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A CURRENT UPDATE ON THE USE OF INTRAORAL SCANNERS IN DENTISTRY - A REVIEW OF LITERATURE

Mohamed Zahoor Ul Huqh[1], Johari Yap Abdullah[2,*], Taseef Hasan Farook[3], Nafij bin Jamayet[4] and Anand Marya[5,†]

[1]PhD Scholar, Orthodontic unit, School of Dental Sciences, Health Campus, Universiti Sains Malaysia, Kubang Kerian, Kota Bharu-Malaysia
[2]Senior Lecturer, Craniofacial Imaging Lab, School of Dental Sciences, Health Campus, Universiti Sains Malaysia, Kubang Kerian, Kota Bharu-Malaysia
[3]Maxillofacial Prosthetic Service, Prosthodontic Unit, School of Dental Sciences, Health Campus, Universiti Sains Malaysia, Kubang Kerian, Kota Bharu -Malaysia
[4]Senior Lecturer, Division of Clinical Dentistry (Prosthodontics), School of Dentistry, International Medical University, Bukit Jalil, Kuala Lumpur-Malaysia
[5]Associate Professor, Head of the Department of Orthodontics, University of Puthisastra, Phnom Penh, Cambodia

ABSTRACT

Background. The aim of this review was to determine the current clinical applications of intraoral scanners IOS and its limitations. *Materials and Methods.* The literature search was carried out using electronic databases such as PubMed, Embase and Science Direct. Both observational studies like case-control, comparative, prospective, retrospective, cohort, case reports, and experimental studies like randomized control trials and cross over trials were selected for this review. The keywords used based on a search strategy: intraoral scanners, optical impressions, digital impressions, and intraoral scanning systems. *Results.* 59 articles out of which only 54 articles were selected in this narrative review and 5 articles were removed as these studies did not match the selection criteria and the journal articles which were published over a period of 10-years from Jan 2011 to Jan 2021 were included. *Conclusion.* IOS system is less time consuming when compared with other conventional methods of impression making. In terms of patient benefits, it reduces pain and discomfort. Ease of communicating with patients and educate them by providing video presentations before delivering any appliance or prostheses. Advanced technology is reshaping the future of digital dentistry, not only in orthodontics but also in other fields of dentistry as well.

[*] Email: johariyap@usm.my Mob: +609 767 5565.
[†] *Correspondence:* Anand Marya, BDS, MS, MFDS RCS ED, MFDS RCPSG, Assistant Professor, Head of Orthodontics, University of Puthisastra, Phnom Penh, Cambodia, Email: amarya@puthisastra.edu.kh

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ABBREVIATIONS

IOS - Intraoral scanners

INTRODUCTION

Intraoral scanners (IOS) are widely used for making digital impressions in dentistry which captures the exact replica of the mouth [1-3]. In recent years there is a considerable increase in the number of intraoral scanners in the market. The impression with IOS has already been proven to be the superior method than the conventional methods of impression-taking and appear to be a promising development for the future. Optical intraoral scanning system has a wide range of applications in various fields of dentistry like Orthodontics, Prosthodontics and Implantology etc. [2].

The optical impression includes measuring the shape of the teeth surface or gums optically in the patient's mouth directly. It provides three-dimensional feature data, e.g., the surface formation of the tooth abutment, opposing tooth, the status of occlusion and gum shape. The principles for capturing data include active triangulation, confocal microscopy, and the form of wavefront sampling. All the data obtained is processed into digital data which reflects as virtual models on the image. Then it is transferred as stereolithography (STL) data, which are used for material composition in Computer-Aided Machine (CAM) and for designing in Computer-Aided Design (CAD) software and digital workflow into the manufacturing device. Thus, the practical use of IOS makes traditional impression material and dental casts no longer in use [4].

Although IOS are becoming extremely popular in the field of clinical dentistry, a limited number of reviews are available in the literature based on these devices [5]. The conventional method of impression making has some disadvantages associated with plaster models, such as subject vulnerability like gag reflex and discomfort which has been overcome with the use of digital plaster models. The digital impressions made through IOS has many advantages in terms of time, cost, required space and digital models [6]. Hence, the purpose of this review was to determine the current clinical applications of IOS and its limitations.

MATERIALS AND METHODS

Search Strategy

A search was carried out using electronic databases such as PubMed, Embase and Science Direct. Both observational studies like case-control, comparative, prospective, retrospective, cohort, case reports, and experimental studies like randomized control trials and cross over trials were selected for this review. The keywords used based on a search strategy: intraoral scanners, optical impressions, digital impressions, and intraoral scanning systems.

The search was confined to only full-text published articles in English and those published in peer-reviewed journals from January 2011 to January 2021 were included. Title and abstracts of the articles were screened, and full texts of all relevant publications were obtained, and data was extracted.

RESULTS

A total of 59 articles out of which only 54 articles were included in this narrative review because the remaining 5 articles did not fulfill the selection criteria and these articles were published over a period of 10-years from Jan 2011 to Jan 2021 which demonstrated considerable change in relation to the study design, type of the study and results. Among these articles, 7 were randomized controlled trials, 17 were previous literature reviews, 15 were systematic reviews, 2 were meta-analysis, 12 were clinical trials and 1 Cross-sectional study as mentioned in (Table 1).

Types of IOS

There are about more than 20 IOS models are commercially available in the market. They are classified as All-in-one scanning platforms with CAD/CAM technique and others as standalone scanners. The previous scanning system layouts the intraoral scanning data into 3D models as image files or generates the appliance design using CAD software which enables the user to forward the digital data models and design to the dental laboratory as displayed in (Figure 1) [4].

A standalone scanner is also called as “one-day treatment” device, which helps in designing prosthetic appliances using 3D data model from the optical-impression. The target prosthetic appliance can be completed and delivered on the same day with required materials pre-installed and processed immediately with standalone scanner as shown in (Figure 2) [4].

Characteristics of Scanners

A dental surface digitization system may be based on contact or non-contact techniques where three-dimensional images are collected [60, 61]. The three-dimensional contact scanners scan the surface area of the object through a probe with hard steel tip. The non-contact laser scanner emits laser beam or a kind of light source on its return captures the object’s geometry by triangulation [62, 63].

The optical scanner involves the combination of light source, three-dimensional structure, and the reciprocal relationship at a defined angle in the receiving unit. The system can calculate 3D data through this angle. The white light projections can act as illumination source [64]. Calibration is important on scanning surface with properties identical to that of the target to be scanned [65].

The currently available intraoral scanning systems are differentiated by features like the light source, the operating principle, the export file format among others, the need to eliminate the shiny surfaces and the operating system [52, 66, 67].

Table 1. Reference Studies, Study design, Scanner used and Indications

nos.	References	Study Design	Scanner Used	Indications
1	Waldecker et al. [7]	Clinical trial	CAD/CAM	Full crown FPD Inlays & Implants
2	Marques et al. [8]	Review	Trios, True definition, CEREC Bluecam, CEREC omnicam, Comet VZ250, LavaCOS, iTero, CS 3600, ZFX Intrascan	Inlays, Onlays, Digital impressions, Fixed partial denture prostheses
3	Jedlinski et al. [9]	Systematic review	Carestream CS3600, i500, 3Shape Trios3, Sirona Omnicam, Primescan	3D Orthodontics, Fabrication of Orthodontic appliances and retainers. Orthodontic tooth movement
4	Jabri et al. [10]	Review	iTero	Analyzing Orthodontic study models
5	Michelinakis et al. [11]	Review	iTero Trios LavaCOS Omnicam DWIO, Emerald	Fixed Implant prostheses
6	Sawase and Kuroshima [12]	Review	iTero Trios 3 LavaCOS Omnicam ZFX Intrascan CS3500, CS3600 Planmeca planscan	Implant dentistry
7	Garciagil et al. [13]	Systematic review	Trios, LavaCOS, iTero	Implant dentistry Digital impression Fixed prostheses
8	Aswani et al. [14]	Review	CEREC AC Bluecam, Lava Chairside Oral Scanner COS, iTero, Zfx IntraScan, Trios, E4D dentist	Fixed prosthodontics
9	Nikoyan and Patil. [15]	Review	Digital IOS	Implant dentistry
10	Ammoun et al. [16]	Review	3Shape TRIOS 3M True definition	Tooth preparation design

nos.	References	Study Design	Scanner Used	Indications
11	Sulaiman [17]	Review	CAD/CAM	processed PMMA restorations, single crowns and fixed partial dentures.
12	Giachetti et al. [18]	Systematic review	3M True definition scanner, 3M LavaCOS, Cadent iTero, 3Shape Trios and CEREC Bluecam	digital impression with full dentition and palatal soft tissues
13	Tabesh et al. [19]	Systematic review	LavaCOS and Lava True Definition scanner; 3M ESPE, CEREC AC Bluecam and CEREC AC Omnicam, Dentsply Sirona	single-unit zirconia crowns
14	Wulfman et al. [20]	Systematic review	TRIOS, 3Shape, CEREC Omnicam, Dentsply Sirona	Digital implant impressions, full-arch implant impressions
15	Carneiro Pereira et al. [21]	Systematic review	Trios-3Shape, CS 35001, Zfx Intrascan Planmeca Planscan and 3M ESPE	Implant position Implant supported fixed prostheses
16	Papaspyridakos et al. [22]	Meta-analysis	True Definition iTero, Trios Cerec omnicam	Implant impressions for partially and completely edentulous patients
17	Kustrzycka et al. [23]	Systematic review	Trios3Cart, Trios3Pod, Trios4Pod, and Primescan True Definition, TRIOS, CEREC Omnicam, and Emerald Scanner	tooth-supported appliances edentulous mandible
18	Schlenz et al. [24]	Clinical Trial	CAD/CAM Trios 3	Full coverage crowns, ‘COM’, resin composite; ‘ZIR’, zirconium dioxide; ‘NPA’, non-precious alloy
19	Bandiaky et al. [25]	Systematic review	Trios, LavaCOS, iTero	complete-coverage, fixed tooth-supported prostheses
20	Moreno Soriano et al. [26]	Systematic review	CAD/CAM	Intraoral prosthetic rehabilitation
21	Luqmani et al. [27]	RCT	Carestream 3600	Digital impression
22	Schlenz et al. [28]	Clinical Trial	True Definition (TRU), Primescan (PRI), CS 3600 (CAR), and TRIOS 3 (TIO)	periodontally compromised dentition; full-arch impression, aligner treatment; orthodontics; digital prosthodontics
23	Fuenki et al. [29]	Systematic review	Candent iTero, Trios 3, LavaCOS, True definition, CEREC omnicam	Digital impression, Maxillomandibular relationship record, Digital removable partial denture
24	Pan et al. [30]	Clinical Trial	CAD/CAM	Digital impression Single tooth implant
25	Sivaramakrishnan et al. [31]	Meta-analysis	LavaCOS, iTero, CEREC	Digital impressions

Table 1. (Continued)

nos.	References	Study Design	Scanner Used	Indications
26	Kiatkroekkrai et al. [32]	RCT	Trios	Assessment of 3D Implants Optical impression
27	Cappare et al. [33]	RCT	Carestream CS 3600	Full arch rehabilitation, crestal bone loss, digital impression workflow, Implant prosthodontics
28	Blatz and Conez. [34]	Review	CAD/CAM	single-unit inlays, onlays, crowns, veneers, implant abutments, and restorations to fixed and removable dental prostheses
29	Kihara et al. [35]	Review	Planscan, 3Shape D800, CEREC Omnicam, Cerec Bluecam, iTero CS350, 3Shape TRIOS 3	extensive removable prosthesis, such as mouth guards and complete dentures
30	Takeuchi et al. [36]	Review	3M True Definition CEREC omnicam Planmeca Planscan Trios, Trophy 3DI pro	restorations and fixed dental prostheses
31	Mizumoto and Yilmaz [37]	Systematic Review	CAD/CAM	Intraoral Scan body Digital implant impressions
32	Memari et al. [38]	Review	Trios, 3Shape, iTero, LavaCOS, Lava True definition, CEREC, LavaScan, Dental wings 7series	impression and stone die
33	Muhlemann et al. [39]	Systematic review	iTero, CEREC omnicam	implant-supported prostheses
34	Mangano et al. [40]	Review	CS3600	Intraoral digital impression
35	Sailer et al. [41]	RCT	Lava C.O.S, iTero, CEREC bluecam	Digital workflow for fabrication of zirconia-ceramic FPD
36	Kirschneck et al. [42]	Cross-sectional	Lythos, Tetrachrome, Impregum	Digital dental models
37	Zhang et al. [43]	Clinical trial	Trios	Monolithic zirconia crowns
38	Sakornwimon and Leevailoj. [44]	Clinical trial	D900L	Monolithic zirconia crowns, Digital impressions
39	Alikhasi et al. [45]	Systematic review	Lava Scan ST, Trios, iTero, True definition	Digital Implant Impression
40	Richert et al. [46]	Review	Trios, iTero	Tooth preparation, Full arch impression
41	Mangano et al. [5]	Review	iTero, Trios, CEREC	fabricating restorations or custom devices in prostheses, surgery and orthodontics
42	Aragón et al. [47]	Systematic review	OrthoProof, Lava, iOC intraoral, Lava COS, iTero and D250	Tooth widths, Bolton ratio measurements, and image superimposition

nos.	References	Study Design	Scanner Used	Indications
43	Ahrberg et al. [48]	RCT	Lava C.O.S	All ceramic restorations
44	Hafez et al. [49]	Review	CAD/CAM	3D printing
45	Boeddinghaus et al. [50]	Clinical Trial	CEREC omnicam, True definition, Trios	Single tooth restorations, Digital impressions
46	Gjelvold et al. [51]	RCT	Trios	Digital impression, single-unit crown restorations
47	Goracci et al. [52]	Systematic review	LavaCOS iTero	Full arch impressions
48	Pradies et al. [53]	Clinical Trial	LavaCOS	All ceramic crowns, Digital impression
49	Yuzbasioglu et al. [54]	Clinical Trial	CEREC Omnicam	Digital impression
50	Schubert et al. [55]	Clinical Trial	OraScanner	virtual superimposition evaluate bracket positioning
51	Vannoort [56]	Review	3M, 3Shape and iTero	High quality dental prostheses
52	Galhano et al. [57]	Clinical Trial	CEREC Bluecam, LavaC.O.S. System, iTero System, and E4D System	Optical impression
53	Esquivel-Upshaw et al. [58]	RCT	3D Laser Scanner	crown fabrication and the wear measurement; core-ceramic, veneers, and enamel
54	Logozzo et al. [59]	Clinical Trial	CEREC®, iTero, Trios, E4D, LavaCOS, IOS fastscan, DENSYS-3D, DPI-3D, 3D progress, Directscan	Restorative Dentistry

Figure 1. All-in-one scanning platforms with CAD/CAM system [4].

Figure 2. Standalone Scanning System with CAD/CAM [4].

DISCUSSION

The accuracy of the IOS mainly depends on two factors i.e., trueness and precision. Trueness is the deviation of geometry of the impression from the original geometry, while precision is the deviation between impressions that are replicated [2, 68].

The IOS are capable of scanning micro and macro-objects with high degree of trueness and precision. The individual morphological details of dental surfaces can be scanned using optimal scanning technique with higher resolution and repeatability. At different magnification levels, even small and large morphological constructions can be obtained. It is possible to scan various model materials [68].

Most of the studies discussed about adaptation accuracy in IOS use. Several of them compared the adaptability of newly manufactured crowns. In one study authors reported no significant difference in accuracy between the crowns manufactured by conventional technique and by the model-less IOS methods: 60 to 70 μm close to the crown margin, 80 to

90 μm near the axial wall center, and at the occlusal surface about 150 to 170 μm [69]. In other words, most of the studies reported the IOS accuracy substitutes the accuracy of the conventional impression and indirect techniques compared with IOS working models [69, 70].

IOS has many advantages over conventional method of impression making such as; less discomfort to the patients, time efficient, simplified procedure for the operator, cost effective, no more plaster casts, reduced risk of infection, real-time impression scanning and visualization, image management and archiving, virtual follow-ups, rapid communication with patients and dental technicians, Merging intraoral digital data with 3D facial-scan models enhances comprehensive diagnoses, improves dental implant treatment efficiency and aids in detection of cracks and dental caries [4, 5].

Clinical Applications of IOS

IOS can be utilized in various fields of dentistry for fabrication of restorations or custom-made appliances in surgery, prosthodontics, and orthodontics for diagnostic purposes to deliver safe and efficient dental treatments [71, 72].

Digital scanners can be used in orthodontics for many applications. It mainly depends on device capabilities, reference software, clinician, and the dental laboratory. Nevertheless, the IOS have been utilized for treatment planning for fabricating indirect bonding trays [73], for lingual and palatal custom device design and construction [74], for technology of clear aligners [75], for simulating Orthognathic surgery and constructing wafers [76, 77] and recently, for scoring surgical outcomes in Cleft, Lip and Palate patients [78]. The ability to provide advanced patient care, treatment efficiency and effectiveness in the field of orthodontics will continue to emerge with the development of new cutting-edge technologies [62].

From the perspective of this review, it is evident that the IOS are a reasonable alternative to conventional methods of impressions for making accurate models in fixed prosthodontics. The modern IOS that allows for making digital impressions that have a range of applications such as preparing models for treatment planning or communicating with patients to deliver final models for provisional or permanent restorations with ceramic, metallic, hybrid and polymeric materials [67].

Routinely the impression trays, materials and copings are used with conventional impression methods for dental implants to allocate the position of intra-oral dental implants into a working stone cast model to fabricate the implant-supported prostheses. In general, the screw-retained open impression trays and copings are preferably used to generate accurate impressions. Regardless, for screw-retained impression copings more mouth opening is required. When the impressions are removed from the patient's mouth the screw retention must be loosened through the holes on top of the impression trays with the help of screw drivers. Alternatively, for optical impressions with IOS for dental implants there is no need for excessive mouth opening. Hence, the scan bodies which are inserted in dental implants simply scanned by IOS system to record the dental implant position [79]. Optical technology has been a paradigm shift in the field of dental implantology. Although, there is a minute detail available on the application of optical technology in implant prostheses since it is a new technology and emerging as advanced technique under the current conditions [12].

Utilizing IOS in oral examinations at schools would enable the collection of significant amounts of data related to the oral cavity which can be used for epidemiological studies in relation to dental caries or gingival status by doing analysis using software. IOS system can be used for identifying disaster victims or patients with dementia. The remaining teeth records or dental treatments have been witnessed as a critical means for identification of unknown persons, e.g., victims of natural disaster and rambling dementia patients. The application of IOS renders immediate construction of a personal database information and its 3D data-collection capability which enables the expedited matching with data records obtained from the disaster site [4].

Limitations of IOS

Training is mandatory to operate IOS because precise and rapid measurements are required while taking optical impression.

Visualization of targeted operating field is important as oral fluid especially gingival fluid can cause error in measurement due to optical refraction. Since the device only measures the objects which are confirmed visually.

While taking Implant-impressions the IOS requires scan bodies, the compatible CAD/CAM system, and the reference software in the implant system.

At present mandibular position cannot be obtained with IOS which is unchangeable because dynamic occlusion cannot be simulated. Nevertheless, few CAD software's have virtual articulators that mounts re-adjustment with jaw-motion parameter.

CONCLUSION

We can conclude this narrative review by emphasizing the fact that use of IOS optical impressions have many advantages over conventional methods. The IOS system is less time consuming when compared with other conventional methods of impression making. In terms of patient benefits, it reduces pain and discomfort. Ease of communicating with patients and educate them by providing video presentations before delivering any appliance or prostheses.

Advanced technology is reshaping the future of digital dentistry, not only in orthodontics but also in other fields of dentistry as well. There are numerous intraoral scanners available in the market that suit the needs of the patients in various branches of clinical dentistry. Further to enhance its diagnostic accuracy the updated software's must be used. The prospective longitudinal and randomized clinical trials should be conducted for accurate diagnosis and better treatment planning especially in the field of implant dentistry and craniofacial defects like cleft lip and palate.

Conflicts of Interest

The authors declare there is no conflict of interest.

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