EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 69, 2273:2280, July, 2023

Print ISSN 0070-9484 • Online ISSN 2090-2360

EDJ EGYPTIAN DENTAL JOURNAL

Conservative Dentistry and Endodontics

Submit Date : 24-02-2023 • Accept Date : 29-05-2023 • Available online: 10-07-2023 • DOI : 10.21608/EDJ.2023.195798.2459

THE EFFECT OF DIFFERENT SCANNING SYSTEMS ON MARGINAL AND INTERNAL ADAPTATION OF INDIRECT RESTORATIONS

Emad Abdelfatah Aboalazm* *and* Nasser Hussein Ali**

ABSTRACT

Aim: This study aimed to compare the efficacy, of 4 different intra-oral scanners and a conventional impression technique, to produce marginal and internal adaptation of indirect restorations.

Materials and Method: A total of 25 lower right acrylic second molar models were selected for the preparation of standardized MOD inlay cavities. Prepared acrylic molar models were divided into 5 groups according to digital or conventional impression used: Group I: CEREC Primescan, Group II: Medit i700, Group III: Smart scan 3D version 2, Group IV: Aoralscan 3, Group V: Flexceed additional silicone impression. Inlay restorations were milled from E-max blocks. Inlays were cemented in corresponding cavities using self-adhesive resin cement (Panavia SA). The restored teeth models were cut in buccolingual and mesiodistal directions. Measurement of the gap at buccal, lingual, and pulpal tooth-restoration interfaces was performed using a stereo microscope. Image analysis software was used to assess internal adaptation. Results were obtained and statistically analyzed.

Results: Group I had significantly the least average gap ($39.17 \pm 2.08\ \mu m$), followed by Group II ($43.82 \pm 1.82\ \mu m$) which was insignificantly different from Group V ($46.92 \pm 2.77\ \mu m$). Group IV had a significantly wider gap ($55.66 \pm 2.99\ \mu m$) than Group V, while Group III had a significantly wider gap ($60.21 \pm 1.66\ \mu m$) than all the other groups.

Conclusion: Primescan is the most efficient system, while Smart scan 3D version 2 is the least accurate system.

KEYWORDS: Intra-oral scanner, marginal gap, internal fit

* Associate Professor, Conservative Dentistry Department, Faculty of Oral and Dental Medicine, Egyptian Russian University

** Associate Professor, Fixed Prosthodontics Department, Faculty of Oral and Dental Medicine, Modern University for Technology and Informations (MTI)

INTRODUCTION

Marginal adaptation, biocompatibility, good esthetics, and sufficient mechanical strength are the main requirements for successful dental restorations.[1] Inadequate marginal accuracy can result in plaque accumulation and subject the abutment teeth to a high risk of caries.[2-5]

Although direct restorations have shown superior restoration integrity, indirect restorations are usually superior in strength, and precision of fabrication, and allow for a wider variety in the choice of material. Investigations in long-term studies detect no significantly lower failure rates of ceramic [6] or composite [7] inlays compared to direct composite restorations.

Moreover, the increased awareness of benefits of conservation of tooth structure in modern societies has led to the increased popularity of the inlay-retained fixed dental prosthesis (IRFDP) for the replacement of missing posterior teeth.[8]

Adequate marginal and internal adaptation of dental restorations requires an accurate impression of the prepared abutment teeth. Even though the entire procedure is performed meticulously, a restoration will theoretically never fit perfectly to the preparation margin. Microscopical gaps of a few microns between the restoration and the tooth will always be present. Marginal gaps ranging from 25 to 40 µm were considered proper by the ADA No. 8.9. Previous studies revealed that when the gap between the tooth and restoration exceeds 120 μm, should be unaccepted.[9-14]

The benefits of using digital intraoral scanners compared to traditional impressions include; better accuracy, reduced chair time, improved patient comfort, enhanced communication, increased flexibility, and enhanced visualization. Different models of Intra-oral scanners are provided with a variety of options including; scanning speed, scanning flow, scanner size, various ease of use, and have a wide range of prices**.** [15]

This study aimed to compare the marginal and internal accuracy of inlay restorations obtained with 4 different intra-oral scanners and a conventional elastomeric impression technique. The first null hypotheses tested in the current study was that there would be no differences in marginal and internal adaptation of inlay restorations, obtained with different intraoral scanners. The second null hypothesis was that convectional elastomeric impression technique would be less accurate than intraoral scanners.

MATERIALS AND METHODS

Ethical approval: This in vitro study was approved by the Research Ethics Committee (REC), Faculty of Dentistry, Ain Shams University number (FDASU-Rec ER 022331).

Sample size calculation: According to a previous study by Çise Özal et al, 2021[16] (as reference), sample size calculation was done. According to this study, the accepted sample size was 5 per group, when the response of each subject group had a normal distribution with a standard deviation of 19.2, the estimated mean difference was 40 when the power was 80% & type I error probability was 0.05. PS Power 3.1.6 was used to calculate the sample size.

A total of 25 acrylic models of lower right second molars (Nissin dental model, Japan) were selected for the preparation of standardized MOD inlay cavities. Medium coarseness blue labeled tapered diamond stones with flat ends (TF -12 Mani Japan) were used with a high-speed handpiece mounted in a paralleling device (NOUVAG AF30 milling machine, Switzerland). Preparation design was made following the guidelines for ceramic inlay preparation as described in Table 1. [17,18]

TABLE (1) Preparation parameters:

Cavity depth	2mm +/- 0.2
Degree of taper of buccal lingual and axial walls	10-12 degrees
Isthmus portion width	2 mm
Internal line angles	Rounded
Cavo-surface angles	90 degrees

Prepared models were divided into 5 groups (n=5) according to the type of scanner or impression used for data capturing into the following:

Group I: CEREC Primescan (Dentsply, Sirona. USA)

Group II: Medit i700 (MEDIT corporation, Seoul, Republic of Korea)

Group III: Smart scan 3D version 2 (Runyes Medical Instrument Co., Ningbo, China)

Group IV: Aoralscan 3 (SHINING 3D Tech Co., Ltd Zhejiang, China)

Group V: Flexceed additional silicone (GC Japan

For group V; the impressions were poured with type IV dental stone (Elite Dental Stones Zhermack, Italy), then the stone cast models have scanned with a lab extraoral scanner (DOF Edge 3 Dental scanner Seoul, Korea).

The scanned images were manipulated with the corresponding software for each system and inlay restorations were milled from E-max CAD blocks (Ivoclar Vivadent) using a milling machine (Cori Tech 350i 5-axis, Germany).

The internal surfaces of restorations were cleaned with air-water spray, air-dried, treated for 60 seconds with 4% buffered hydrofluoric etchant acid (Porcelain etchant, Bisco, Inc., Schaumburg, IL), washed by air-water spray for 1 minute and air dried. After that, silane coupling agent (Monobond plus, Ivoclar Vivadent) was applied on the fitting surfaces of the restorations for 1 minute using a micro-brush and then air dried. Each restoration was cemented in its corresponding cavity using self-adhesive resin cement (Panavia SA cement universal). Materials used and their composition are shown in Table 2.

During cementation, the prepared acrylic teeth models were held vertically in the lower compartment of the universal testing machine and immediately after the seating of the restoration by finger pressure, a 3 Kg load was applied at the central fossa of the restoration by a special rod attached to the upper compartment of the universal testing machine (Instron model 3345 England) and the load was kept till hardening of the cement.

The restored teeth models were embedded in a slow-curing transparent epoxy resin (Kemapoxy, 150 RGL Egypt) with the aid of a pre-constructed silicon mold, [19] and the assemblies were fixed in the vice of the low-speed precision diamond saw (Isomet 4000 Buehler USA) by the tightening screws to standardize the sectioning site, two perpendicular cuts, for each restored tooth model, as shown in fig (1) in buccolingual and mesiodistal axes were made by the device diamond disk (Isomet blade 10LC, 0.3mm thickness) under water cooling.

Restoration/cavity interfacial gap was assessed at buccal, lingual, and pulpal walls at 4 equally distant points for each wall [20], using a stereo microscope (MA 100 Nikon Japan at magnification 70 X). Image analysis software (Ominmet Buehler USA) was used to assess internal adaptation.

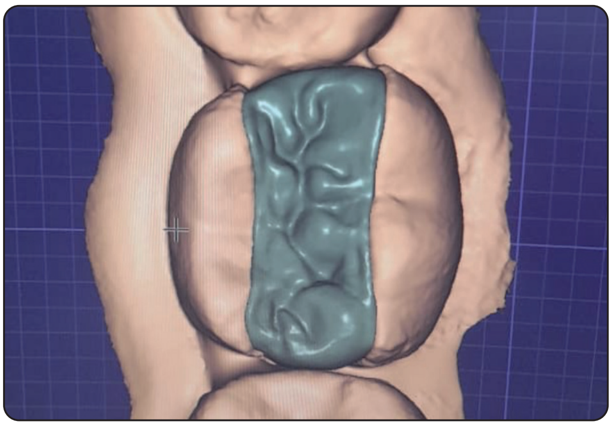

Fig. (1) Location of buccolingual and mesiodistal cuts

TABLE (2) Showing materials used and their composition

Trade name	Scientific name	Composition	Company	Bach no.
IPS e.max CAD	Lithium disilicate glass-ceramic CAD/CAM blocks.	>57% SiO2, Li2O, K2O, P2O5, ZrO2, ZnO, Al2O3, MgO, pigments.	Ivoclar Vivadent, Schaan, Liechtenstein.	R51558
IPS ceramic etchant gel	Ceramic etching gel	5% hydrofluoric acid, water, thickener, surfactant	Ivoclar Vivadent, Schaan, Liechtenstein.	V37045
Monobond plus	Silane coupling agent	Silane methacrylate, phosphoric methacrylate, and sulfide methacrylate.	Ivoclar Vivadent, Schaan, Liechtenstein.	
Panavia SA cement universal	Self-adhesive resin cement	Paste A: Monomer (10-MDP,Bis-GMA, TEGDMA, HEMA, another methacrylate monomer), filler (silanated barium glass filler, silanated colloidal silica), initiator, pigment, others Paste B: Methacrylate monomer, filler (silanated barium glass filler, aluminum oxide, silanated sodium fluoride), accelerator, pigment, silane coupling agent, others	Kuraray Noritake Dental	A80067

*Abbreviations**: Bis-GMA: bis-phenol A di glycidylmethacrylate. UDMA: urethane dimethacrylate, TEGDMA: tri ethylene glycol dimethacrylate, Bis-EMA: Ethoxylated bisphenol-A dimethacrylate HEMA: hydroxyl ethyl methacrylate, CQ: camphorquinone.***

Statistical analysis was done using SPSS 16 (Statistical Package for Scientific Studies). Analysis of the given data was done using the Shapiro-Wilk test and the Kolmogorov-Smirnov test for normality. This revealed that data were obtained from nonparametric data. Comparing different intervals was done by using One Way ANOVA test followed by Tukey's Post Hoc test.

RESULTS

Comparison of the obtained measurements of the tooth-restoration gap between different groups was done using One Way ANOVA test (Table 3) (Fig. 2, 3) the differences were considered significant at P<0.05. This was followed by Tukey`s Post Hoc test for multiple comparisons. Statistical analysis revealed that:

The gap at the buccal margin

Group I had a significantly lower marginal gap (35.7±6.66μm) than all other Groups, followed by Group II (44.57±4.41μm) and Group V (50.73±7.09μm) with insignificant difference between them, while Group III (61.15±4.72μm) scored the highest marginal gap but was not significantly higher than Group IV (53.75±4.47μm).

The gap at the buccal wall

Group, I scored the lowest gap at the buccal wall (43.79±3.01 μm) which was not significantly higher than Group II (45.64±3.65 μm) and Group V (49.59±5.04 μm). Group IV had a significantly higher gap (57.38±6.28μm) than Group I and II but insignificantly higher than Group V (49.59±5.04μm). Group III scored a significantly higher gaps (61.6±3.56μm) than all the other groups except for Group IV which was not significantly lower than group III.

The gap at the lingual margin

Group, I had the lowest marginal gap (37.91±5.19μm) which was not significantly lower than group II (43.03 ± 4.67 μm) and Group V (42.36 ± 2.02 μm). Group III had significantly

TABLE (3) Mean and standard deviation of all surfaces of all groups. Also, a comparison between all groups was done by using One Way ANOVA test:

Group	Buccal				Lingual				floor		Average gap	
	Margin		Wall		Margin		Wall					
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Group I	35.70 ^{a}	6.66	43.79 ^{a}	3.01	37.91 ^{a}	5.19	39.14 ^{a}	2.01	39.33 ^{a}	2.55	39.17 ^{a}	2.08
Group II	44.57 ^{b}	4.41	45.64 ^{a}	3.65	43.03 ^{a}	4.67	43.37 ^{ab}	3.57	42.47 ^{ab}	1.88	43.82 ^{b}	1.82
Group III	61.15 ^{c}	4.72	61.60 ^{c}	3.56	61.49 ^{b}	6.57	60.54 ^{c}	2.80	56.27 ^{c}	2.01	60.21 ^{d}	1.66
Group IV	53.75 ^{c}	4.47	57.38 ^{bc}	6.28	58.12 ^{b}	4.71	55.57 ^{c}	6.53	53.49 ^{c}	2.28	55.66 ^{c}	2.99
Group V	50.73 ^{bc}	7.09	49.59 ^{ab}	5.04	42.36 ^{a}	2.20	47.22 ^{b}	1.73	44.69 ^{b}	1.16	46.92 ^{b}	2.77
P value	<0.0001*		<0.0001*		<0.0001*		<0.0001*		<0.0001*		<0.0001*	

M: mean SD: standard deviation
P: probability level which is significant at P ≤ 0.05
Means with the same superscript letters along each column were insignificantly different as P > 0.05.
Means with different superscript letters along each column were significantly different as P <0.05.

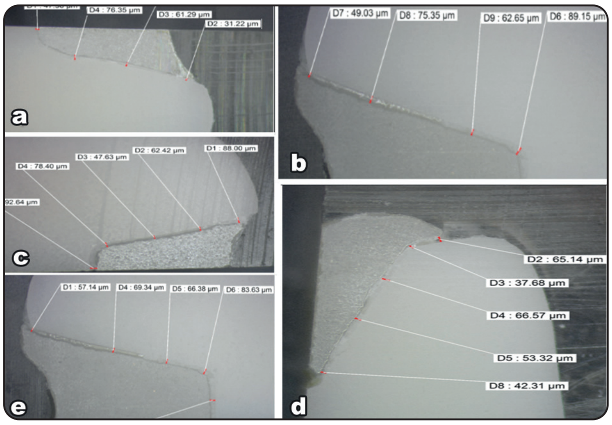

Fig. (2) Tooth-restoration gaps; a: Gp I (Primescan), b: Gp II (Medit), c: Gp III (Smartscan), d: Gp IV (Aoralscan), e: Gp V (conventional impression)

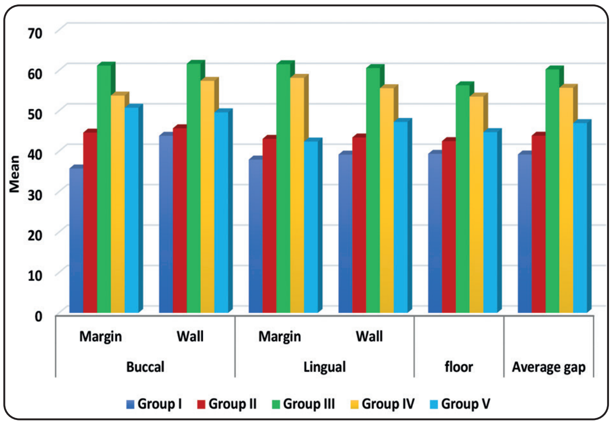

Fig (3): Bar chart showing means of tooth-restoration gaps in all groups

higher gaps (61.49±6.57 μm) than the other groups except for Group IV (58.12±4.71 μm) which was not significantly lower than Group III.

The gap at the lingual wall

Group, I had the lowest gap at the lingual wall (39.14 ±2.01 μm) which was not significantly lower than Group II (43.37 ± 3.57 μm) but significantly lower than all the other groups. Group V had a non-significantly wider gap (47.22 ±1.73 μm) than Group II. Group III had the widest gap (60.54 ±2.8μm) which was not significantly wider than that of Group IV (55.57±6.53 μm). Both Groups III and IV had significantly wider gaps than all the other groups.

The gap at the pulpal floor

Group, I had the lowest gap at the pulpal floor (39.33±2.55 μm) which was not significantly lower than group II (42.47±1.88 μm) but significantly lower than all the other groups. Group V had a non-significantly wider gap (44.69 ±1.16 μm) than group II. Group III had the widest gap (56.27 ± 2.01 μm) which was not significantly wider than that of group IV (53.49 ±2.28 μm). Both groups III and IV had a significantly wider gaps than all the other groups.

The average gap all over the restoration-cavity interface

Group, I had a significantly lower average gap (39.17±2.08 μm) than the other groups, followed by Group II (43.82±1.82 μm) which was insignificantly lower than Group V (46.92±2.77 μm). Group IV had significantly wider gaps (55.66 ± 2.99 μm) than Group V, while Group III had a significantly wider gap (60.21±1.66 μm) than all the other groups.

DISCUSSION

The transition to digital dentistry simplified the dental practice with the wide acceptance by dental practitioners. Digital three-dimensional imaging has gained great interest in dentistry as means to generate an imprint of the oral cavity.[21] While the accuracy of intra-oral scanner (IOS) systems appears to be promising and comparable to conventional methods, they are still vulnerable to inaccuracies.[22] Four of the commercially available and most commonly used intra-oral scanners were selected in this study to assess their influence on the precision of fit of the final restoration. Identical acrylic teeth models were selected for preparation of standardized MOD for the elimination of variation of natural teeth shape, size, and difficulty in the reproduction of adjacent contacts, as the geometry of the scanned surfaces is one of the factors that affect the scanning accuracy.[21,22] Manufacturing of the restoration was done by CAD/CAM technology and the cementation protocol was standardized for all groups.

The results of this study showed that differences between acquisition systems have a statistically significant influence on marginal and internal fit which is in agreement with Alexis et al., 2019 [22] and Vahap Çin et al., 2023 [23]. The least average gap was obtained with primescan system which was significantly lower than the other systems. This result comes in accordance with Zimmermann et al., 2020 [24] and Adam Brian, 2021 [25] who found significantly higher accuracy with primescan compared with other intra-oral scanning systems.

The technology of primescan includes a structured light–confocal microscopy including smart pexil sensor. A high-precision Smart Pixel Sensor captures the data at a high resolution and assesses the contrast in each pixel. For every 3-D image, primescan consolidates more than 50,000 images and captures up to one million 3-D points per second, thereby offering a level of scanning outstanding precision. Calculation of the 3-D points is done by an optical high-frequency contrast analysis, resulting in an increased level of accuracy. [26-29]

Medit i700 system uses 3D full-color streaming imaging technology with 10.9 μm ± 0.98 accuracy in full arch scanning as stated by the manufacturer. Although, it achieved a significantly wider average gap than primescan group, the average gap was less than that obtained with Flexceed additional silicone impression but with a non-significant difference. This result comes in accordance with Rafael, et al, 2021 [30] who found similar prosthodontic outcomes for workflows implementing conventional impression and intra-oral scanners, and in agreement with Sang J et al., 2020 [31] who found superior accuracy of extra-oral scanners than intra-oral scanners. This comes in disagreement with Fernando et al., 2020 [32] who found that, the intraoral scanner produced better trueness and precision than scanning the polysulfide impressions or the stone casts with a laboratory scanner.

Aoralscan 3 is a recently introduced system, it affords contactless scanning with structured light, at a relatively low cost. The system automatically filters out unnecessary soft tissue data, and has a scanning depth of up to 22 mm. Aoralscan group scored an average gap a significantly wider than groups Primescan, Medit, and Flexceed additional silicone impression, but had a significantly smaller average gap than Smart scan group.

Smart scan 3D version 2 system has optical continuous video collection imaging technology, with 20 μm accuracy. Nevertheless, Smart scan group had significantly wider average gap than the other groups, it is still within the acceptable range.[33-35] It is to be mentioned that the marginal gap of all groups ranged from 35.7 to 61.49 μm and internal fit ranged from 39.14 to 61.6 μm which is considered clinically acceptable (< 120 μm) [16, 31-35]

The first null hypotheses of this study was rejected as there was significant differences in marginal and internal adaptation of inlay restorations obtained by tested intraoral scanners, and the second null hypotheses was also rejected as the accuracy of the conventional elastomeric impression technique was not inferior to all tested scanners.

CONCLUSION

Under the limitations of the current study, it can be concluded that Primescan is the most efficient system, followed by both Medit i700 system and Flexceed additional silicone impression, while Smart scan 3D version 2 is the least accurate system followed by Aoralscan 3 system.

REFERENCES

1. Karlsson S. The fit of Procera titanium crowns. An in vitro and clinical study. Acta Odontol Scand 1993;51:129-34.
2. Felton DA, Kanoy BE, Bayne SC, Wirthman GP. Effect of in vivo crown margin discrepancies on periodontal health. J Prosthet Dent 1991;65:357-64.
3. Valderhaug J, Birkeland JM. Periodontal conditions in patients 5 years following insertion of fixed protheses. J Oral Rehabil 1976;3:237-43.
4. Valderhaug J, Heloe LA. Oral hygiene in a group of supervised patients with fixed protheses. J Periodontol 1977;48:221-4.
5. Lang NP, Kiel RA, Anderhalden K. Clinical and microbiological effects of subgingival restorations with overhanging or clinical perfect margins. J Clin Periodontol 1983;10:563-78.
6. Lange, R. T. (2009). “Clinical Evaluation of Ceramic Inlays Compared to Composite Restorations”. Operative Dentistry. 34 (3): 263–272.
7. Pallesen, U; Qvist, V (2003). “Composite resin fillings and inlays. An 11-year evaluation. (2003)”. Clin Oral Invest. 7 (2): 71–79.
8. Lutz F., Göhring T. N. Fiber-reinforced inlay fixed partial dentures: maximum preservation of dental hard tissue. Journal of Esthetic Dentistry. 2000;12(3):164–171.
9. Hayashi M, WilsonNH, (2003) Marginal deterioration as a predictor of failure of a posterior composite. Eur J Oral Sci 111:155–162
10. Hickel R, Peschke A, Tyas M, Mjor I, Bayne S, Peters M, Hiller KA, Randall R, Vanherle G, Heintze SD (2010) FDI World Dental Federation - clinical criteria for the evaluation of direct and indirect restorations. Update and clinical examples. J Adhes Dent 12:259–272
11. Hickel R, Peschke A, Tyas M, Mjor I, Bayne S, Peters M, Hiller KA, Randall R, Vanherle G, Heintze SD (2010) FDI World Dental Federation: clinical criteria for the evaluation of direct and indirect restorations-update and clinical examples. Clin Oral Investig 14:349–366
12. Kidd EA, Joyston-Bechal S, Beighton D (1995) Marginal ditching and staining as a predictor of secondary caries around amalgam restorations: a clinical and microbiological study. J Dent Res 74:1206–1211
13. Opdam NJ, Roeters FJ, Feilzer AJ, Verdonschot EH (1998) Marginal integrity and postoperative sensitivity in class 2 resin composite restorations in vivo. J Dent 26:555–562
14. Opdam NJ, Roeters FJ, Feilzer AJ, Smale I (1998) A radiographic and scanning electron microscopic study of approximal margins of class II resin composite restorations placed in vivo. J Dent 26:319–327
15. Aman Merchant, Deepak Nallaswamy and Subhabrata Maiti Awareness of Intraoral Scanners and Knowledge of Effects of Different Lights on the Accuracy of Intraoral Scanners Among Dental Students and Practitioners. Biosc.Biotech.Res. Comm. Special Issue Vol 13 No 7(1) 2020 Pp-85-90
16. Çise Özal, Mutahhar Ulusoy In-vitro evaluation of marginal and internal fit of 3-unit monolithic zirconia restorations fabricated using digital scanning technologies. J Adv Prosthodont 2021;13:373-84
17. Bergman M. The clinical performance of ceramic inlays: a review. Aust Dent J. 1999; 44(3):157–168.
18. Yang S, Cook N, Paddock C. All-ceramic inlays and onlays. Clin Update. 2005;27(2):1–2)
19. Giovanni Tommaso Rocca & Ladislav Gregor & Maria Jose Sandoval & Ivo Krejci & Didier Dietschi In vitro evaluation of marginal and internal adaptation after occlusal stressing of indirect class II composite restorations with different

resinous bases and interface treatments. “Post-fatigue adaptation of indirect composite restorations” Clin Oral Invest DOI 10.1007/s00784-011-0632-x November 2011

20. MP Rippe, C Monaco, L Volpe, MA Bottino, R Scotti, LF Valandro Different Methods for Inlay Production: Effect on Internal and Marginal Adaptation, Adjustment Time, and Contact Point Operative Dentistry, 2017, 42-4, 436-444
21. Jonas Winkler, Nikolaos Gkantidis Trueness and precision of intraoral scanners in the maxillary dental arch: an in vivo analysis. Scientific Reports (2020) 10:1172 | https://doi.org/10.1038/s41598-020-58075-7
22. J Abduo , M Elseyoufi Accuracy of Intraoral Scanners: A Systematic Review of Influencing Factors Eur J Prosthodont Restor Dent. 2018 Aug 30;26(3):101-121.
23. Robert Nedelcu, Pontus Olsson, Ingela Nyström and Andreas Thor Finish line distinctness and accuracy in 7 intraoral scanners versus conventional impression: an in vitro descriptive comparisonBMC Oral Health (2018) 18:27
24. Alexis Goujat, Hazem Abouelleil, Pierre Colon, Christophe Jeannin, Nelly Pradelle, Dominique Seux, Brigitte Grosgogeat Marginal and internal fit of CAD-CAM inlay/onlay restorations: A systematic review of in vitro studies J Prosthet Dent, 2019, 121 (4), pp.590-597.e3.
25. Vahap Çin, Ayça Deniz ˙Izgi , Ediz Kale and Burak Yilmaz Marginal and Internal Fit of Monolithic Zirconia Crowns Fabricated by Using Two Different CAD-CAM Workflows: An In Vitro Study Prosthesis 2023, 5, 35–47. https://doi.org/10.3390/prosthesis5010003
26. M. Zimmermann, A. Ender, A. Mehl, Local accuracy of actual intraoral scanning systems for single-tooth preparations in vitro. J Am Dent Assoc 151(2) (2020) 127-135
27. Adam Brian Nulty A Comparison of Full Arch Trueness and Precision of Nine Intra-Oral Digital Scanners and Four Lab Digital Scanners. June 2021Dentistry Journal 9(7):75
28. F. Mangano, H. Lerner, B. Margiani, I. Solop, N. Latuta, O. Admakin, Congruence between Meshes and Library Files of Implant Scanbodies: An In Vitro Study Comparing Five Intraoral Scanners, J Clin Med 9(7) (2020)
29. M.A. Schlenz, V. Schubert, A. Schmidt, B. Wostmann, S. Ruf, K. Klaus, Digital versus Conventional Impression Taking Focusing on Interdental Areas: A Clinical Trial, Int J Environ Res Public Health 17(13) (2020).
30. N. Knechtle, D. Wiedemeier, A. Mehl, A. Ender, Accuracy of digital complete-arch, multi-implant scans made in the edentulous jaw with gingival movement simulation: An in vitro study, J Prosthet Dent (2021).
31. R. D’Haese, T. Vrombaut, H. Roeykens, S. Vandeweghe, In Vitro Accuracy of Digital and Conventional Impressions for Full-Arch ImplantSupported Prostheses, J Clin Med 11(3) (2022)
32. Rafael Siqueira , Matthew Galli , Zhaozhao Chen , Gustavo Mendonça, Luiz Meirelles , Hom-Lay Wang , Hsun-Liang Chan. Intraoral scanning reduces procedure time and improves patient comfort in fixed prosthodontics and implant dentistry: a systematic review. Clin Oral Investig. 2021 Dec;25(12):6517-6531.
33. Sang J. Lee, Soo-Woo Kim, Joshua J. Lee, and Chan W. Cheong Comparison of intraoral and Extraoral Digital Scanners: Evaluation of Surface Topography and precision. Dent J (Basel). 2020 Jun; 8(2): 52.
34. Fernando Zarone, Gennaro Ruggiero, Marco Ferrari, Francesco Mangano, Tim Joda, Roberto Sorrentino Accuracy of chairside intraoral scanner compared with a laboratory scanner for the completely edentulous maxilla: An in vitro 3-dimensional comparative analysis. J Prosthet Dent 124(6):761.e1-761.e7 December 2020
35. McLean JW, von Fraunhofer JA. The estimation of cement film thickness by an in vivo technique. Br Dent J. 1971;131:107–111.
36. Shereen Hafez Ibrahim, Haitham Amr, Ahmed A. Hassan, Ahmed Elzohairy Internal fit evaluation of indirect restorations fabricated from CAD/CAM composite blocks versus ceramic blocks in badly broken teeth using cone beam CT (CBCT): double-blinded randomized clinical trial. Heliyon 8 (2022) e09466
37. Philipp C. Pott, Agnieszka Rzasa, Meike Stiesch, Michael Eisenburger Internal and Marginal Fit of Modern Indirect Class II Composite Inlays JDMT, Volume 3, Number 3, September 2014.