Digital Dentistry Journal 1 (2025) 100004

Contents lists available at ScienceDirect

Digital Dentistry Journal

journal homepage: www.sciencedirect.com/journal/digital-dentistry-journal

Does intraoral scanning influence the patient's view of dental restorations? A comparative study

Marianna Soares Nogueira Borges [a], Gabriela Greghi de Carvalho [a], Gabriela Ayres de Souza [a], Karen Pintado-Palomino [b,c], Bruna Neves de Freitas [a], Camila Tirapelli [a,*]

[a] Department of Dental Materials and Prosthodontics, Ribeirão Preto School of Dentistry, University of São Paulo (USP), Ribeirão Preto, São Paulo, Brazil
[b] Department of Restorative Dentistry, Ribeirão Preto School of Dentistry, University of São Paulo (USP), Ribeirão Preto, São Paulo, Brazil
[c] Department of Restorative Dentistry, School of Dentistry, Federal University of Minas Gerais, Belo Horizonte, Minas Gerais, Brazil

ARTICLE INFO

Keywords:
Composite resins
Judgment
Clinical diagnosis
Computer assisted diagnosis

ABSTRACT

Objectives: To compare intraoral scanning (IOS) and indirect visual observation on the patients' view regarding their resin composite restorations.
Methods: Patients scored their anterior and posterior resin composite restoration through indirect visual observation with a regular mirror followed by a mirror with magnification. After one week, the patients were scanned and scored the same restoration, visualizing it at the IOS touchscreen monitor. The "patient view" criterion of the Fédération Dentaire Internationale (FDI) was used to score considering 1 (totally satisfied) to 5 (totally unsatisfied) of patient's opinion.When the score assigned was greater than 1, the reasons for dissatisfaction were registered through questionnaires with options according to FDI criteria adapted for patient analyses. Descriptive statistics were carried out to analyze the frequencies of scores. Kruskal-Wallis with multiple comparison tests were used to compare scores and reasons for dissatisfaction.
Results: Significant differences were found among IOS and mirrors ($P < 0.0001$) and reasons for dissatisfaction ($P < 0.0001$). Score 2 prevailed, followed by 3 and 1. Patients were more satisfied with their restoration when they were observed with a regular mirror. Regarding reasons for lower satisfaction, "inappropriate color" and "inappropriate contour" were prevalent.
Conclusions: Patients can be more critical towards the esthetics of their resin composite restorations when viewing them through IOS images and magnifying mirrors.
Clinical significance: IOS can allow patients to have a direct, colored and possibly magnified view of their intraoral conditions; this can decrease their satisfaction with dental restorations. This is clinically relevant because intraoral scanners are being used in the diagnosis process and dentist-patient communication.

1. Introduction

The introduction of intraoral scanners (IOS) has revolutionized the clinical workflow in dentistry, extending far beyond digital impressions to significantly impact patient examination, diagnosis and overall communication. Beyond impression-making, intraoral scanners facilitate the early detection of dental conditions through automated caries detection [1], wear analysis, and volumetric comparisons over time [2], enabling objective monitoring of disease progression. Additionally, integrated artificial intelligence (AI) and machine learning algorithms embedded in modern IOS assist in identifying occlusal discrepancies [3], assessing soft tissue conditions [2], and detecting structural anomalies with greater precision. The seamless integration of IOS with computer-aided design/-computer-aided manufacturing (CAD/CAM) systems, digital smile design [4], and orthodontic simulations [5] further streamlines the diagnostic process, reducing chairside time and improving overall clinical efficiency [6]. Moreover, IOS optimizes patient communication and education, as real-time digital scans allow patients to visualize their oral health status, increasing treatment understanding and acceptance.

In this context where, such a digital device may change the diagnosis

* Corresponding author. Universidade de São Paulo, Faculdade de Odontologia de Ribeirão Preto, Departamento de Materiais Dentários e Prótese, Avenida do Café, sn, Bairro Monte Alegre, Ribeirão Preto, CEP 14040904, São Paulo, Brazil.
E-mail addresses: marianna.snborges@usp.br (M.S.N. Borges), karpintado@gmail.com (K. Pintado-Palomino), bnevesfreitas@alumni.usp.br (B.N. de Freitas), catirapelli@forp.usp.br (C. Tirapelli).

https://doi.org/10.1016/j.ddj.2025.100004
Received 13 December 2024; Received in revised form 7 February 2025; Accepted 18 March 2025
Available online 19 March 2025

and possibly the treatment plan [7–12], it is relevant to observe whether intraoral scanners (IOS) that can provide direct, real-time, colored and magnified three-dimensional images of the intraoral surfaces and are becoming a tool in dentist-patient communication, could change the patients' satisfaction regarding their dental restorations when they visualize the scanned image of their teeth [11,12].

In the assessment of dental restorations made by the dentist, the patient's perspective is particularly important, as reasons for failures can be influenced by esthetic appearance driven by personal demand [13–15]. This aspect is inherently subjective and may vary among individuals depending on factors such as educational level, age, and the social environment [15–17]. In this sense, the Fédération Dentaire Internationale (FDI) developed criteria that have been used to evaluate the quality of dental restorations. These criteria include esthetic, functional and biological parameters by using 16 different categories [18]. Besides being more clinically sensitive, the FDI criteria is the only one to consider the patient's opinion by the "patient's view" criterion, adding value to it [19]. This criterion requires that the patients' opinions regarding their own restorations be scored using a visual analogue scale. Additionally, it is recommended that the reason for dissatisfaction be registered through an interview with the patients [18]. However, in clinical studies the "patient's view" criterion is poorly explored [19]. Freitas et al. [13] showed that from 58 studies that assessed resin composite performance, only 17 referred to have used patient's view with brief details about its approach, not describing the assessment method or the conditions (e.g. regular or with magnification mirror, light conditions, digital devices) in which the patients observe their own dental restoration.

Within the perspective of the patient's view, it is important to take into account new digital devices that can provide the visualization of intraoral surfaces in a new fashion for both professionals and patients [1,12]. Studies have reported that patients usually preferred digital to conventional impressions [6,20,21]. Among the reasons for that are the taste of materials used in conventional impressions, shortness of breath and activation of the gag reflex, anxiety, fear of conventional impression repetition, and overall discomfort [6,22]. Besides enhancing patient comfort, it is stated that IOS can benefit the communication [6,20,23] between dental professionals and patients, possibly due to the fact that digitized oral structures are displayed on a direct view, on large and interactive screens, facilitating the patients' understanding of their conditions. The possibility of looking at the scanned image could allow the professional and, consequently, the patients to see more details. In literature, few studies [24,25] have evaluated the perception of facial and dental discrepancies in two-dimensional (2D) and three-dimensional (3D) simulations. The previous findings indicated that the type of dimensional representation affected the esthetic perception of laypersons, dental students and dentists. The results showed that, for the same dental esthetic disparity simulated in 2D and 3D representations, the 3D simulation obtained higher esthetic ratings regarding dental discrepancies than the 2D image in all population groups [24]. In this sense, it is worth starting a process of understanding and discussing whether such a level of improved visualization can lead to unnecessary restorative procedures.

Considering the background, this clinical study aims to compare IOSs with conventional methods on the patients' perception regarding their resin composite restorations in anterior and posterior teeth when looking at images generated by IOS. The null hypothesis is that there is no difference in the patient's view considering IOS, a regular handle mirror, and a handle mirror with magnification. Understanding whether IOS images change the patients' view regarding their dental restorations can be clinically relevant as IOS has become a definitive tool to aid dentist-patient communication.

2. Materials and methods

2.1. Study design

This is a cross-sectional observational clinical study comparing the patients' view regarding their own restorations with colored IOS three-dimensional images, a regular handle mirror, and a handle mirror with magnification. This study was conducted in accordance with relevant laws and institutional guidelines, being approved by the local research ethics committee from Ribeirão Preto School of Dentistry (CAAE: 34682020.5.0000.5419) and complied with the Declaration of Helsinki. Information about the study was provided to the participants both verbally and in writing, and those who agreed to participate signed the consent form before the study began.

2.2. Criteria of eligibility

The inclusion criteria were patients aged 18–70 years old, with at least 24 teeth, and having at least one resin composite restoration. The restoration could involve one or more surfaces (buccal, lingual, and/or and occlusal surfaces) of anterior or posterior maxillary or mandible teeth, which had been placed at least 06 months prior to this study. The exclusion criteria were orthodontic appliance users; restorations involving rotated teeth; restoration on adjacent teeth; strict approximal resin composite restorations; subgingival restorations; and restorations that showed any changes in esthetics, functional or biological characteristics within one week from the first appointment.

The restorations were clinically selected by one experienced and trained operator (dentist/MSNB), with dental explorer and mirror number 5, air of triple syringe and artificial light. Afterwards, the restorations were included or excluded from study, following the eligibility criteria. In cases where the patient had more than one dental restoration meeting the inclusion criteria, one restoration per dental quadrant was selected. If the participant had more than one restoration, they were evaluated one at a time.

2.3. Sample size

The sample size was composed by anterior and posterior dental restorations. It was calculated based on a previous study [13] where dissatisfaction with dental restoration among laypeople was 50 % on average, and on a pilot test considering the design of this study. A level of confidence of 95 % and a power test of 80 % (G*Power v 3.1.9.7; Heinrich-Heine-Universität Düsseldorf) was also considered. The minimum total sample size was 38 dental restorations, and the number of participants included was 41. According to the eligibility criteria, the study counted with a total of 70 restorations.

2.4. Dental restoration visualization

Initially, anamnesis was taken, and a dental prophylaxis was performed. Then, the participants sat on a dental chair at a 90-degree angle perpendicular to the ground. Subsequently, they were instructed to visualize their restoration through.

a) Regular handle mirror and handle mirror with magnification: First, the participants scored their dental restoration through a visual observation using facial mirrors, under the guidance of the operator. Each participant sat on a dental chair at 90° relative to the ground and in front of a window, providing natural morning light (9–11 a.m.). Subsequently, the participants received and held a facial mirror (10 cm in diameter and with no additional light). The mirror had a side with no amplification (regular mirror) and the amplification of 2x on the opposite side. The operator informed the participant where the respective dental restoration was located and asked them to observe it by looking at it with the mirror without magnification. For restorations located on the posterior teeth (mainly at lingual or occlusal surfaces of the teeth in the upper jaw), visualization was helped with the assistance of the operator positioning an occlusal mirror to reflect the image onto the facial mirror. No time limit was imposed, allowing the patients to take their time to reach a conclusion; however, it was

required that they provide their response during the same clinical session. Subsequently, the operator asked the participants to score their satisfaction with their restoration using a visual analogue scale, similar to the one proposed by the FDI criteria [18]. The scale had five levels of satisfaction, adapted to meanings that the participant could easily understand (Fig. 1). After 60 min, in the same session, the same procedure was repeated using the mirror with magnification.

b) Intraoral scanning: One week after having scored their dental restoration with the aid of the handheld mirror, the participants returned to the dental clinic and an IOS was performed by the same operator (CEREC Primescan equipment, Dentsply Sirona, Germany) following the manufacturer's technique. After completing the scanning, the dental restoration was observed by the participant by looking at the screen attached to the scanner (Cerec SW 5.1.3 software). The participant was allowed to interact with the image by rotating and magnifying it using the touch screen monitor in a single viewing session. No time limit was imposed, allowing patients to take their time to reach a conclusion; however, it was required that they provide their response during the same clinical session. After the observation of the indicated restoration, patients were asked to score their satisfaction using the visual analogue scale, which was identical to the previous procedure (i.e. handheld mirror).

After scoring their restoration with each method, for those restorations scored higher than 1, the patients were assisted in reporting the reasons for dissatisfaction, which were recorded by the operator, as outlined by the used criteria [18]. Thus, the operator asked: 'What bothers you regarding this restoration?'. The reason for dissatisfaction was classified by the operator according to options listed by the authors of this study, based on FDI criteria. For such a proposal, the authors considered biological, mechanical and esthetic parameters, using words commonly reported by the patients in daily clinical practice and listed in Table 1. If the patients reported a reason for dissatisfaction that had not been anticipated by the authors, this reason would be included. The same operator was present and guided the patient through the entire process, from the selection of the restoration to the scanning and recording of the reason for dissatisfaction. During all methodology, it was allowed for the patient to ask any question to the operator regarding the methodology, however, it was also clarified that questions regarding the conditions of restoration would not be answered.

2.5. Statistical analysis

The variable measured was the patient's view, according to scores. The sample, consisting of anterior and posterior restorations, received scores ranging from 1 to 5 (in order to observe the level of satisfaction),

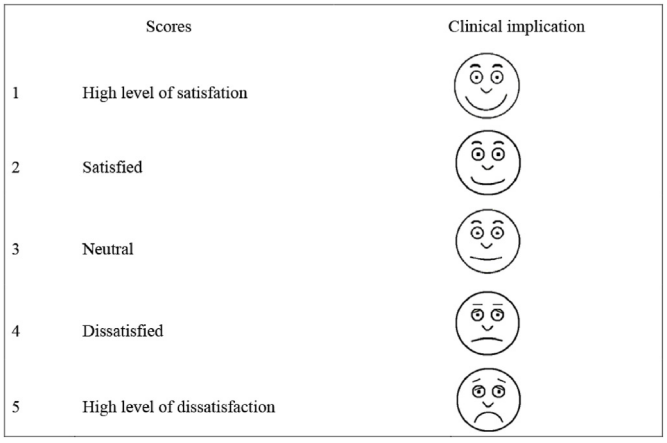


Fig. 1. Representation of the patient's view criterion and its respective scores, following the FDI criteria.

Table 1
Reasons for patient's dissatisfaction regarding direct resin composite restorations.

Reasons for dissatisfaction		FDI criteria
A	Poor brightness	Esthetics
B	Presence of stains	
C	Inappropriate color	
D	Inappropriate contour	
E	Presence of fractures	Functional
F	Difficulty using dental floss	
G	Presence of hypersensitivity	Biologic
H	Presence of bleeding	

and scores from A to H (in order to label the reason for dissatisfaction when it was mentioned) for each factor of variation, represented by the groups IOS, regular mirror, mirror with magnification. As the scores are categorical data, a descriptive analysis of these data was carried out to observe their distribution and frequencies (absolute and relative). In order to observe the factors of variation (methods of visualization), the Kruskal-Wallis's test and Tukey's post-hoc test with multiple comparisons was used to compare the frequency of scores for the level of satisfaction (1–5) and reason for dissatisfaction (A to H) among groups. In all tests, the level of significance was set at $P < 0.05$ and calculations were performed by using GraphPad Prism software version 8.0.1 for Windows (Boston, Massachusetts, United State).

3. Results

Fig. 2 shows the frequency of the scores collected with the different methods of visualization. For all of them, score 2 was most frequent followed by scores 3 and 1. The mirror without magnification showed the highest frequency of score 1, in which patients are totally satisfied with their composite resin restoration. The different visualization methods showed a statistically significant difference among scores. When comparing frequency among methods of visualization, significant difference is observed between scores 1 and 3. Thus, when patients looked at their resin restorations using a mirror with magnification and IOS images, their satisfaction decreased, represented by the increased frequency of score 3 compared to the regular mirror. As the magnification of the visualization methods improves (Fig. 3), score 1 (highest level of satisfaction) showed a decrease.

Furthermore, observing the visualization methods separately, there are significant statistical differences between the reasons for dissatisfaction (Fig. 3). Considering the regular mirror and mirror with magnification, the prevalence of inadequate color and inadequate contour was

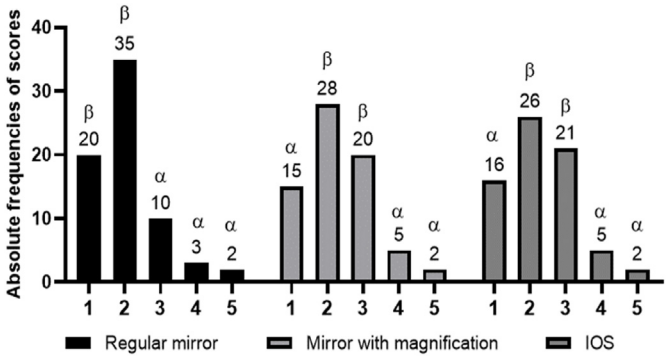


Fig. 2. Graphic illustration of the frequency of scores from patient's view observations. Statistically significant differences among the methods used for visualization are represented by different Greek letters ($P < 0.0001$).
1: Clinically very good restoration; 2: Clinically good restoration; 3: Clinically satisfactory restoration; 4: Clinically unsatisfactory restoration; Clinically poor restoration; IOS: Intraoral scanning.

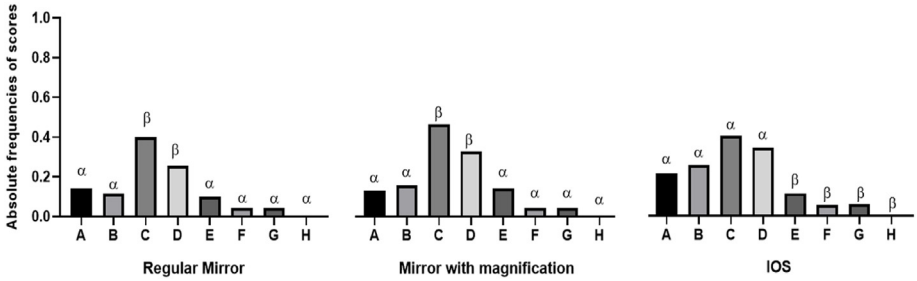


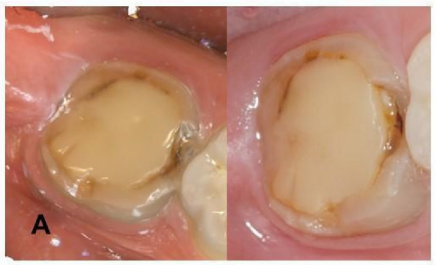
Fig. 3. Graphic illustration of reasons for patients' dissatisfaction regarding their resin composite restorations by different visualization methods. Different Greek letters represent statistically significant differences between the scores ($P < 0.0001$).
A: Poor brightness; B: Presence of stains; C: Inappropriate color; D: Inappropriate contour; E: Presence of fractures; F: Difficulty of using dental floss; G: Presence of hypersensitivity; H: Presence of bleeding; IOS: Intraoral scanning.

higher when compared to all the other reasons, evidencing a tendency for greater criticism from participants. When IOS is the visualization method under observation, there are more reasons for dissatisfaction with significant greater frequencies (inappropriate color, inappropriate contour, presence of stains, and poor brightness).

Fig. 4 shows some examples of the restorations included in the study and their respective patient's view. In some cases, changes in scores can be seen, as well as reasons for dissatisfaction. Table 2 shows the demographic data of patients and the corresponding teeth where the restorations were located. It is possible to observe the patients were 27.79 years old on average and were mostly women with an average of 1.71 restorations each (41 patients/70 restorations). In addition, restorations were more frequent in the following teeth: first lower molar (30), first upper molar (20) and upper central incisor (10).

4. Discussion

This study showed that IOS and mirror with magnification can decrease patients' satisfaction with their direct resin composite restoration and the null hypothesis that there would have been no difference between patients' view regarding their resin composite restorations depending on the visualization methods was rejected. This is clinically



	Regular mirror	Mirror with magnification	IOS
Score	5	5	5
Reasons for dissatisfaction	A, C, D, E	A,C,D,E	A,C,D,E

	Regular mirror	Mirror with magnification	IOS
Score	1	3	4
Reasons for dissatisfaction	-	A,D	A,D

	Regular mirror	Mirror with magnification	IOS
Score	3	3	4
Reasons for dissatisfaction	D	D	D,E, F,G

	Regular mirror	Mirror with magnification	IOS
Score	2	2	1
Reasons for dissatisfaction	E	E	-

Fig. 4. Examples of restorations included in the study. The image at the right is from the IOS screen and the one at the left is an intraoral photograph that was only used to illustrate the clinical situation, not being a method of visualization in this study. Next to the image, the table shows the score and reasons for dissatisfaction. A: Poor Brightness; B: Presence of Stains; C: Inappropriate Color; D: Inappropriate Contour; E: Presence of Fractures; F: Difficulty Using Dental Floss; G: Presence of Sensitivity; H: Presence of Bleeding.

Table 2
Demographic data of the participants of the study.

Sample	Patient	41
	Restoration	70
Age	Age range	20–52
	Average	27,79
Sex	Women	29
	Men	12
Teeth examined	ICS	10
	ICI	0
	ILS	5
	ILI	0
	CS	0
	CI	0
	PMS	3
	PMI	2
	MS	20
	MI	30

relevant as digital tools and magnification are increasingly being used in the process of examination and communication between dentist and patients.

IOS and mirror with amplification had a prevalence of score 2, which is followed by score 3, while using a regular mirror, score 2 is followed by score 1. This fact may be due to the greater difficulty in observing restorations using a mirror without amplification, which may result in a lower criticism. In this sense, the greater criticism when a method with magnification was compared to a method without magnification one was also identified in a previous study evaluating dental restorations [9]. This aspect was important in the present methodology, as the observation started with the non-magnification method, progressing to magnification, and concluding with the visualization of images generated by the IOS, which offer the greatest magnification potential. The scores 4 and 5, which indicate poor levels of satisfaction with the dental restorations, are low for all methods, which means that patients perceived their restorations mostly as satisfactory. This may be a result of the sample characteristics, once they were not undergoing or seeking restorative treatment; they were invited to be examined and selected if they met the criteria.

There are various types of magnification available in dentistry, such as: microscopes, loupes, digital photography and IOS; they have been widely used, as they provide greater visual acuity [10]. However, some of these methods, such as loupes and microscopes, cannot allow the patient to view their own restorations. In this respect, other methods such as IOS have been increasingly applied to the examination and diagnosis process with the potential to also enhance communication with the patient, who can better understand their intraoral conditions by viewing the images [3]. However, few studies approached the IOS considering the patients' perspective. In literature, Cardoso-Silva et al. [1] evaluated enamel defects by using IOS and direct visual analysis, observing that the extent and severity of the enamel defects were assessed differently. When the IOS and direct visual assessment were compared, the highest scores were when the images observed were from the IOS, corroborating the results of this study. In addition, regarding the use of digital photography in the examination process, Signori et al. [7] compared the assessment of clinical examination and digital photography for the evaluation of dental restorations and found more criticism in the evaluation of dental restoration from the assessment with digital photography.

Regarding the dissatisfaction reported by patients when observing their restorations using different methods of visualization, in this study the authors decided to examine it as encouraged by FDI criteria. Observing the reasons for dissatisfaction and discussing them is relevant because repairing and especially replacing resin composite restorations exclusively due to esthetic reasons must be carefully considered, and the principles of the minimally invasive dentistry must be followed [15]. The prevalence of factors C (inappropriate color) and D (inappropriate contour) highlights the greatest criticism arising from esthetic issues which also corroborates the finding that can vary between professional and layperson, and among laypersons from different countries, according to a multicenter study [13].

When comparing the different methods, there was a change in the absolute frequency of reasons for dissatisfaction with the dental restoration. For IOS, poor brightness (A), presence of stains (B), inappropriate color (C) and inappropriate contour (D) significantly prevail while for mirrors with and without magnification, poor brightness (A) and stain (B) showed significantly lower frequencies. The image resulting from the intraoral scan is larger and allows the patient to manipulate the image by enlarging and rotating it, which consequently enables one to better see the characteristics of the restorations, such as their colors. In this scenario, it would be interesting to understand how IOS can lead to a different perception of brightness and staining. In this study the IOS used was a Primescan (Dentsply Sirona) and the image displayed at the touch screen monitor was visually similar to the one captured with digital photograph Sony Alpha a65 digital camera, (Sony Corporation, Minato, Tokyo, Japan) with a Macro lens of 100 mm F/2.8 equipped with a ring flash. Nevertheless, it can be different for other IOS equipment. From literature, evidence is still scarce; a study regarding dental color [11] and IOS (TRIOS; 3Shape A/S) shows that it is more accurate than visual methods and that color systems present in them can be used as an alternative method of shade selection, not excluding, however, the visual methods [12]. Thus, future studies would contribute to this matter, especially because there are different IOS technologies and brands available in the market and, therefore, the image visualization may differ among them.

Taking the results of this study into consideration, it is possible to state that IOS allowed patients' views regarding their dental restoration with increased criticism, since the image is larger and has very good visual quality. In this context, while IOS and magnification are valuable tools that can enhance diagnosis and communication between professionals and patients, their use must be grounded in a scientifically-based clinical approach and guided by the principles of minimally invasive dentistry. As limitations, it is worth mentioning that the results can be considered only for the IOS used in this work, and that similar and related studies in the field are still scarce, which can restrict the discussion of the results found. Other types of magnification (e.g. loupes) methods were not used, as they cannot easily capture and/or record images to be shown to the patient. For future studies, it would be valuable to compare different IOS and the patients' views, especially regarding color and brightness. Additionally, the use of IOS in the process of exam, diagnosis and patient communication in dentistry can be studied in other fields such as prosthodontics, periodontics and pediatric dentistry.

5. Conclusions

According to the results presented in this study it was possible to conclude that patients' satisfaction with their restorations decreases after viewing images generated by the IOS and using magnifying mirrors, with esthetic dissatisfaction being more pronounced particularly when observing the high-resolution digital images generated by the IOS. The detailed and enlarged views provided by the IOS allowed patients to detect minor discrepancies that might not be noticeable under normal conditions, influencing their perception about their dental conditions.

CRediT authorship contribution statement

Marianna Soares Nogueira Borges: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Gabriela Greghi de Carvalho:** Writing – original draft, Validation, Methodology, Investigation, Data curation, Conceptualization. **Gabriela Ayres de Souza:** Software, Resources, Methodology, Investigation. **Karen Pintado-Palomino:** Software, Methodology, Investigation, Data curation. **Bruna Neves de**

Freitas: Software, Methodology, Investigation, Data curation. **Camila Tirapelli:** Writing – review & editing, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Funding sources

This study was financed by grant 2022/16501-8 from São Paulo Research Foundation (FAPESP) and grant code 001 from Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES).

Patient consent

I confirm that we have received a complete written informed consent from the patient for the publication of this study and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

GLOSSARY

IOS Intraoral scanning.
CAD Computer-aided design.
CAM computer-aided manufacturing.
FDI International dental federation.
2D Two-dimensional.
3D Three-dimensional.

Data availability

Data will be made available on request.

References

[1] L. Cardoso-Silva, F. Vicioni-Marques, F.W.G. de Paula-Silva, B.N. de Freitas, P. Nelson-Filho, C. Tirapelli, F.K. de Carvalho, Comparison between intraoral scanning and direct visual analysis for the assessment of developmental defects of enamel, J. Dent. 137 (2023) 104677, https://doi.org/10.1016/j.jdent.2023.104677.

[2] F. Angelone, A.M. Ponsiglione, C. Ricciardi, G. Cesarelli, M. Sansone, F. Amato, Diagnostic applications of intraoral scanners: a systematic review, J Imaging 9 (2023) 134, https://doi.org/10.3390/jimaging9070134.

[3] N. Schulz-Weidner, M. Gruber, E.M. Schraml, B. Wöstmann, N. Krämer, M.A. Schlenz, Improving the communication of dental findings in pediatric dentistry by using intraoral scans as a visual aid: a randomized clinical trial, Dent. J. 12 (2024) 15, https://doi.org/10.3390/dj12010015.

[4] T. Joda, M. Balmer, R.E. Jung, A. Ioannidis, Clinical use of digital applications for diagnostic and treatment planning in prosthodontics: a scoping review, Clin. Oral Implants Res. 35 (2024) 782–792, https://doi.org/10.1111/clr.14230.

[5] F. Mangano, A. Gandolfi, G. Luongo, S. Logozzo, Intraoral scanners in dentistry: a review of the current literature, BMC Oral Health 17 (2017) 149, https://doi.org/10.1186/s12903-017-0442-x.

[6] R. Siqueira, M. Galli, Z. Chen, G. Mendonça, L. Meirelles, H.L. Wang, H.L. Chan, Intraoral scanning reduces procedure time and improves patient comfort in fixed prosthodontics and implant dentistry: a systematic review, Clin. Oral Invest. 25 (2021) 6517–6531, https://doi.org/10.1007/s00784-021-04157-3.

[7] C. Signori, K. Collares, C.B.F. Cumerlato, M.B. Correa, N.J.M. Opdam, M.S. Cenci, Validation of assessment of intraoral digital photography for evaluation of dental restorations in clinical research, J. Dent. 71 (2018) 54–60, https://doi.org/10.1016/j.jdent.2018.02.001.

[8] Y. Chen, W. Lee, G.A. Ferretti, R.L. Slayton, S. Nelson, Agreement between photographic and clinical examinations in detecting developmental defects of enamel in infants, J. Publ. Health Dent. 73 (2013) 204–209, https://doi.org/10.1111/jphd.12014.

[9] C.V.V.B. de Almeida, K. Pintado-Palomino, J.H.P. Fortes, R.J.G. da Motta, B.N. de Freitas, W. Matsumoto, M.T.M. de Oliveira Cavalcanti, J. Alves, C. Tirapelli, Digital photography vs. clinical assessment of resin composite restorations, Odontology 109 (2021) 184–192, https://doi.org/10.1007/s10266-020-00511-1.

[10] M.G. Bud, O.D. Pop, S. Cîmpean, Benefits of using magnification in dental specialties—a narrative review, Med Pharm Rep 96 (2023) 254–257, https://doi.org/10.15386/mpr-2556.

[11] W.F. Liberato, I.C. Barreto, P.P. Costa, C.C. de Almeida, W. Pimentel, R.A. Tiossi, Comparison between visual, intraoral scanner, and spectrophotometer shade matching: a clinical study, J. Prosthet. Dent 121 (2019) 271–275, https://doi.org/10.1016/j.prosdent.2018.05.004.

[12] A. Czigola, I. Róth, V. Vitai, D. Fehér, P. Hermann, J. Borbély, Comparing the effectiveness of shade measurement by intraoral scanner, digital spectrophotometer, and visual shade assessment, J. Esthetic Restor. Dent. 33 (2021) 1166–1174, https://doi.org/10.1111/jerd.12810.

[13] B.N. Freitas, K. Pintado-Palomino, C.V.V.B. de Almeida, P.B. Cruvinel, A.E. Souza-Gabriel, S.A.M. Corona, S. Geraldeli, B. Grosgogeat, J.F. Roulet, C. Tirapelli, Clinical decision-making in anterior resin composite restorations: a multicenter evaluation, J. Dent. 113 (2021) 103757, https://doi.org/10.1016/j.jdent.2021.103757.

[14] B.N. Freitas, P.O.D. Silva, K. Pintado-Palomino, C.V.V.B. de Almeida, A.E. Souza-Gabriel, S.A.M. Corona, S. Geraldeli, B. Grosgogeat, J.F. Roulet, C. Tirapelli, Patients' satisfaction concerning direct anterior dental restoration, Braz. Dent. J. 34 (2023) 82–93, https://doi.org/10.1590/0103-6440202305260.

[15] F.F. Demarco, K. Collares, F.H. Coelho-de-Souza, M.B. Correa, M.S. Cenci, R.R. Moraes, N.J. Opdam, Anterior composite restorations: a systematic review on long-term survival and reasons for failure, Dent. Mater. 31 (2015) 1214–1224, https://doi.org/10.1016/j.dental.2015.07.005.

[16] M.B. Correa, M.A. Peres, K.G. Peres, B.L. Horta, A.J. Barros, F.F. Demarco, Do socioeconomic determinants affect the quality of posterior dental restorations? A multilevel approach, J. Dent. 41 (2013) 960–967, https://doi.org/10.1016/j.jdent.2013.02.010.

[17] T.J. Heaven, V.V. Gordan, M.S. Litaker, J.L. Fellows, D. Brad Rindal, A.R. Firestone, G.H. Gilbert, Agreement among dentists' restorative treatment planning thresholds for primary occlusal caries, primary proximal caries and existing restorations: findings from the National Dental Practice-Based Research Network, J. Dent. 41 (2013) 718–725, https://doi.org/10.1016/j.jdent.2013.05.014.

[18] R. Hickel, S. Mesinger, N. Opdam, B. Loomans, R. Frankenberger, M. Cadenaro, J. Burgess, A. Peschke, S.D. Heintze, J. Kühnisch, Revised FDI criteria for evaluating direct and indirect dental restorations—recommendations for its clinical use, interpretation, and reporting, Clin. Oral Invest. 27 (2023) 2573–2592, https://doi.org/10.1007/s00784-022-04814-1.

[19] T. Marquillier, S. Doméjean, J. Le Clerc, F. Chemla, K. Gritsch, J.C. Maurin, P. Millet, M. Pérard, B. Grosgogeat, E. Dursun, The use of FDI criteria in clinical trials on direct dental restorations: a scoping review, J. Dent. 68 (2018) 1–9, https://doi.org/10.1016/j.jdent.2017.10.007.

[20] S.J. Lee, F.Z. Jamjoom, T. Le, A. Radics, G.O. Gallucci, A clinical study comparing digital scanning and conventional impression making for implant-supported prostheses: a crossover clinical trial, J. Prosthet. Dent 128 (2022) 42–48, https://doi.org/10.1016/j.prosdent.2020.12.043.

[21] J. Abduo, M. Elseyoufi, Accuracy of intraoral scanners: a systematic review of influencing factors, Eur. J. Prosthodont. Restor. Dent. 26 (2018) 101–121, https://doi.org/10.1922/EJPRD_01752Abduo21.

[22] C. Kunavisarut, W. Jarangkul, S. Pornprasertsuk-Damrongsri, T. Joda, Patient-reported outcome measures (PROMs) comparing digital and conventional workflows for treatment with posterior single-unit implant restorations: a randomized controlled trial, J. Dent. 117 (2022) 103875, https://doi.org/10.1016/j.jdent.2021.103875.

[23] S.B. Patzelt, C. Lamprinos, S. Stampf, W. Att, The time efficiency of intraoral scanners: an in vitro comparative study, J. Am. Dent. Assoc. 145 (2014) 542–551, https://doi.org/10.14219/jada.2014.23.

[24] M. Revilla-León, H.E. Campbell, M.J. Meyer, M. Umorin, A. Sones, A. Zandinejad, Esthetic dental perception comparisons between 2D- and 3D-simulated dental discrepancies, J. Prosthet. Dent 124 (2020) 763–773, https://doi.org/10.1016/j.prosdent.2019.11.015.

[25] M. Revilla-León, M.T. Ashby, M.J. Meyer, M. Umorin, J.J. Barrington, A. Zandinejad, Layperson and dental professional perception when evaluating their own virtually 2D or 3D simulated esthetic discrepancies, J. Prosthodont. 29 (2020) 466–471, https://doi.org/10.1111/jopr.13182.