JO JOURNAL OF OSSEOINTEGRATION periodontics and prosthodontics

Comparison of internal fit of lithium disilicate crowns fabricated with CAD/CAM technology using two different intraoral scanners

G. VERNIANI, E. FERRARI CAGIDIACO, C. MARRUGANTI, G. PAPAVASILEIOU*, M. FERRARI

Department of Medical Biotechnologies, Division of Dental Materials and Fixed Prosthodontics, University of Siena, Italy
* National and Kapodistrian University of Athens, Greece

TO CITE THIS ARTICLE
Verniani G, Ferrari Cagidiaco e, Marruganti C, Papavasileiou G, Ferrari M. Comparison of internal fit of lithium disilicate crowns fabricated with CAD/CAM technology using two different intraoral scanners. J Osseointegr 2021;13(4):S293-S298.

DOI 10.23805/JO.2021.13.S04.7

KEYWORDS Internal fit; CAD/CAM technology; Intraoral scanners.

ABSTRACT

Aim The aim of this *in vitro* study was to compare variations in the internal fit of lithium disilicate single crowns fabricated with computer-aided design and computer-aided manufacturing (CAD/CAM) technology using two digital impression systems.
Methods 20 molars were prepared for lithium disilicate single crowns with vertical margins. The teeth were scanned using a model scanner in order to create master scans. Then, two intraoral scanners (IOS) were used to take impressions of the 20 teeth: Trios 3 Basic (3Shape, Copenhagen, Denmark) and Aadva (GC, Tokyo, Japan). The 40 .stl files of the impressions were exported and overlapped with the master scans using the software Aadva GC 2.1.2 Dental DB that, using colors from blue to red, highlights (in red) the areas of discrepancy along the impressions of the abutments. The ratio of red was evaluated to assess if there were any statistically significant differences between the two scanners. The digital impressions were used to fabricate 40 lithium disilicate crowns by means of CAD/CAM technology (for each abutment two crowns were fabricated with both devices). Then, 20 crowns, 10 from each IOS device, were randomly selected and luted to the 20 prepared teeth. Teeth were embedded in self-curing transparent resin and then cut into 1 mm thick slices by means of a low speed, precision cutting machine (Buehler Isomet) using a diamond blade. Slices were then observed under optical microscope (Nikon) to evaluate cement thickness around the abutments.
Results No statistically significant differences were found, regardless of precision discrepancies in the impressions taken with the two tested IOS systems. The marginal fit of complete lithium disilicate crowns made with a complete digital workflow from the impression taken with the two tested devices showed comparable levels of marginal fit.
Conclusions Both intraoral scanners tested showed good performance and, based on the results of this *in vitro* study, they both can be considered useful for clinical application.

INTRODUCTION

Complete coverage crowns are one of the most common fixed prosthodontic treatments performed by dentists. Long term success of these rehabilitations is based on an accurate cast. For many years such step has been achieved by means of conventional impressions, but nowadays the performances of the new intraoral scanners (IOS) have opened new perspectives in fixed prosthodontics. Recently, many technological advances improved the quality of the impressions performed by IOS to the point that the level of optical impressions for the fabrication of fixed restorations is as accurate as or even better than that of traditional methods (1, 2).
Marginal and internal fit are the two main clinical factors for the achievement of a good and long-lasting restoration (3, 4). Many studies have shown the importance of accuracy of fit for clinical success, but they mostly limited their analysis to single crown fit and in particular to marginal accuracy (5,6,7). Many studies investigating internal fit of crowns and FDPs are based on measurements of distinct points of sectioned tooth-crown assemblies (8,9) without taking into consideration the whole surface of the restoration. The internal fit is also an important criterion and has a direct effect on the seating of the crown and subsequently on the marginal fit. An incongruous internal fit of the restoration can in fact lead to pre-contacts between the restoration's material and some areas of the abutment that can create a variable thickness of cement along the surface and especially an exposition of it at the margin. The exposition of cement at the margin leads to dissolution of the material by oral fluids, microleakage, and biofilm accumulation with consequences such as caries or endodontic and periodontal problems (10,11).
Traditional impression workflow has been performed

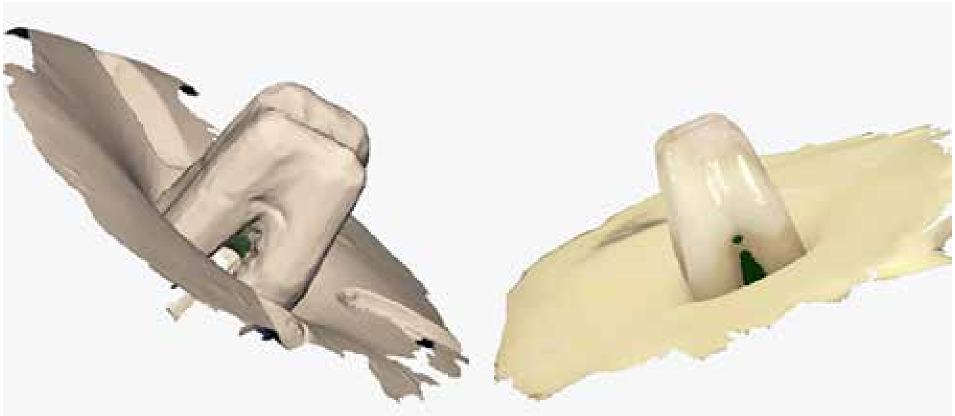

FIG. 1 Digital impression obtained by the two IOS (Trios 3 basic, left, and Experimental Aadva, right).

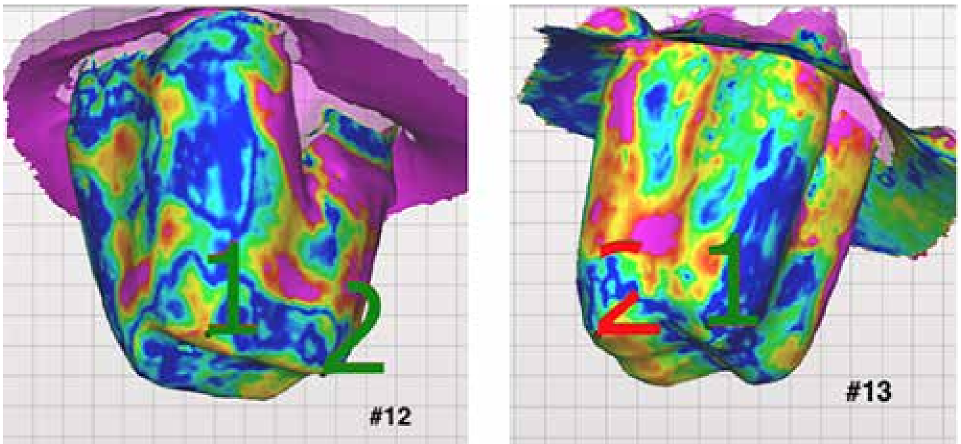

FIG. 2 Superimposition of IOS and lab scanner .stl files.

for many years using polyether (PE) or polyvinylsiloxane (PVS) with great results. The final outcome is strongly affected by dimensional changes of both impression materials and gypsum, due to variation in temperature, time elapsed between impression making and pouring, surface wettability of the gypsum, and disinfection procedures (12,13,14,15). All such possible errors in the traditional procedure are eliminated in the digital one.
Digital impression taking by means of IOS has changed all the workflow, because the acquisition of patients' anatomy is directly transformed in a .stl file that can be sent to the lab in a few minutes. Thus, the technician works directly on the .stl file and, thanks to specific softwares (CAD technology), can realize a digital project of the final restoration that is sent directly to the CAM machine. In this workflow fixed restorations are fabricated with new materials, such as lithium disilicate or zirconia, that present excellent esthetics also in monolithic use and great mechanical properties.
Advances in both CAD-CAM technology and in the use of new materials have led to the production of more accurate milled restorations (16), so that the use of IOS in a complete digital workflow is going to be the immediate future of clinical practice.
Currently, there are many different scanners on the market, so the purpose of the present *in vitro* study was to evaluate the internal fit of crowns made from impressions taken by two different IOS. More specifically, the aim of the study was first to compare impressions of abutments made using two different IOS and evaluate, in microns, possible discrepancies in all the 3D surfaces. Secondly, to compare the internal fit of lithium disilicate full crowns made from the two different impressions and observe cement thickness along the abutment-crown surface.
The null hypotheses tested were:
1) the .stl files generated by the two IOS had significant discrepancies when compared with a laboratory scanner;
2) the internal fit of the crowns generated from impressions taken with the two different devices has statistically significant differences.

MATERIALS AND METHODS

A total sample of 20 intact human molars, extracted for orthodontic reasons and stored in saline solution, were prepared, with appropriate tooth reduction for a complete crown and a vertical finishing line. The abutments were included in 20 customized supports made of putty polyvinyl siloxane and were scanned with a lab scan (Aadva Lab scanner 2, GC, Tokyo, Japan), used as controls. The 20 teeth were also scanned with

1	4,88%
2	3,21%
3	5,02%
4	3,98%
5	2,21%
6	5,89%
7	7,63%
8	7,51%
9	2,71%
10	3,21%
11	4,21%
12	2,98%
13	3,87%
14	9,11%
15	0,74%
16	0,97%
17	10,33%
18	2,07%
19	0,49%
20	1,98%
average:	4,15%

TABLE 1 Percentage of red of 3Shape impressions (.stl).

1	5,01%
2	3,93%
3	7,4%
4	4,32%
5	5,2%
6	6,11%
7	4,23%
8	3,55%
9	2,16%
10	3,43%
11	4,67%
12	3,12%
13	4,43%
14	14,91%
15	1,3%
16	1,02%
17	22,3%
18	1,7%
19	0,99%
20	1,78%
averageL:	5,078%

TABLE 2 Percentage of red of Aadva GC impressions (.stl).

FIG. 3 Optical microscope image of cement along the crown-abutment surface.

two intraoral scanners, so that 20 digital impressions were made using Trios 3 Basic (3Shape, Copenhagen, Denmark) and 20 using Experimental Aadva (GC, Tokyo, Japan) (Fig. 1); in total 40 digital impressions were taken according to the manufacturers' protocols.
The 40 .stl files obtained were exported in a computer and matched: each control .stl file obtained from the lab scanner was matched with the .stl file obtained by Trios 3 Basic and with the .stl file obtained by Aadva.
The superimpositions of the two impressions and the control one, taken with the lab scan, were analyzed with the software Aadva 2.1.2 Dental DB, GC (Fig. 2). This program, thanks to the "register mesh" function, permits to superimpose two impressions and detect all differences between them in microns, evaluating among the 3D surface and highlighting the areas where there are more discrepancies through a color scale from 0 to 100 micron, from blue to red.
Then the amount of surface discrepancy from 0.08 to 0.1 mm, highlighted in red, was calculated and reported in tables in form of percentage, showing the percentage of discrepancy between impressions taken using Trios 3 Basic and those of the lab scan (Table 1) and the discrepancies between Aadva and the lab scan (Table 2). In this way it was possible to compare the precision of the two scanners in micron, taking the lab scanner as a reference. In order to evaluate the statistical significance of the difference in the percentages of red between the two scanners, since the data did not pass the normality test (test of Shapiro-Wilk: $p<0,05$), the Mann-Whitney U test was performed.
The generated .stl files were delivered to a milling center and then crowns were fabricated. After that, 10 crowns from each group were randomly selected and then luted in the corresponding abutments with a resin cement (LinkForce; GC Co., Tokyo, Japan).
For luting the lithium disilicate crowns, the following adhesive protocol was performed: hydrofluoric acid at 9% in the internal part of the crown, wash, dry and primer with silane, orthophosphoric acid 37% on the abutment, wash, dry, adhesive, polymerization. The cement was placed in the internal part of the crowns, and they were positioned on the abutments and light-cured from all sides. The teeth were embedded in transparent self-curing acrylic resin and then sliced using a low-speed diamond saw under water cooling (Buehler, Isomet).
The result was to have 1 mm thick slices along their long axis and perpendicularly to the proximal margins, so that the thickness of the resin cement was calculated with an optical microscope (Nikon) along the surface of the abutment (Fig. 3).
Cement thickness (Table 3, 4) was analyzed with Student t test, after validating the assumptions of normality

	cervical margin A	cervical margin B	axial wall A	axial wall B	occlusal wall
3	55	65	45	65	140
8	70	75	70	75	180
10	55	70	85	75	100
12	75	105	80	45	120
14	120	130	95	75	200
15	135	95	75	80	180
16	115	90	55	90	155
17	105	120	60	75	165
19	105	105	75	90	170
20	120	130	50	75	210
average	95,5	98,5	69	74,5	162

TABLE 3 Cement thickness of 3Shape crowns

	cervical margin A	cervical margin B	axial wall A	axial wall B	occlusal wall
1	110	90	55	65	185
2	55	75	70	85	210
4	60	55	45	65	220
5	75	65	90	75	190
6	55	70	75	60	155
7	110	90	80	90	170
9	100	120	50	55	190
11	125	135	55	75	195
13	100	90	70	80	180
18	75	65	60	75	210
average	86,5	85,5	65	72,5	190,5

TABLE 4 Cement thickness of Aadva GC crowns

(Shapiro-Wilk's test, $p>0.05$) and variance (Levene test, $p>0.05$) homogeneity in the two groups.

RESULTS

Descriptive statistics of cement thickness measured in microns and the statistical significance of the differences between the two experimental groups in these variables are reported in the tables.
Table 5 shows the descriptive statistics of discrepancy bigger than 0.08 mm in the two groups.
The Mann-Whitney U test revealed that there were no statistically significant differences in the orange/red percentages between the two scanners.
The result of the statistics of cement thickness are reported in tables 6-10.

Scanner	N	median	interquartile range
3Shape	10	4,08	1,97-5,10
GC	10	3,54	2,14-5,45

TABLE 5 Descriptive statistics of the discrepancy bigger than 0,08 mm in the two groups.

Only in the occlusal wall, cement thickness values were statistically significantly higher in GC scanner than in 3shape scanner ($p=0.035$). No statistically significant difference was found in the other sections ($p>0.05$).

DISCUSSION

The purpose of this *in vitro* study was to evaluate the performance of two intraoral scanners for the realization of lithium disilicate complete crowns and to determine if there were statistically significant differences between the two devices. The use of a lab scan impression as reference was fundamental to evaluate the difference in the precision of the two devices because it can be considered as the gold standard in terms of precision (17, 18). The impressions obtained with the two devices were separately superimposed on those of the lab scan and trough the software (Aadva GC 2.1.2 Dental DB) it was possible to highlight the differences, i.e. discrepancy, using a color scale, from blue to red, along all the surface of the impressions and not only in standardized points. The red areas for each abutment, where discrepancy was between 0.08 and 0.1 mm, were calculated and analyzed. In this way the precision of

Scanner	N	average	standard deviation	statistical significance
3Shape	10	95.5	29.19	NS (p=0.47)
GC	10	86.5	25.60	

NS statistically non significative difference
** statistically significative difference*

TABLE 6 Descriptive statistics of cement thickness measured in μm at cervical margin A.

Scanner	N	average	standard deviation	statistical significance
3Shape	10	98.5	23.81	NS (p=0.25)
GC	10	85.5	25.43	

NS statistically non significative difference
** statistically significative difference*

TABLE 7 Descriptive statistics of cement thickness measured in μm at cervical margin B.

Scanner	N	average	standard deviation	statistical significance
3Shape	10	69	16.12	NS (p=0.56)
GC	10	65	14.33	

NS statistically non significative difference
** statistically significative difference*

TABLE 8 Descriptive statistics of cement thickness measured in μm at axial wall A.

Scanner	N	average	standard deviation	statistical significance
3Shape	10	74.5	12.79	NS (p=0.71)
GC	10	72.5	11.11	

NS statistically non significative difference
** statistically significative difference*

TABLE 9 Descriptive statistics of cement thickness measured in μm at axial wall B.

Scanner	N	average	standard deviation	statistical significance
3Shape	10	162	34.33	NS (p=0.035)
GC	10	190.5	19.64	

NS statistically non significative difference
** statistically significative difference*

TABLE 10 Descriptive statistics of cement thickness measured in μm at occlusal wall.

the two scanners was analyzed separately and then compared and no statistically significant differences were found between them.

Then, cement thickness was evaluated in 5 points along the surface and these measures are a direct indicator of the precision of the restorations created with a complete digital workflow from the two tested devices. The cement thickness along the surface of the abutments does not have standardized value, since most of the data in literature refer to cement thickness at the margin, which is usually set under 120 μm, as McLean described (19). But it must be taken into consideration that the internal fit is also an important criterion and has a direct effect on the seating of the crown and consequently on the marginal fit, so it should be considered as a primary factor for the good outcome of a fixed restoration. Indeed, 25-um-thick die spacer has been shown to improve the seating of a crown and increase the retention of the restoration by 25% (20). In another study, increasing cement thickness was shown to decrease the fracture resistance of the ceramic restorations because of the greater deformation of the porcelain into the cement layer and the decreased thickness of the restorations (21). However, the result of this study showed that the gap at the margins was under a clinical acceptability (21-23).

Trios 3 (3Shape) scanner is a well-known and clinically accepted scanner and often used as reference when new scanners are tested, whereas Aadva is a new device just launched in the market: the comparison between them showed similar clinical performances. It can be reported that, although it was not specifically investigated in this study, the scanner speed of Trios 3 was about 20% shorter than Aadva.

From this *in vitro* study no statistically significant difference was found between the cement thickness of the two tested devices apart from the occlusal wall where the Aadva crowns showed ticker layers of cement than 3Shape ones. Both the tested devices showed good results in this *in vitro* study, but further studies should be carried out to evaluate the performance of the devices in intraoral conditions because many clinical factors can affect the precision such as patient and hand movements during scanning as well as the presence of saliva and reflections from tooth and adjacent structures (21-27).

CONCLUSION

The two IOS systems tested showed comparable levels of precision in impression making for lithium disilicate complete coverage crowns regarding internal fit. Further studies are needed to validate the accuracy of these scanners in clinical conditions.

REFERENCES

1 Chochlidakis KM, Papaspyridakos P, Geminiani A, Chen CJ, Feng IJ, Ercoli C. Digital versus conventional impressions for fixed prosthodontics: A systematic review and meta-analysis. J Prosthet Dent 2016 Aug;116(2):184-190.
2 Pecciarini, M, Biagioni A, Ferrari, M. A systematic review of clinical trials on digital impression of prepared teeth. J Osseointegr 2019;112:92–97.
3 Karlsson S. The fit of Procera titanium crowns. An in vitro and clinical study. Acta Odontol Scand 1993Jun;51(3):129-34.
4 Besimo C, Jeger C, Guggenheim R. Marginal adaptation of titanium frameworks produced by CAD/CAM techniques. Int J Prosthodont 1997 Nov-Dec;10(6):541-6.
5 Abdel-Azim T, Rogers K, Elathamna E, Zandinejad A, Metz M, Morton D. Comparison of the marginal fit of lithium disilicate crowns fabricated with CAD/CAM technology by using conventional impressions and two intraoral digital scanners. J Prosthet Dent 2015 Oct;114(4):554-9.
6 Tsirogiannis P, Reissmann DR, Heydecke G. Evaluation of the marginal fit of single-unit, complete-coverage ceramic restorations fabricated after digital and conventional impressions: A systematic review and meta-analysis. J Prosthet Dent 2016 Sep;116(3):328-335.e2.
7 Anadioti E, Aquilino SA, Gratton DG, Holloway JA, Denry I, Thomas GW, Qian F. 3D and 2D marginal fit of pressed and CAD/CAM lithium disilicate crowns made from digital and conventional impressions. J Prosthodont 2014 Dec;23(8):610-7.
8 Sjögren G. Marginal and internal fit of four different types of ceramic inlays after luting. An in vitro study. Acta Odontol Scand 1995 Feb;53(1):24-8.
9 Lee JH, Son K, Lee KB. Marginal and internal fit of ceramic restorations fabricated using digital scanning and conventional impressions: A clinical study. J Clin Med 2020 Dec 14;9(12):4035.
10 Gardner FM. Margins of complete crowns--literature review. J Prosthet Dent 1982; Oct;48(4):396-400.
11 Larson TD. The clinical significance of marginal fit. Northwest Dent 2012; 91(1):22-9.
12 Thongthammachat S, Moore BK, Barco MT 2nd, Hovijitra S, Brown DT, Andres CJ. Dimensional accuracy of dental casts: influence of tray material, impression material, and time. J Prosthodont 2002 Jun; 11(2):98-108.
13 Johnson GH, Craig RG. Accuracy of four types of rubber impression materials compared with time of pour and a repeat pour of models. J Prosthet Dent 1985 Apr;53(4):484-90.
14 Purk JH, Willes MG, Tira DE, Eick JD, Hung SH. The effects of different storage conditions on polyether and polyvinylsiloxane impressions. J Am Dent Assoc 1998 Jul;129(7):1014-21.
15 Oda Y, Matsumoto T, Sumii T. Evaluation of dimensional stability of elastomeric impression materials during disinfection. Bull Tokyo Dent Coll 1995 Feb;36(1):1-7.
16 Strub JR, Rekow ED, Witkowski S. Computer-aided design and fabrication of dental restorations: current systems and future possibilities. J Am Dent Assoc 2006 Sep;137(9):1289-96.
17 Flügge TV, Att W, Metzger MC, Nelson K. Precision of Dental Implant Digitization Using Intraoral Scanners. Int J Prosthodont 2016 May-Jun;29(3):277-83.
18 Mandelli F, Gherlone E, Gastaldi G, Ferrari M. Evaluation of the accuracy of extraoral laboratory scanners with a single-tooth abutment model: A 3D analysis. J Prosthodont Res 2017 Oct;61(4):363-370.
19 McLean JW, von Fraunhofer JA. The estimation of cement film thickness by an in vivo technique. Br Dent J 1971;131(3):107-11.
20 Eames WB, O'Neal SJ, Monteiro J, Miller C, Roan JD Jr, Cohen KS. Techniques to improve the seating of castings. J Am Dent Assoc 1978 Mar;96(3):432-7.
21 Tuntiprawon M, Wilson PR. The effect of cement thickness on the fracture strength of all-ceramic crowns. Aust Dent J 1995;40:17-21.
22 Keeling A, Wu J, Ferrari M. Confounding factors affecting the marginal quality of an intra-oral scan. J Dent 2017 Apr;59:33-40.
23 Ferrari Cagidiaco E, Grandini S, Goracci C, Joda T. A pilot trial on lithium disilicate partial crowns using a novel prosthodontic functional index for teeth (FIT). BMC Oral Health 2019;19 (1): 276.
24 Strauß P, Mosch R, Sandmaier M, Von See C. Intraoral scanner accuracy: the influence of manual movement? J Osseointegr 2021;13(4 Supplement):S285-S288.
25 Skordou T, Kebi L, Osnes C, Keeling A. The effect of two different milling instrument sets on cad proposed cement thickness and fit surface of chairside cad crowns. J Osseointegr 2021;13(4 Supplement):S271-S278.
26 Al Ibrahim I, Keeling A, Osnes C. The effect of operator scanning speed on the trueness and precision of full-arch digital impressions captured in vitro using an intraoral scanner. J Osseointegr 2021;13(4 Supplement):S265-S270.
27 Sorrentino R, Ruggiero G, Leone R, Ferrari M, Zarone F. Area accuracy gradient and artificial markers: a three-dimensional analysis of the accuracy of IOS scans on the completely edentulous upper jaw. J Osseointegr 2021;13(4 Supplement):S257-S264.