which involve the use of impression materials that can cause discomfort or inaccuracies, IOS provides a non-invasive, precise, and efficient method for creating digital impressions.[1,2]

The integration of intraoral scanning technology into prosthodontics aligns with the broader trend of digitization in dentistry. It has significantly improved the accuracy and efficiency of procedures, including crowns, bridges, veneers, dentures, and implant-supported restorations. Additionally, IOS technology facilitates seamless communication between clinicians, dental laboratories, and CAD/CAM systems, ensuring faster production and improved outcomes for patients.[3]

As the demand for accuracy, efficiency, and patient comfort continues to grow, intraoral scanners are becoming an essential tool in modern prosthodontic practice. Their ability to enhance treatment planning, reduce chair time and improve patient satisfaction marks a paradigm shift in the field, setting new standards for dental care.

MECHANISM

Intraoral scanners function by using a combination of optical and laser technologies to capture detailed 3D images of the oral cavity. As the scanner is moved around the teeth and gums, it emits light and captures the reflected data, which is then processed to create a digital model of the patient's mouth. This digital impression is not only more accurate than traditional methods but also allows for immediate visualization, enabling dentists to make real-time adjustments. The integration with CAD/CAM technology allows for the seamless design and manufacturing of dental restorations, significantly improving the workflow and outcomes in prosthodontics.[5,6]

Intraoral scanner consists of software, hardware which is a handheld camera and a computer.[7] Obtaining data and speed of measurements acquisition in addition to the resolution is one of the most important in the choice of the system and its broad applicability. Size of the scanning field is minimally 14x14mm, and optimally 25x14mm. The range of scanning depth should be at least 10 mm to get the adequate clarity and for proper placement of scanner in desired area, but should not be greater than 14 mm, if so then the image may not be clear or there will be fog on the scanning surface. Scanner resolution should be at least 25μm.[8]

Intraoral scanners	**Emission used**
Three-dimensional laser scanners	Emits **laser beam of light** source and detect its return.
Optical scanner	Projects white light or a laser source. Source and the receiving unit in this type are at the certain angle to each other.
Mechanical scanner	Gypsum model is obtained from a conventional printing is scanned and used. The master model is read mechanically line by line and structure is measured using a ruby ball.
Photographic technology Scanners	A field of view in this type is in the form of a cone, making it unable to collect information from those hidden surfaces. It records individual images of the denture.
Video technology scanners	Open standard tessellation language is the most used digital format. They record scanned areas working in a through sequential shots at high speed similar way as a video camera.

SCANNING DEPTH : The accuracy of an intraoral scanner can be affected by the depth of the scan. For example, one study found that the accuracy of an intraoral scanner decreases as the depth increases.

The depth of an intraoral scanner can vary depending on the model, but some examples include: Medit i900: Has a scan depth of 12–23 mm Shining 3D Aoralscan 3: Has a scan depth of -2–20 mm from the tip's exit surface Sirona Primescan: Has a dynamic depth scan technology that can measure up to 20 mm

1.**Scanning speed:** One of the most important factors when choosing an intraoral scanner is the speed of the scan. Therefore, the first thing that doctors take into account for the development has been the speed of full arch scanning. Although the evaluation is relative, the five star rating gives an idea of which ones are faster or slower.[10,11]

2.Scanning flow: not only the speed of the scan is relevant, but also how smooth the experience is. Whether the intraoral scanner handles well in the corner and anterior region.

or recovers quickly after losing the scan. Also if it joins the images well or if it loses frequency. The assessment of the scan flow, indicates which experience has been irregular or in any case, the lack of response.

3.**Intraoral scanner size**: Not only the size of the intraoral scanner head was taken into account, but also the weight and overall size. Although, judging from the overall size, some scanners are heavier and more complicated than others. The focus has been on ergonomics, weight and overall, how comfortable the scanner feels in the hand and when scanning.

4. **Ease of use:** This criterion takes into account both the hardware and the way the software was managed or if there were any problems with scanning, processing and general workflow.

5.Intraoral scanner price: Another criteria that dentists consider quite important is the price. Since this can vary, depending on the input cost, complements distributors, software charges, cloud data for the storage of scanned files and geographical location. No exact numbers are provided, but a relative comparison based on the most expensive and least expensive scanners.

6. **Subscription requirements and maintenance packages**: The subscription requirement for the use of the intraoral scanner may be mandatory, recommended or not required. The assessment has been made on this basis, as some companies claim that they do not require any kind of subscription, but this is sometimes not entirely true. Many have some kind of annual subscription for support and maintenance and others even require a subscription to be able to use them.

7.Open or closed scan export: all scanners are now open (more or less), which allows to export at least one of the following source files STL, OBJ and/or PLY; however, they did not take this criteria into account for the evaluation.

8.**Autoclave scanning tips**: If the tips can be autoclaved and how many cycles can be completed before replacing them. But if this feature is there, its an important asset in maintaining sterlisation protocols in clinic

9.Touch screen: the intraoral scanners connected to the trolleys are actually screen touch. This does not apply to those connected to a laptop via a USB port as the screen will work as a touch screen, but not all the software was designed with touch interaction in mind and can be better handled with a mouse and keyboard.

10.Wireless scanner: the assessment is based on whether or not wireless options are available for the scanner.
11.**Caries detection:** this criterion is based on whether or not the intraoral scanner has caries detection function such as transillumination or fluorescence.
12.**CAD Integration:** One may wonder if the scanner has integrated CAD/CAM design functions. If not, clinician will have to export the files and the prostheses will have to be designed in third-party software such as Exocad.[12]

HISTORICAL PERSPECTIVE
Evolution of Intraoral Scanners: In past, many researchers have conducted a research in the dental field for making prosthesis through 3D digitization.
In 1973, Dr. Francois Duret was the first one to propose the CAD/CAM technique to the dental world. Later along with Dr. Christian Termoz, they patented the method and apparatus for making prosthesis, especially a dental prosthesis .Young and Altschuler developed an intraoral grid surface mapping system by suggesting the idea of using optical instrumentation to in 1977. However, this system was not successful in the dental market because of its complexity and cost. In the 1980 a Swiss dentist, Dr Werner Mörmann in association with Marco Brandestini, an Italian electrical engineer invented first digital intraoral scanner.

Lava C.O.S. system is given by Lava Chair-side Oral Scanner; 3M ESPE, Seefeld, Germany. This system is invented in 2006 and launched in market by 2008. By emitting pulsating visible blue light, scanner works with a mobile host computer and a touch-screen display. It works under the principle of active wave-front sampling. It has the 13.2-mm wide smallest scanner tip.

The iTero intraoral scanner came in market in 2007 which utilizes parallel co focal imaging technology with red laser to capture a color 3D digital impression. Up to 3.5 million data points per arch will be obtained using this scan. A total of 1,00,000 points of laser light can be generated at 300 focal depths of the tooth structure. Use of this system is limited for digital impression making since it doesn't come with a milling machine.
Planscan was driven in market by E4D Technologies in 2008. Real time laser video-streaming technology along with blue light is used to capture the dental data. Built-in heated mirrors along with Scanner tips. Main advantage of this is a high level of disinfection and patient's compliance. This is a powder-free system.

E4D system by D4D Technologies, LLC (Richardson, TX) developed in 2008. It uses red laser as a light source. Micro-mirrors provided can vibrate at the speed of 20,000 Hrz under the principle of optical coherence tomography and co focal microscopy.

CEREC Bluecam being first Sirona system use photography for intraoral protocol after the ideally originated in 2009. One quadrant of the digital impression can be captured within 1 minute and the antagonist in a few seconds using this system.7Using a powerful light-emitting diode, Camera can allow the acquisition of high resolution images. Nowadays this scanner is not popular in the market due to more recent systems. A thin layer of titanium dioxide powder as a contrast medium is needed.

TRIOS In 2010, 3SHAPE (Copenhagen, Denmark) launched this system. System uses ultrafast optical scanning technology and is presented to market in 2011.

TRIOSR Pod
TRIOSR Pod has a simple construction with a handheld scanner only which makes it more mobile and flexible. It is compatible with iPad or other computers. It also takes digital intraoral photographs which could be useful for documentation shade matching is now automated with this system, which or communication purposes. Nedelcu et al stated that TRIOS displayed the highest level of finish line distinctness.

CEREC OmniCam is Sirona's most recent system which was released in the summer of 2012. System creates a full-color digital cast with digital streaming.10creates images via stitching together individual images to create monochromatic yellow stone-like digital cast. This scanner is a next level of CEREC BlueCam. Its video camera generates a 3Dmodel with real color and time. Also, export the STL files can be exported to external systems through a specific license. It's a powder free system.6

CS 3500, is one of the recently available powder-free intraoral scanners released in market in 2013. The wand is supposed to keep still during capturing since it is a click-and-point system. Additionally, adequate overlapping of the single images which should be ≥ 50% of the previous image is essential.10

True Definition which was introduced into the market in 2016 by 3M. System uses blue LED light and a video imaging system for data collection. It requires a light dusting with titanium oxide reflective powder and the scanning area should be properly isolated.10

Virtuo vivo is another name of DWIO (Dental Wings Intraoral) Straumann Canada. This system came in market in 2017 and uses open architecture files to capture digital impressions. Total five types of 3D scanners were incorporated into the system which works simultaneously to capture areas of difficult access. System has developed DWOS CAD software used for the designing of restoration. The small tip helps to make 3D capture easier, using a "Multi-scan Imaging Technology". The light weighted hand-piece is made of metal and is around 105grm.6

CEREC PrimeScan It is the latest evolution of the IOS of this manufacturer which contains touch-panel and screen, with the all new CEREC 5 software and was available in market since 2019.

ZFX IntraScan The concept is to be as portable as possible. This system, launched in the year 2012, comes with hardware and light scanner that can be adapted to any other computer. Working distance of this optical scanner is 18mmand can capture 18 images per second. The digital files do not require specific systems to decode them.

WOW was launched in the year 2019 by Biotech Dental (France). Images with hyper realistic texture and color can be developed using open system which develops a complete digital workflow. Scanning process is powder free to use its video photogrammetric technology.

Mediti500 developed by Dent Core (Spain)in the year 2018, whose main focus was on productivity, costs and efficiency. Pause site can be resumed using two high-speed cameras. Differentiation between the soft tissue and dental structure can be made using video photogrammetry.

Benefits of intraoral scanning systems:

Compared to conventional impression-taking followed by the manufacture of a plaster model, numerous advantages are offered by digital intraoral scanning and the subsequent creation of a digital dataset. These benefits are described below.

1.Real-time visualization

Early quality analysis of the digital model on the computer monitor can take place either during or directly following the scanning procedure.

2.Easy repeatability

If the results are not of a satisfactory quality, the scanning procedure can be repeated quickly and easily.

3.Selective repeatability

In contrast to conventional impression-taking, a repetition of the scan can be selectively limited to the affected area only .

4.Selective capture of the relevant areas

With a scan, the critical areas can be recorded first.

5.No need to disinfect and clean dental impressions and impression trays

Intraoral scanners can be easily disinfected and the used scanner tips are sometimes autoclavable.

6.Analysis options preparation/restoration

With digital models, important preparation parameters such as the path of insertion or the distance from the respective antagonist tooth can be monitored directly on the computer screen

7.No wear of the model

A digital model is not subject to the wear that occurs when checking the fit of a restoration on a physical model.

8.Rapid communication and availability

The further processing of digital models can be implemented without any great loss of time. Digital data transfer via cloud- based systems saves on transport costs.

9.Archivability

Unlike conventionally manufactured models, digital models can be archived more simply and efficiently as more space is saved.

10.Economic material Use

Digital impression-taking avoids waste products and is there- fore advantageous in terms of sustainability and resource conservation.

11.Chairside option
Besides saving time, single-visit dental treatment offers other advantages such as immediate, bacteria-impermeable seal- ing of the dentin wound and adhesive stabilization of the residual hard tooth substance

12.Virtual snipping tool
In addition to the possibility of rescanning to selectively cap- ture defective areas, the virtual snipping tool can be used to perform an overview scan before treatment begins

13. Virtual follow-up
Digital models can be used to visualize numerous intraoral analyses of changes such as tooth migration, dental tipping, tooth rotation, recession, and abrasion, as opposed to con- ventional models.

14. True color representation
Some intraoral scanning systems now produce true-color models, which allows for the improvement of the capture of elements such as dental structures and gingival texture

15. Possibility of data fusion
A digital dataset can be linked to other datasets such as a facial scan, or 3D radiograph images (computed tomography [CT] or cone beam computed tomography [CBCT]).

Drawbacks of intraoral scanning systems
Despite the numerous benefits of digital impression-taking with intraoral scanners, there are some limitations of intraoral scanning with the subsequent generation of a digital model dataset. These limitations are described below.

1.Learning curve
Optical impression-taking is not simple to perform for begin- ners, as correct measurement requires adherence to complex scan paths. Optical impression-taking requires a certain amount of familiarization time; the learning curve is initially extremely flat.

2.Implant restorations
For the precise determination of the implant position, an additional implant-specific scan body is required for digital impression-taking with intraoral scanners. This scan body must be available for the corresponding implant system and must also be compatible with the CAD software being used.

3.Static and dynamic occlusion
It is not possible to alter the occlusion at a later stage with some intraoral scanning systems. In the case of extensive res- torations, the limits of feasibility are reached regarding loss of occlusal support. Furthermore, many systems do not permit the simulation of dynamic occlusion.

4.Scanning fees and closed systems
In some systems, the user has to pay scanning fees to per- form a digital scan. In many cases, scan data will then first be sent to company owned, cloud-based storage systems; as the data are in an encoded file format, this is a closed system. An open Standard Triangulation Language (STL) data export for further processing using any CAD software is often, if at all, only possible after exporting the file from this platform.

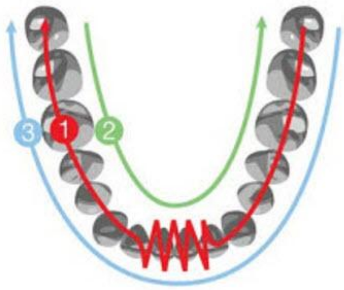
5.Cost
Intraoral scan systems are still expensive. The current prices mean that the cost–benefit ratio is not yet feasible for many users.

6.Scan paths
In addition to the different technical modes of functioning of the various scanners, a correct scan path is decisive for successful scanning results at the present state of the technology. Various scientific analyses show the influence of the scan path on the accuracy of the data capture, both *in vitro* and *in vivo.* Scan path means that the intraoral scanner must be moved according to a specific movement pattern in order to obtain the greatest possible precision of the virtual model.

This is to ensure that the individual images generated by the optical system are superimposed with sufficient accuracy. Especially for the capture of large areas such as quadrants and full-jaw images, a sufficient data volume must be generated not only in the mesiodistal direction but also by adding lateral images to complete the scan path, and, above all, to close it again by crossing over the occlusal surface and returning to the starting point of the scan movement The capture of structureless areas and/or areas with a steep downward.

Full arch

The general principles are applied in the following 2 examples:



Example I: Lower full arch, antagonist

▶ **Step 1:** Antagonist: Start directly on the occlusion (first molar), then sweep along the occlusion. Slowly wiggle the scanner when passing the centrals.

▶ **Step 2:** Lower jaw: Roll 45-90 degrees to the lingual side and sweep to the second molar. Use the tip to keep the tongue away.

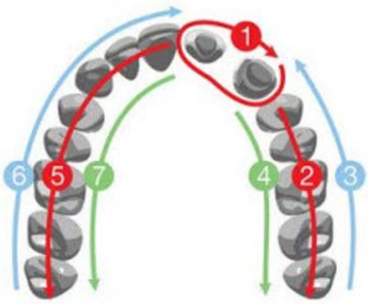
▶ **Step 3:** Roll to the buccal side and complete the buccal sweep.

Example II: Upper full arch, with preparation

Start with the preparation:

▶ **Step 1:** Go to the occlusal side of the preparation.

- Roll to the palatal side.
- Roll to the buccal side.
- Rotate almost 90 degrees to get the best angle for the approximal sides and contact point both distal and mesial.
- Rotate back to the occlusal.



▶ **Step 2:** Swipe along the occlusion.

▶ **Step 3:** Upper jaw: Roll 45-90 degrees to the buccal side and complete the buccal sweep on one side of the preparation.

▶ **Step 4:** Roll to the palatal side and complete sweep.

▶ **Step 5:** Complete scanning on the other side of the preparation by performing the occlusal sweep first.

▶ **Step 6:** Perform the buccal sweep.

▶ **Step 7:** Perform the palatal sweep.

7. Tracking and Software:

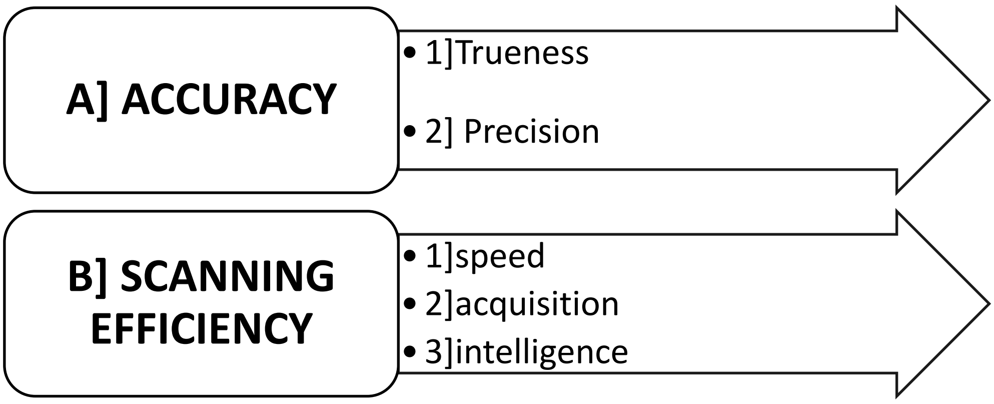
Sometimes during impression, tracking could be lost which may destabilize the software when distance to the object or scan path is not respected; movement is too fast or too jerky. A scan strategy must be followed beginning, for example, with easy parts (occlusal faces of posterior teeth) so that the software has enough information if tracking is lost. Manufacturers are currently developing different strategies and software, algorithms to continue scanning when tracking is lost mainly by recognizing saved geometry of the object. For this, practitioners need to rescan a meaningful area without being stationary to give enough information to the camera and software. The second scan will allow matching the previous POI, and the software will complete this missed area. This rematching of POI is directly influenced by a complex geometry of the object such as high curvatures or many hidden faces that reduce the number of POI and complicates the process for the software.

Classification of intraoral scanners:

Class A = the manufacturer offers its own scanner, CAD software, and CAM (milling) unit.
Class B = the manufacturer offers its own scanner and CAD software only.
Class C = the manufacturer offers its own scanner only. Digital scanners are used to replace traditional impressions, so we developed a three-tiered system based on traditional timings for easy reference.

- **Tier 3**: The scanner is able to complete a full arch scan and export an STL model successfully, without time limit.
- **Tier 2**: The scanner is able to complete Tier-3 tasks faster than silicone impressions (around 5 minutes).
- **Tier 1**: The scanner is able to complete Tier-3 tasks faster than alginate impressions (around 1 minute).

SCANNING EFFICIENCY AND ACCURACY
Completing an intraoral scan is not simply a matter of whipping the scanner around as fast as you can. The scanner needs to also consistently acquire useful data for 3D model reconstruction. In the event that the scanner has captured bad data (i.e. tongue, cheeks, fingers, etc) it needs to be able to fix them, preferably on the fly and without user intervention.



A] ACCURACY
The main feature an IOS should have is accuracy: a scanner should be able to detect an accurate impression. In metrics and engineering, accuracy is defined as the closeness of agreement between a measured quantity value and a true quantity value of a measurand ultimately;
Accuracy is the sum of: -
1]Trueness and
2] Precision.

1] Trueness:
Trueness, usually expressed in terms of bias, is the closeness of agreement between the expectation of a test result or a measurement result and a true value. Ideally, an IOS should have high trueness (it should be able to match reality as closely as possible). An IOS should therefore be as true as possible, that is, be able to detect any impression detail and permit the establishment of a virtual 3D model as similar as possible to the actual model, and that little or nothing deviates from reality. The only means of calculating the trueness of an IOS is to overlap its scans with a reference scan obtained with a powerful industrial machine (industrial optical scanner, articulated arm, coordinate measuring machine) .After the overlapping of these images/models, powerful reverse-engineering software can be used to generate colorimetric maps displaying the distances/differences between the surfaces of the IOS and the reference model at micrometric level.

2] Precision
Precision is defined as the closeness of agreement between indications or measured quantity values obtained by replicate measurements on the same objects under specified conditions. Precision can be calculated more easily, simply by overlapping different scans/models taken with the same IOS at different times and again evaluating the distances/differences at micrometric level . In fact, the trueness and precision obtained with the optical impressions for these types of short-span restorations are comparable to those obtained with conventional impressions. However, optical impressions do not appear to have the same accuracy as conventional impressions in the case of long-span restorations (FULL MOUTH RESTORATIONS).

B] SCANNING EFFICIENCY
Scanning efficiency can be divided into three parts: speed, acquisition, intelligence.
1.SPEED:
Scanning speed is certainly a matter of great importance for an IOS. IOS have different scanning speeds, and the latest-generation devices are generally faster than the oldest ones. However, the literature has not clarified which device can be more efficient: in fact, the scanning speed does not depend only on the device, but largely on the experience of the clinician.

2]ACQUISITION AND INTELLIGENCE:
IOS should be able to fit in an open workflow and should have an affordable purchase and management price. Ideally, an IOS should have two outputs: a proprietary file with legal value and an open-format file (e.g... STL, OBJ, PLY). The inability to freely dispose off STL files, or the need to pay fees to unlock them, certainly represents the main limits of closed systems. However, the inclusion within an integrated system may encourage workflow, especially in the case of less experienced users. In addition, some closed systems offer a complete, fully integrated digital workflow, from scanning to milling, and provide chair-side solutions. Finally, converting files (e.g. the conversion of proprietary files to open formats) may result in loss of quality and information.

DISCUSSION

Intraoral scanners are pivotal in modern dentistry, particularly in the field of prosthodontics, where they are used to create highly accurate 3D representations of a patient's mouth. Unlike traditional impression techniques that often involve the use of alginate or silicone materials, which can be uncomfortable and messy, intraoral scanners provide a more streamlined and hygienic alternative. These digital tools utilize optical or laser scanning technology to capture detailed images, which are then converted into a 3D model. Recent advancements in intraoral scanners have significantly improved their accuracy, allowing for more precise measurements and better-fitting prosthetic devices. The speed of scanning has also increased, enabling dental professionals to complete the process in a fraction of the time it would take with conventional methods. This efficiency not only enhances the patient experience but also allows for more patients to be seen in a given timeframe. Moreover, the software that accompanies these scanners has evolved, offering enhanced visualization tools that help dentists analyze dental structures more effectively. This capability aids in diagnosing issues and planning treatments with greater precision. The integration of intraoral scanners with CAD/CAM (Computer-Aided Design and Computer-Aided Manufacturing) technology has further transformed the workflow in dental practices. It allows for the direct design and fabrication of restorations, such as crowns and bridges, from the digital impressions captured by the scanner. Additionally, intraoral scanners improve communication between dentists and dental laboratories. The digital files can be easily shared, reducing the chances of miscommunication and errors that can occur with physical impressions. This streamlined process not only saves time but also enhances the overall quality of prosthodontic outcomes. In summary, the advancements in intraoral scanning technology are making dental procedures more comfortable for patients, increasing operational efficiency for dental practices, and ultimately leading to better results in prosthodontics. As technology continues to evolve, we can expect even more innovations that will further enhance the capabilities of intraoral scanners in the future.

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