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ORIGINAL ARTICLE

Comparison of Two Different Intraoral Scanners for Determination of Caries Related Volume Loss in Caries Removal

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ABSTRACT

Objective: The study aimed to compare cavity volume data obtained with two different intraoral scanners. **Methods:** One hundred extracted molar teeth were divided into groups according to ICDAS-II classification, and scanned with Cerec Omnicam (Dentsply Sirona) and iTero Element Flex (Align Technology). The caries-infected tissues were removed regarding either minimally invasive or conventional cavity principles. Samples were scanned again and volumetric data were assessed by Meshmixer 3.5 (Autodesk) 3D modeling software. Statistical evaluations were performed with Mann Whitney U test and Spearman's Correlation test. The significance level was $\alpha=0.05$. **Results:** Although there was a significant difference between obtained initial volume readings of two scanners for 3M and 3C groups ($p < 0.05$), no significant difference was observed among other groups ($p \geq 0.05$). Regarding the comparison of final volume readings of two scanners, a significant difference was found for 5M group ($p = 0.036$), whereas no significant difference was observed for other groups ($p \geq 0.05$). Percentage of volume loss between two scanners was statistically similar ($p \geq 0.05$). **Conclusion:** Data obtained with Cerec Omnicam and iTero Element Flex were compatible with volumetric assessments. Both intraoral scanners may be considered effective for calculating caries-related cavity volumes. Minimally invasive cavity principles may provide less volume loss compared to conventional cavity principles.

Key words: cavity preparation, ICDAS, intraoral scanner, minimally invasive, volume loss

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INTRODUCTION

Tooth decay is a bacterial disease that occurs when the mineral structure of enamel and dentin dissolves by bacterial metabolic acids. Generally, it starts due to the disruption of demineralization and remineralization balance on the tooth surface in favor of demineralization. The demineralization process, which starts at the microscopic level, can progress to cavitation if not intervened.[1] There are many treatment options ranging from remineralization treatment to direct and indirect restorations. It is important to determine the characteristics of the carious lesion, such as size, activity, and stage in terms of treatment planning.[2,3] The inclusion of the tissues surrounding the caries lesion, especially the pits and fissures, into the cavity preparation, known as Black cavity principles was preferred in restorative treatment for many years.[4] Recently, as a result of the developments in the restorative materials and bonding to dental tissue, it is possible to restore teeth with minimal tissue removal. This approach was considered as 'minimally invasive dentistry'.[4] Dental hard tissues are lost due to various mechanisms such as dental caries and acute or chronic trauma. There is a direct relationship between the amount of remaining intact hard tissue and the longevity of the tooth and also the restoration.[3-5] Dentin has the potential of remineralization like the enamel tissue. In terms of the minimally invasive principles, the infected dentin layer reaching the dentin tissue is removed and the affected dentin layer, which has the potential of remineralization, is generally preserved. During the caries removal, it was aimed to protect not only healthy tooth tissue but also the tissues that have remineralization potential.[5]

Diagnostic methods such as radiographic analysis and fluorescent techniques may give the operator an idea about the amount of carious tissue during the examination phase. In addition, the scores of a visual inspection system, the International Caries Detection and Assessment System II (ICDAS II), were reported to be consistent with the histological, microscopic, and radiological stages of the caries, previously.[6,7] Optical coherence tomography (OCT); is another diagnostic method for the diagnosis of oral diseases, that uses near-infrared light (NIR) to display the differences in optical characteristics of teeth and soft tissues with micron-level high-resolution images. The light reflected from the deep layers of the tissue shows a delay compared to the light reflected from the surface. This amount of delay between the lights reflected from the tissues is calculated.[8] The reflected rays are interpreted to produce images that represent the optical reflection of the tissue in the cross-sectional plane. Unlike other methods, OCT combines a very small optical fiber measuring 0.5 mm in diameter with a high-resolution capacity, allowing the object to be imaged at the micrometer level and does not contain ionizing radiation. Optical coherence tomography, with its high spatial resolution, is a reliable alternative to other diagnostic methods.[9,10]

The number and thickness of cavity walls were taken as a reference when evaluating the amount of hard tissue according to the literature, however, it is also possible to determine the loss by using three-dimensional (3D) calculations with recent technological developments.[11] Some of the 3D technologies are based on X-ray-based cross-sectional images such as computed tomography and cone-beam computed tomography. Micro-computed tomography, with thinner radiological sections, provides high-resolution *in vitro* images which are very useful for research.[12] Other dental 3D methods are the CAD-CAM (computer-aided design-computer-aided manufacturing) systems. CAD-CAM systems entered dentistry in the 80s and till then many CAD-CAM systems have been designed by several companies.[13] These systems are based on processing the received data with scanners, with appropriate computer software.[14] Digital impressions are obtained by taking 3D images of teeth and surrounding soft tissues with the scanner, the restorations are digitally designed in the system software, and the virtual restorations are produced by milling or 3D printers.[13] The data obtained with the scanners of CAD-CAM systems can also be used in other software. Meshmixer 3.5 (Autodesk, USA) is an open-source 3D modeling software that can be used for purposes such as 3D dental modeling, prosthesis and implant planning, and post-traumatic surgical modeling.[15-17] CAD-Cam systems vary in their principle to obtain scanned data. Cerec Omnicam (Sirona, Bensheim, Germany) is based on the principle of active triangulation and confocal microscopy. In this scanning system, imaging is performed powder-free with non-polarized white LED light. The disadvantage of the closed system, which it had in the first days of its release, was eliminated by converting the images taken to STL format by up-to-date software.[18] iTero Element Flex (Cadent, Carlstadt, USA) is based on the parallel confocal principle. With 100,000 red light beams produced in a third of a second, digital images are created by a combination of optical and laser imaging techniques. With this system, images can be obtained on the intraoral structures without using any reflective agents such as titanium dioxide powder.[19]

In the present study, intraoral scanners have been preferred to other methods, because they are easily accessible and widely used in dental clinics. Regarding our study, only a limited number of researchers studied the CAD-CAM systems for volumetric calculations.[11] The data obtained with the intraoral scanners were evaluated by transferring them to a related software that may calculate the volume quantitatively.[11] This study aimed to compare the scanning efficiency of two clinical intraoral scanners for the volumetric loss of dental hard tissues following cavity preparation. The h_1 hypothesis of this study was that the volumetric percentage of lost dental tissue obtained by two different intraoral 3D scanners was different.

METHODS

Experimental groups

This study was carried out with the approval of the ethics committee with protocol number 2019-319. One hundred mandibular molar teeth similar in size without hypoplasia, cracks, any periodontal tissue or debris including caries only on occlusal surface, extracted within the last 6 months were kept in 0.1% thymol solution and examined according to the ICDAS II classification. The teeth with ICDAS 0, 3, 4 and 5 scores were included and divided into 4 main groups. The main groups separated according to the ICDAS score were divided into 10 subgroups (N=10). The teeth with ICDAS 0 score were included as the control group. The teeth with ICDAS 1 and 2 scores with no loss of dental substance and the teeth with ICDAS 6 score including excessive loss of dental substance were both excluded from the study. The teeth were embedded in cylindrical cold acrylic blocks with a diameter of 3 cm from 2 mm below the cementoenamel junction (SC Cold Acrylic, Imicryl, Konya, Turkey).

Initial data collection

In order to calculate the quantitative amount of volume loss, all samples were scanned with Cerec Omnicam (Dentsply Sirona, Bensheim, Germany) and iTero Element Flex (Align Technology, CA, USA) intraoral scanners. The initial 3D data were obtained in STL (standard triangle language) format. Before the scanning process, a reference line was created with a diamond bur along the cementoenamel junction.

Cavity preparation
Cavity preparation was performed for ICDAS 3, 4 and 5 groups, except the control groups. Removal of the carious lesion in these groups was performed by using two different principles to evaluate the effect of the 'minimally invasive approach' and the 'conventional approach' on volume loss (Figure 1). Regarding the conventional cavity preparation group (3C, 4C, and 5C), all infected and affected layers of caries were removed. In the minimally invasive cavity preparation group (3M, 4M, and 5M) only the infected layers were removed while the affected layers were left untouched.

Minimally invasive cavity preparation
The infected tissues of the samples were removed using a #14 diamond round bur (Cerabur, Comet, Germany) with a high-speed drill in enamel and a #14 ceramic round bur (Cerabur, Comet, Germany) with a low-speed drill in dentin under water cooling, in terms of the minimally invasive cavity principles. Wherever the ceramic bur stopped removing dental substance, that point was considered as the reference point for termination of cavity preparation. The values of 20 and below measured by the DIAGNOdent Pen (KaVo Dental Corporation, Biberach, Germany) were determined as the limit (initial lesion according to the manufacturer) in the minimally invasive cavity preparation groups. The device was calibrated before each measurement.

Conventional cavity preparation
Infected tissues of the samples were removed using a #14 diamond round bur (Cerabur, Comet, Germany) with a high-speed drill in enamel and a #14 stainless steel round bur (Cerabur, Comet, Germany) with a low-speed drill in dentin under water cooling, in terms of the conventional Black cavity principles. Tissue removal continued until all discolored areas were completely removed till the healthy dentin tissue with yellow color. The values of 10 and below (sound tissue according to the manufacturer) measured with the DIAGNOdent Pen were determined as the limit in the conventional cavity preparation groups. The device was calibrated before each measurement.

Final data collection
After the cavity preparation was completed, the final 3D images of the samples were recorded in STL format for each intraoral scanner.

Volumetric assessment
All recorded STL data were uploaded in Meshmixer 3.5 (Autodesk, USA) 3D modeling software (Figure 2). The volumetric calculations for the data of each scanner were performed on the software by using the initial and final 3D data of each sample. Following the calculations, the volume loss parameters were expressed as percentages.

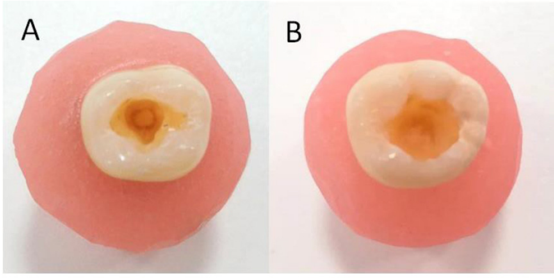

Figure 1. Cavities prepared according to different principles. A. Cavity prepared according to minimally invasive cavity principle B. Cavity prepared according to conventional cavity principle.

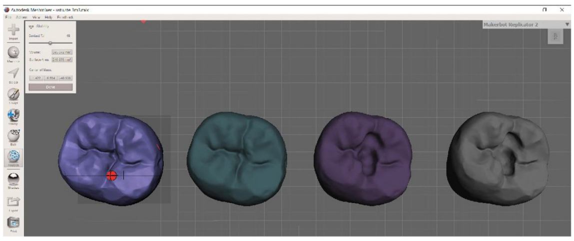

Figure 2. The image of initial and final images taken from the same tooth in the modeling program.

Statistical analysis
The data obtained in this study were analyzed using the Stata 15.1 software. Mann Whitney U test was used to compare two independent groups, in terms of the continuous variables not showing normal distribution. Spearman's Correlation test was used to evaluate the correlation between the two scanners. The significance was set at $p < 0.05$.

RESULTS

Regarding the comparison between the initial volumetric data, a significant difference was found between the scanners ($p = 0.003$). The initial volume values were significantly greater for Cerec Omnicam (401.4 ± 67.35; 393.98 ± 48.72) compared to the Itero Element Flex (399.94 ± 67.04; 392.78 ± 47.90) for the groups 3M ($p = 0.005$) and 3C ($p = 0.028$). There was no significant difference between the scanners for control groups as well as 4M ($p = 0.241$), 4C ($p = 0.284$), 5M ($p = 0.332$) and 5C ($p = 0.96$) (Table 1).

Regarding the comparison between the final volumetric data, a significant difference was also found between the scanners ($p = 0.011$). The final volume values for group 5M were significantly greater for the Cerec Omnicam (336.74 ± 64.34) compared to the Itero Element Flex (335.07 ± 65.16) ($p = 0.036$). No significant difference was observed among the groups 3M ($p = 0.202$), 3C ($p = 0.114$), 4M ($p = 0.646$), 4C ($p = 0.721$) and 5C ($p = 0.169$) (Table 1).

Table 1. Comparison of the two scanners in terms of initial and final volume values, and percentage of volume loss.

Groups	Initial volume values. Mean ± *SD (mm³)*			Final volume values. Mean ± *SD (mm³)*			Percentage of volume loss Mean ± *SD (%)*		
	Cerec Omnicam	iTero Element Flex	p	Cerec Omnicam	iTero Element Flex	p	Cerec Omnicam	iTero Element Flex	p
ICDAS 0 (Intact tooth)	433.62 ± 64.99	434.31 ± 64.91	0.284						
ICDAS 3 Control	409.53 ± 99.48	409.52 ± 99.26	0.8785						
3M	401.4 ± 67.35	399.94 ± 67.04	0.005	392.16 ± 65.23	391.58 ± 65.07	0.202	2.42 ± 0.84	2.07 ± 0.83	0.074
3C	393.98 ± 48.72	392.78 ± 47.90	0.0284	368.39 ± 56.20	367.72 ± 55.59	0.1141	6.72 ± 4.91	6.60 ± 4.98	0.2845
ICDAS 4 Control	390.31 ± 44.21	390.09 ± 44.35	0.2411						
4M	431.50 ± 42.61	430.42 ± 41.92	0.241	396.13 ± 54.89	396.08 ± 54.65	0.646	8.47 ± 5.52	8.26 ± 5.40	0.386
4 C	392.74 ± 71.64	392.36 ± 72.08	0.2845	334.73 ± 86.10	335.08 ± 86.97	0.7213	15.86 ± 7.91	15.72 ± 8.02	0.7989
ICDAS 5 Control	425.66 ± 61.36	425.56 ± 61.21	0.7213						
5M	422.40 ± 72.80	421.92 ± 73.67	0.332	336.74 ± 64.34	335.07 ± 65.16	0.036	20.15 ± 8.89	20.44 ± 9.25	0.092
5C	407.54 ± 76.43	407.34 ± 75.97	0.9594	307.31 ± 88.17	306.16 ± 88.91	0.1688	25.36 ± 10.93	25.67 ± 10.87	0.1688
p			0.003			**0.011**			0.757

The statistical comparisons between the experimental groups for the percentages of volumetric loss of the lost dental tissues after cavity preparation are presented in Table 1. The least volume loss was observed in group 3M, while the highest volume loss was observed in group 5C. There was no significant difference between the scanners in terms of percentage of volume loss (p = 0.757).

When the groups were compared regarding the volume loss, cavities prepared with the minimally invasive principle presented lower percent than those prepared with the conventional principle (3M (2.42 ± 0.84; 2.07 ± 0.83) <3C (6.72 ± 4,91; 6.60 ± 4.98) <4M (8.47 ± 5.52; 8.26 ± 5.40) <4C (15.86 ± 7.91; 15.72 ± 8.02) <5M (20.15 ± 8.89; 20.44 ± 9.25) <5C (25.36 ± 10.93; 25.67 ± 10.87)) (Table 1). When groups were compared in terms of volume loss according to the data of both scanners (Cerec Omnicam; iTero Element Flex) significant differences were found between 3M and 3C (p = 0.001; p = 0.000), as well as 4M and 4C (p = 0.015; p = 0.015). When comparing groups 5M and 5C, no statistically significant difference was found between the two scanners, regarding the cavity preparation principles comparisons through the volume loss (p = 0.226; p = 0.289) (Table 2).

Table 2. Comparison of the cavity preparation types in terms of volume loss according to ICDAS scores.

Groups	Cerec Omnicam p	iTero Element Flex p
3M-3C	0.0015	0.0009
4M-4C	0.0156	0.0156
5M-5C	0.2265	0.2899

M: Minimal invasive cavity preparation group, C: Conventional cavity preparation group.

The mean volume loss values obtained from Cerec Omnicam were 4.57 ± 4.07 % in groups 3M and 3C, 12.17 ± 7.6 % in groups 4M and 4C; and 22.76 ± 10.06 % in groups 5M and 5C.

The mean volume loss values obtained from iTero were 4.34 ± 4.18 % in the groups 3M and 3C, 11.99 ± 7.68 % in the groups 4M and 4C; and 23.06 ± 10.19 % in the groups 5M and 5C.

The correlation between the two scanners was evaluated using Spearman's rank correlation coefficients (rho). Positive correlations were found for both the initial and final measurements (rho = 0.9962 and rho = 0.9956, respectively).

DISCUSSION

In the present study, two intraoral scanners by different companies were compared through the obtained data of volumetric tissue loss before and after the cavity preparation. According to the results, the collected volumetric percentages of the lost dental tissues were similar among the measurements of the two scanners. Therefore, the (h_1) hypothesis of the study was rejected. Positive correlations were found between the two observed scanners for both the initial and the final measurements.

The effective factors for accuracy and repeatability of the scanning may vary.[20,21] Technical features such as the scanning strategy of the device, computer software, the combination of the images in the software, and the software's ability y to remove the artifacts were considered effective factors related to the scanner.[22-24] The scanning strategy of the operator, scanning distance, and also angulation were considered effective factors related to the operator.[25,26] In the present study, the samples were scanned from 2 mm distances, starting with the buccal surface and following with the occlusal and lingual surfaces. Each scan lasted 15 seconds. The 3D images of the samples were recorded in STL format and the STL data were uploaded in Meshmixer 3.5 (Autodesk, USA) 3D modeling software.

There are previous studies stating that the digital impressions obtained with intraoral scanners reflect dental structures more accurately compared to the traditional impressions.[27-29] Renne *et al.* compared 7 different intraoral scanners (3Shape D800, iTero, 3Shape TRIOS 3, Carestream 3500, Planscan, CEREC Omnicam, and CEREC Bluecam) *in vitro* and reported that the scanners differ in terms of accuracy, reproducibility, and the time required for a full scan.[30] Kim *et al.* compared the reliability and precision of 9 different intraoral scanners (CEREC Omnicam, Carestream 3500, FastScan, E4D Dentist, iTero, PlanScan, TRIOS - 2nd generation, True Definition, Zfx IntraScan) and reported that the scanners differed in terms of repeatability during the scan on flat/indent protrusion surfaces, sharp edges, and corners.[31] Consistent with this repost, Rudolph *et al.* considered tooth shape, curvature, and inclination are the dominant factors determining the precision of the digital dental images obtained by the intraoral scanners.[32] Mangano et al. compared 12 different intraoral scanners (iTero Elements 5D, Primescan, Omnicam, CS 3700, CS 3600, TRIOS 3, I-500, Emerald S, Emerald, Virtuo Vivo, Dwio, Runeyes Quickscan) and found different levels of trueness among the intraoral scanners. Superior results were obtained by iTero Elements 5D (mean error 31.4 μm) than Omnicam (mean error 79.6 μm) with the mesh/mesh method.[21]

Minimally invasive dentistry has certain approaches such as prevention of caries, early diagnosis, remineralization of initial lesions, and minimal tissue loss during the cavity preparation.[4,33] In terms of amalgam restorations, the principles of Black cavities based on the retention and expansion for protection, have been replaced by contemporary cavity preparations with less tissue loss as a result of the development of adhesive materials. The minimally invasive approach also limits the size of the cavity with caries lesions and avoids unnecessary widening, and deepening of the cavity to minimize the loss of the dental hard tissue.[34] In this study, the volume loss of the teeth was compared, following the minimally invasive and the conventional cavity preparations, in terms of the ICDAS scores.

Laser fluorescence (DIAGNOdent Pen) measurements are a common and valid method used in recent years to determine the border point of carious tissue removal.[35] Compared to caries detection dyes, DIAGNOdent was found to be more successful in detecting affected dentinal caries.[36] In order to determine the caries-affected dentin border by laser fluorescence method, different measurement values are taken as basis in the literature. There are studies stating that values of 30 and below are dentin caries that do not require intervention.[35,37] Yonemoto *et al.*, on the other hand, evaluated samples with DIAGNOdent measurements of 21-30, 11-20, <10 in their study, and stated that the affected dentin layer was not damaged at values between 11-20.[38] In many studies in the literature, laser fluorescence measurement values of 20 and below have been accepted as the cut-off point for affected dentin.[39,40]

In this study, it was aimed not to remove the affected dentin layer in the minimally invasive cavity preparation groups. In these groups, diamond bur was used in enamel and ceramic bur in dentin with rotary instruments to remove caries. Laser fluorescence (DIAGNOdent Pen) measurement was made at the point where the ceramic bur stopped moving. Values of 20 or less measured in the center of the lesion were accepted as the cavity limit and the preparation was terminated. In the traditional cavity preparation groups, a diamond round bur was used in enamel and a steel round bur in dentin. Tissue removal was continued until healthy dentin tissue was achieved in terms of color and hardness. Confirmation was made when the DIAGNOdent measurements for the post-preparation control were less than 10.

According to the results regarding the cavity preparation principles and the volume loss in this study, it was observed that the minimally invasive cavity preparation caused less volume loss, therefore protecting the dental tissues more than the conventional preparation type for all the experimented groups. While the difference in volume loss between the two cavity principles was also significant for groups 3M-3C and 4M-4C, including the small and medium-sized cavities. But, the difference in volume loss between the two cavity principles was not significant for 5M-5C groups, including the cavities with 20-25% of volume loss (Table 2).

In the present study, two different intraoral scanners were compared in terms of the volume difference of the 3D data obtained. For most of the groups, the calculated values in mm^3 did not differ between the scanners. Hack and Patzelt, compared 6 different intraoral scanners including Cerec Omnicam and iTero Elements 2 and reported that there was a significant difference between the reliability and reproducibility parameters of Cerec Omnicam and iTero Element devices. They stated that iTero Element showed better results than Cerec Omnicam regarding the trueness measurements between the reference dataset and the intraoral scanner datasets (9.8 ± 2.5 µm; 45.2 ± 17.1 µm) and precision values (7.0 ± 1.4 µm; 16.2 ± 4.0 µm).[41] Yanıkoğlu *et al.* removed caries minimally invasively *in vitro* and assessed the volumetric differences for the data of the Cerec Omnicam scanner. The volume loss was considered 12% for the ICDAS 3, 14% for the ICDAS 4, and 30% for the ICDAS 5.[11] These values are much higher than the volumetric loss calculated in our study (Table 1). This controversial result might be because the groups were composed of teeth with caries only on the occlusal surfaces to provide standardization. In addition, the use of caries detector dye to determine the affected dentin border in the research of Yanıkoğlu *et al.* might have caused a difference in the volume loss. Moreover, while evaluating the volume loss following the cavity preparation, no statistical difference was found between Cerec Omnicam and iTero Element Flex scanners, in terms of the percentage loss of volume, incompatible with the previously mentioned observed positive correlation ($p = 0.757$) (Table 1).

CBCT is specifically designed to produce three-dimensional images of maxillofacial bone structures, teeth, and surrounding tissues. It is based on the principle of obtaining a three-dimensional image by combining cross-sectional images taken by ionizing radiation. An ideal image can be obtained with a significantly lower dose compared to conventional medical computed tomography (CT).[42] In today's dentistry, three-dimensional imaging technologies are frequently used in both clinical and academic studies and are becoming increasingly common. Some of these technologies rely on X-ray-based cross-sectional images such as computed tomography and cone-beam computed tomography. Micro-computed tomography, on the other hand, is an in vitro imaging technique that has begun to be widely used in research, with much thinner radiological sections and high-resolution images.[12] Other three-dimensional image acquisition methods are based on processing the data taken with three-dimensional scanners in appropriate computer programs.[23] There are studies comparing digital impressions taken with intraoral scanners with conventional silicone impressions. Ender and Mehl reported that digital impressions had similar accuracy and validity with traditional impressions in their study in which they compared two intraoral scanners and conventional impression methods on all arch impressions.[43]

Using the data obtained by micro-CT, three-dimensional images can be created with the help of computer programs, and detailed examinations and calculations can be made in the desired regions. This process is called 3D (3D) reconstruction.[44] There are many studies in which it is used to evaluate the amount of tissue removed during caries removal in restorative dental treatment.[45,46] Although micro CT offers advantages such as calculating the mineral density and calculating the amount of removed enamel and dentin, considering the disadvantages such as the fact that these devices are not as easy to access as scanners and that they contain ionizing radiation, scanners are more easily accessible in studies related to caries removal to measure volume loss.

CONCLUSION

Within the limitations of this in vitro study, iTero Element Flex and Cerec Omnicam intraoral scanners presented a similar efficiency for the quantitative assessment of caries-related percent loss of volume. This result indicates that intraoral scanners of clinical CAD-CAM systems may be useful for quantitative volumetric calculations during cavity preparation. The ICDAS II scores were positively correlated with the percent loss of volume values. The minimally invasive cavity principles may provide less volume loss than the conventional cavity principles. Significant differences were found in volume loss between the minimally invasive and conventional cavity groups when comparing groups 3M-3C ($p < 0.05$) and 4M-4C ($p < 0.05$), while no difference was observed for 5M-5C ($p > 0.05$). This result might be useful for the direct-indirect restoration decision-making and for the related material selection, during the clinical treatment planning.

CLINICAL SIGNIFICANCE

Intraoral scanners, which are widely used systems in the clinic, can be used for different purposes, such as caries diagnosis, color measurement, and 3D impression.

CONFLICT OF INTEREST

The manuscript has been read and approved by all the authors. No potential conflict of interest was reported by any of the authors in this study.

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REFERENCES

1. Featherstone JD. Dental caries: A dynamic disease process. Aust Dent J. 2008; 53(3):286-91.
2. Zero DT, Fontana M, Martínez-Mier EA, Ferreira-Zandoná A, Ando M, González-Cabezas C, Bayne S. The biology, prevention, diagnosis and treatment of dental caries: Scientific advances in the United States. J Am Dent Assoc. 2009; 140 Suppl 1:25S-34S.
3. Hickel R, Manhart J. Longevity of restorations in posterior teeth and reasons for failure. J Adhes Dent. 2001; 3(1):45-64.
4. Tuncer S, Demirci M, Tekçe N. Minimally invasive dentistry concept, approach and strategy. Turkiye Klinikleri J Dent Sci Spec Top. 2014; 5(3):1-11.
5. Featherstone JD, Doméjean S. Minimal intervention dentistry: part 1. From 'compulsive' restorative dentistry to rational therapeutic strategies. Br Dent J. 2012; 213(9):441-5.
6. Jablonski-Momeni A, Stachniss V, Ricketts D, Heinzel-Gutenbrunner M, Pieper K. Reproducibility and accuracy of the ICDAS-II for detection of occlusal caries in vitro. Caries Res. 2008; 42(2):79-87.
7. Diniz MB, Lima LM, Eckert G, Zandona AF, Cordeiro RC, Pinto LS. In vitro evaluation of ICDAS and radiographic examination of occlusal surfaces and their association with treatment decisions. Oper Dent. 2011; 36(2):133-42.
8. Mumcuoğlu T, Erdurman FC, Durukan AH. Principles and novel clinical applications of optical coherence tomography. Turk J Ophthalmol. 2008; 38(2):168-75.
9. Hsieh YS, Ho YC, Lee SY, Chuang CC, Tsai JC, Lin KF, Sun CW. Dental optical coherence tomography. Sensors (Basel). 2013; 13(7):8928-49.
10. Shimada Y, Sadr A, Sumi Y, Tagami J. Application of optical coherence tomography (OCT) for diagnosis of caries, cracks, and defects of restorations. Curr Oral Health Rep. 2015; 2(2):73-80.
11. Yanikoglu F, Korkut B, Celik Z, Cetinbay C, Erkan K, Kocaman A, Tagtekin D. Volumetric tissue loss of carious teeth scored with ICDAS II. Int J Sci Res. 2018; 7(4):69-72.
12. Shahid F, Alam M, Khamis MF. Application of micro-CT in various discipline of clinical and research dentistry. Int J Pharma Bio Sci. 2015; 6(3):1194-206.
13. Liu PR. A panorama of dental CAD/CAM restorative systems. Compend Contin Educ Dent. 2005; 26(7):507-8.
14. Vandenberghe B. The digital patient - Imaging science in dentistry. J Dent. 2018; 74 Suppl 1:S21-6.
15. Goodacre BJ, Swamidass RS, Lozada J, Al-Ardah A, Sahl E. A 3D-printed guide for lateral approach sinus grafting: A dental technique. J Prosthet Dent. 2018; 119(6):897-901.
16. Reymus M, Fotiadou C, Hickel R, Diegritz C. 3D-printed model for hands-on training in dental traumatology. Int Endod J. 2018; 51(11):1313-9.
17. Moser N, Santander P, Quast A. From 3D imaging to 3D printing in dentistry-a practical guide. Int J Comput Dent. 2018; 21(4):345-56.
18. Imburgia M, Logozzo S, Hauschild U, Veronesi G, Mangano C, Mangano FG. Accuracy of four intraoral scanners in oral implantology: A comparative in vitro study. BMC Oral Health. 2017; 17(1):92.
19. Çağlar İ, Duymuş ZY, Sabit A. Contemporary approaches to dental impression systems: Digital impression. J Dent Fac Ataturk Univ. 2015; 25(10):135-140.
20. Mizumoto RM, Yilmaz B. Intraoral scan bodies in implant dentistry: A systematic review. J Prosthet Dent. 2018; 120(3):343-52.
21. Mangano FG, Veronesi G, Hauschild U, Mijiritsky E, Mangano C. Trueness and precision of four intraoral scanners in oral implantology: A comparative in vitro study. PLoS One. 2016; 11(9):e0163107.
22. Ender A, Mehl A. Influence of scanning strategies on the accuracy of digital intraoral scanning systems. Int J Comput Dent. 2013; 16(1):11-21.
23. Zimmermann M, Mehl A, Mörmann WH, Reich S. Intraoral scanning systems - A current overview. Int J Comput Dent. 2015; 18(2):101-29.
24. Ciocca L, Meneghello R, Monaco C, Savio G, Scheda L, Gatto MR, Baldissara P. In vitro assessment of the accuracy of digital impressions prepared using a single system for full-arch restorations on implants. Int J Comput Assist Radiol Surg. 2018; 13(7):1097-108.
25. Flügge TV, Schlager S, Nelson K, Nahles S, Metzger MC. Precision of intraoral digital dental impressions with iTero and extraoral digitization with the iTero and a model scanner. Am J Orthod Dentofacial Orthop. 2013; 144(3):471-8.
26. Ender A, Zimmermann M, Mehl A. Accuracy of complete- and partial-arch impressions of actual intraoral scanning systems in vitro. Int J Comput Dent. 2019; 22(1):11-9.
27. Ender A, Attin T, Mehl A. In vivo precision of conventional and digital methods of obtaining complete-arch dental impressions. J Prosthet Dent. 2016; 115(3):313-20.
28. Ahlholm P, Sipilä K, Vallittu P, Jakonen M, Kotiranta U. Digital versus conventional impressions in fixed prosthodontics: A review. J Prosthodont. 2018; 27(1):35-41.
29. Albdour EA, Shaheen E, Vranckx M, Mangano FG, Politis C, Jacobs R. A novel in vivo method

to evaluate trueness of digital impressions. BMC Oral Health. 2018; 18(1):117.
30. Renne W, Ludlow M, Fryml J, Schurch Z, Mennito A, Kessler R, Lauer A. Evaluation of the accuracy of 7 digital scanners: An in vitro analysis based on 3-dimensional comparisons. J Prosthet Dent. 2017; 118(1):36-42.
31. Kim RJ, Park JM, Shim JS. Accuracy of 9 intraoral scanners for complete-arch image acquisition: A qualitative and quantitative evaluation. J Prosthet Dent. 2018; 120(6):895-903.e1.
32. Rudolph H, Luthardt RG, Walter MH. Computer-aided analysis of the influence of digitizing and surfacing on the accuracy in dental CAD/CAM technology. Comput Biol Med. 2007; 37(5):579-87.
33. Ericson D. What is minimally invasive dentistry? Oral Health Prev Dent. 2004; 2 Suppl 1:287-92.
34. Peters MC, McLean ME. Minimally invasive operative care. I. Minimal intervention and concepts for minimally invasive cavity preparations. J Adhes Dent. 2001; 3(1):7-16.
35. Unlu N, Ermis RB, Sener S, Kucukyilmaz E, Cetin AR. An in vitro comparison of different diagnostic methods in detection of residual dentinal caries. Int J Dent. 2010; 2010:864935.
36. Iwami Y, Shimizu A, Narimatsu M, Hayashi M, Takeshige F, Ebisu S. Relationship between bacterial infection and evaluation using a laser fluorescence device, DIAGNOdent. Eur J Oral Sci. 2004; 112(5):419-23.
37. Lussi A, Hibst R, Paulus R. DIAGNOdent: an optical method for caries detection. J Dent Res. 2004; 83 Spec No C:C80-3.
38. Yonemoto K, Eguro T, Maeda T, Tanaka H. Application of DIAGNOdent as a guide for removing carious dentin with Er:YAG laser. J Dent. 2006; 34(4):269-76.
39. Sirin Karaarslan E, Yildiz E, Cebe MA, Yegin Z, Ozturk B. Evaluation of micro-tensile bond strength of caries-affected human dentine after three different caries removal techniques. J Dent. 2012; 40(10):793-801.
40. Cebe MA, Ozturk B, Sirin Karaarslan E. Effect of caries removal techniques on bond strength to caries affected dentin on gingival wall: AFM observation of dentinal surface. J Adhes Sci Technol. 2016; 30(2):157-170.
41. Hack GD, Patzelt S. Evaluation of the accuracy of six intraoral scanning devices: An in-vitro investigation. ADA Prof Prod Rev. 2015; 10(4):1-5.
42. European Society of Endodontology; Patel S, Durack C, Abella F, Roig M, Shemesh H, Lambrechts P, Lemberg K. European Society of Endodontology position statement: the use of CBCT in endodontics. Int Endod J. 2014; 47(6):502-4.
43. Ender A, Mehl A. Full arch scans: Conventional versus digital impressions--an in-vitro study. Int J Comput Dent. 2011; 14(1):11-21.
44. Kurt MH, Orhan K. Micro-computed tomography in dentistry. Turkiye Klinikleri J Oral Maxillofac Radiol Spec Top. 2016; 2(1):14-21.
45. Ferraz C, Freire AR, Mendonça JS, Fernandes CA, Cardona JC, Yamauti M. Effectiveness of different mechanical methods on dentin caries removal: Micro-CT and digital image evaluation. Oper Dent. 2015; 40(3):263-70.
46. Neves AA, Lourenço RA, Alves HD, Lopes RT, Primo LG. Caries-removal effectiveness of a papain-based chemo-mechanical agent: A quantitative micro-CT study. Scanning. 2015; 37(4):258-64.

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