Three - dimensional Evaluations of the Coating Thickness of Two Optical Conditioning Scanning Sprays

ALEXANDRU VICTOR BURDE[1], DIANA DUDEA[1], STANCA CUC[2]*, MARIOARA MOLDOVAN[2], RADU SEPTIMIU CAMPIAN[1]
[1]University of Medicine and Pharmacy "Iuliu Haþieganu", Faculty of Dental Medicine, 32 Clinicilor Str., 400006, Cluj-Napoca, Romania
[2]Babes Bolyai University, Raluca Ripan Chemistry Research Institute, Department of Polymer Composites, 30 Fantanele Str., 400294, Cluj Napoca, Romania

The purpose of this study was to determine the three-dimensional coating thickness of two scan sprays used in labside digitalization. An assembly consisting of a CoCr tooth with a standard full ceramic crown preparation and a three-dimensionally printed PLA base was duplicated twenty times out of type IV plaster. The plaster models were digitized using a three-dimensional scanner and reference virtual models were acquired (REF). A homogenous coat of spray A was applied on all models and the models were rescanned. After digitalization, the models were steam cleaned and the same technique was used for spray B. The reference scans were compared separately with the scans of group A and B. The resulting data was analyzed with the Student unpaired t-test (α = .05). While there were significant intergroup differences in the three-dimensional comparison of the root mean square of deviations, both scan sprays showed acceptable coating thicknesses for clinical use.

Keywords: Computer-Aided Design; CAD/CAM; Dental Impression; SEM; Optical Conditioning

All ceramic dental restorations are becoming more popular and are more easily obtainable with the introduction of CAD/CAM systems [1-4]. In order to manufacture a custom dental prosthetic device with a subtractive CAD/CAM or additive manufacturing system, the surface of the preparation and surroundings need to be digitized using a mechanical [5, 6] or optical [7, 8] surface measuring device. Optical three-dimensional scanners are essential tools in acquiring the complex geometries of dental arches and deploy the use of structured or unstructured light [9]. There are mainly two types of optical three-dimensional scanners which are being used in dentistry: direct/chairside scanners which capture the intraoral surfaces directly in the patient's mouth via a digital impression [10,11] and indirect/ laboratory scanners which start with a conventional impression that is either directly scanned or is poured out of plaster, and the resulting model is digitized [12]. Optical three-dimensional scanners detect the geometry of objects with the help of reflected light from the surface [13]. Based on this principle, the scanning quality can be influenced by reflective abilities of a surface [5]. The glossiness of teeth can highly limit the scanning results. In some cases the surface color of the impression materials used for the conventional impression or the color of the plaster can be an obstacle for scanning. The most suitable colored objects for three-dimensional scanning are grey and white [14]. Based on this fact, titanium dioxide powder or aerosol spray can be used to increase the opacity of the surface and to produce a uniform reflection of the light [14]. But controlling the distribution of these sprays is limited by a number of factors including the small space between the dental arches and the users' handling experience [15]. While the accumulation of scanning spray on the axial surfaces of the prepared teeth increases the cement space, an excessive build-up of scan spray at the preparation margin may negatively influence the marginal fit of the future restoration resulting in a poor clinical outcome.

The purpose of this study was to determine the three-dimensional coating thickness of two scan sprays used in indirect digitalization of dental casts and metallic abutments.

Experimental part

Materials and methods

For the purpose of this study two optical conditioning scan sprays that contain titanium dioxide as the opacifying agent were chosen, namely spray A- Helling 3D LaserScanning Anti-Glare (Laser Design Inc) and spray B- Digiscan-Spray (YETI Dentalprodukte). Both sprays are delivered in the form of aersol sprays and are provided by the manufacturers with a in-built conventional pump injector.

In order to highlight the number of successive layers of spray required to achieve an optimum opacification of a surface, a macroscopic and microscopic evaluation was performed. The macroscopic evaluation was performed using ten Co-Cr alloy dies simulating a permanent maxillary right first molar with a standard porcelain-fused to metal crown preparation, which were divided into 2 groups (n=5)- group A was coated with one to four consecutive layers of spray A and group B was coated with one to four consecutive layers of spray B (fig.1).

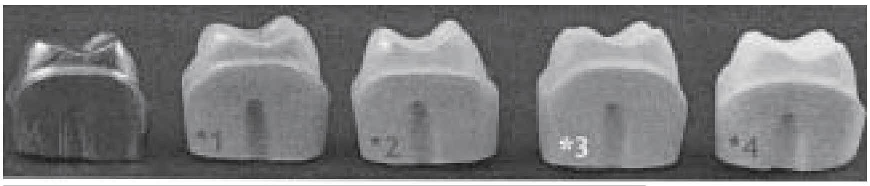

Fig.1. Co-Cr dies coated with spray A (M-control specimen, *n- number of consecutive layers of spray)

* *email: stancabobo@yahoo.com; Tel.: 0757939232*

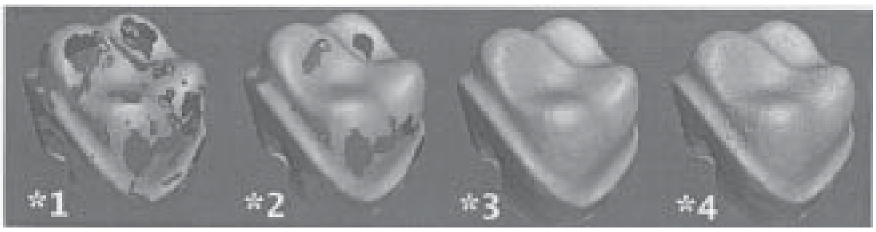

Fig. 2. Surface of scanned Co-Cr dies coated with spray A (*n- number of consecutive layers of spray)

Both groups of coated dies were 3D scanned using an InEos X5 (Sirona Gmbh) structured light scanner. The spray coating of the metallic die was considered optimal when the surface of the scanned die did not contain any holes or excessive spray build-up (fig. 2).

For the microscopic evaluation, two non-porous carbon tabs were coated each with one layer of the two sprays included in this study. The sprays were applied following the manufacturer's instructions, with a distance of 20 centimeters between the nozzle and carbon tabs. A JSM 5510LV (Japan Electron Optics Laboratory Co.) scanning electron microscope was used in order to inspect particle size and coating homogeneity.

The microscopic and macroscopic evaluations determined that three layers of spray A or B are sufficient in order to obtain a homogenous matte surface.

In order to determine the three-dimensional thickness of the optimum coating of the two scan sprays, a rectangular prism support featured with three cones on the X-axis and one cone on Z-axis was digitally designed in the MeshMixer (Autodesk) CAD software. The cones were placed on the support in order to facilitate orientation during scanning and three-dimensional comparison. The resulting support was three-dimensionally printed with a Leapfrog CreatrHS (Leapfrog) fused deposition modelling printer out of polylactic acid filament. On the surface of the printed piece a Co-Cr alloy die was attached with cyanoacrylate. A silicone mold of the resulting piece was created out of Interduplicast (Interdent) duplication silicone and type IV scannable plaster was poured in the mold to create 20 plaster casts (fig. 3).

The plaster casts were numbered and scanned at the highest possible resolution using an ATOS Core 45 (GOM) structured light scanner in order to obtain a reference- REF group of digital casts. An ethyl vinyl acetate foil was vaccum formed over a plaster cast and the area of the foil that was covering the die was sectioned off in order to facilitate the application of scan spray only onto the die.

An experienced user in CAD/CAM technology applied three coatings of spray A to each of the twenty plaster casts. The spray coated casts were then rescanned in order to obtain the digital models of the sprayed dies-group A. After digitalization, the models were steam cleaned and dried in a heating furnace for 4 hours at 80°C. The same technique was used to obtain the digital models of the casts coated with spray B-group B.

Afterwards, all the digital datasets were imported into the Qualify 2013 (Geomagic) inspection software. The parts of the digital models that were outside the area of the die were deleted by software to insure precise superimposition. The 20 datasets for each spray were aligned pairwise by best-fit algorithm to the corresponding models in the REF group in order to calculate the Root Mean Square (RMS) error of Euclidean distances of aligned points. The shortest Euclidean distance from each point of the triangulated surface of each sprayed model to the points of the triangulated surface of the REF model was calculated using the "3D comparison" feature of the software. The avearge number of points used for a comparison between two models was 17000. The software generated a color coded map of the registered deviations for each performed comparison (fig. 4) and the RMS error of the deviations was calculated.

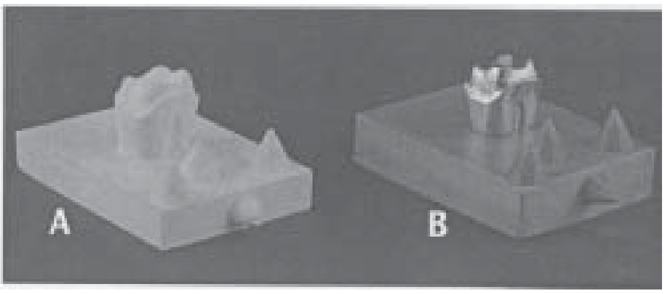

Fig. 3. Plaster cast (A) and the three-dimensionally printed master cast (B)

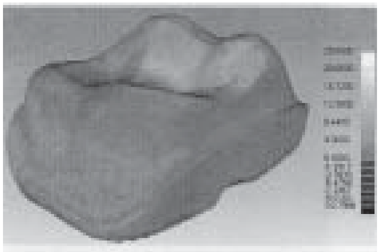

Fig. 4. Color-coded deviation map of a sample in group A compared with the REF model

Statistic analysis was performed with SPSS 20.0 (IBM SPSS Inc). The Levene test was used to test the homogeneity of variances and Student's t-test was used to evaluate the difference between the two groups. The level of significance was set at 0.01.

Results and discussions

The means of the coating thickness of spray A (N=20) was M= 16.08 μm (*SD*= 0.96). By comparison, spray B (N=20) was associated with a numerically smaller means of the coating thickness M= 13.59 μm (*SD*= 0.65). To test the hypothesis that spray A and spray B were associated with statistically significant different means of the coating thickness, an independent samples *t-test* was performed. As can be seen in table 1, the distributions of spray A and B were sufficiently normal for the purposes of conducting a *t-test* (i.e., skew < |2.0| and kurtosis <|9.0|) [16].

Additionally, the assumption of homogeneity of variances was tested and satisfied via Levene's F test, $F(38)= 1.97$, $p=0.169$. The independent samples *t*-test was associated with a statistically significant effect, $t(38)= 13.97$, $p < 0.001$. Thus, spray A was associated with a statistically significantly larger coating thickness than spray B. Cohen's d was estimated at 4.82, which is a large effect based on Cohen's guidelines [17].

Scanning electron microscopy examination showed dense deposits of scanning spray forming an almost continuous layer on all coated samples [18]. The images captured at x500 magnification level revelead that while both sprays have the tendency to form clusters of particles, spray A has larger and more numerous clusters by comparison with spray B (fig. 5).

Further visualisation of the sample coated with spray B, at x1000 magnification level showed a more heterogeneous shaped surface morphology with an increasing number of small particles compared to spray

Spray	n	Mean	SD	Max	Min	Skewness	Kurtosis
A	20	16.08	0.96	14.51	18.32	0.21	2.63
B	20	13.59	0.65	12.24	15.11	-0.22	1.6

Table 1
DESCRIPTIVE STATISTICS ASSOCIATED WITH THE COATING THICKNESS OF THE TESTED SPRAYS

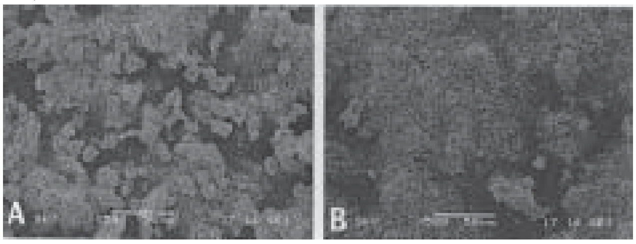

Fig. 5. SEM images of spray A(left) and spray B (right) at x500 magnification level

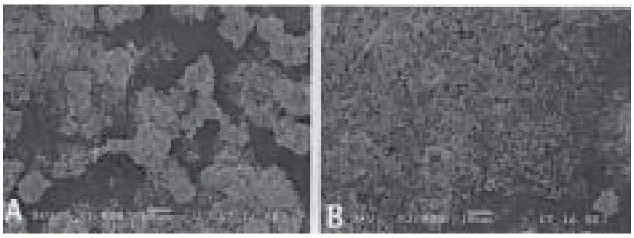

Fig. 6. SEM images of spray A(left) and spray B (right) at x1000 magnification level

A. Multiple, small areas where there is a lack of spray deposit can be observed on all samples, but they are more predominant on the surface of the tab coated with spray A (fig. 6).

A polished metal surface is difficult to scan because of it's highly reflective and shinny apperance. As it can be seen in figure 1, the control die was not coated with scan spray and the acquistion of any surface information was impossible via optical scanning. However, the scanning result improved highly by applying one layer of coating although the quality was still low and the triangulated surface model of the die contained numerous large holes, as it can be seen in figure 2. Dies with thicker coating were scanned one by one and the scanning result improved respectively by increasing the thickness. The best result acquired was when the die was coated with three layers of scan spray. When the thickness of the coating was increased with one more layer of spray, an excessive aggregation of spray could be observed at the margin of the preparation and on the occlusal surface of the die, resulting in a rugged appearance of the surface.

Conclusions

Optical three-dimensional scanners used in the field of dentistry are highly sensitive to the optical proprieties of the scanned surfaces, especially to glossiness and transparency. The use of titanium-dioxide scanning sprays provides optimum optical conditioning proprieties to reflective surfaces.

During the entire manufacturing process of a fixed dental prosthesis (inlay/onlay, crown or bridge), each sequential step in the manufacturing process will add to the final inaccuracy of the marginal adaptation, which has its limits set on 50-75 μm [19-21]. The small size of the spray particles could probably allow the application of scan sprays in a reduced and homogenous coating. However, the application of these sprays by means of conventional pump injectors may distort the geometry of the scanned surface.

In the limits of this study, the coating thickness of the tested scan sprays was in acceptable clinical range, presenting a similar surface morphology. Further clinical research is needed to optimize pump injectors for this type of application or replace these devices with atomization based spray systems.

Acknowledgments: This work was funded by: The Romanian Ministry of Education and Research, National Project TE no. 37/2015.

References

1.LI R.W.K, CHOW T.W., MATINLINNA J.P., J Prosthodont Res., 58, nr.4, 2014, p. 208.

2. MIYAZAKI T., HOTTA Y., KUNII J., KURIYAMA S., TAMAKI Y., Dent Mater J., 28, nr.1, 2009, p.44.

3. NODITI G., TODEA C., Mat.Plastice, 50 nr.1, 2013, p.40.

4. ABDUO J., LYONS K., BENNAMOUN M., Int J Dent., 2014, 783948.

5. QUAAS S., RUDOLPH H., LUTHARDT R.G., J Dent., 35 nr.12, 2007, p.903.

6.PERSSON A.S.K., ODÉN A., ANDERSSON M., SANDBORGH-ENGLUND G., Dent Mater., 25 nr.7, 2009, p.929.

7. TING-SHU S., JIAN S., J Prosthodont., 24 nr.4, 2015, p.313.

8.VOGEL A.B., KILIC F., SCHMIDT F., RÜBEL S., LAPATKI B.G., J Orofac Orthop., 76 nr.4, 2015, p.351.

9. GÜTH J.-F., KEUL C., STIMMELMAYR M., BEUER F., EDELHOFF D., Clin Oral Investig., 17 nr.4, 2013, p.1201.

10. GRÜNHEID T., MCCARTHY S.D., LARSON B.E., Am J Orthod Dentofac Orthop. 146 nr.5, 2014, p.673.

11. NEDELCU R.G., PERSSON A.S.K., J Prosthet Dent., 112 nr.6, 2014, p.1461.

12. PERSSON A.S.K., ANDERSSON M., ODÉN A., SANDBORGH-ENGLUND G., Dent Mater., 24 nr.8, 2008, p.1123.

13. JEON J.-H., KIM H.-Y., KIM J.-H., KIM W.-C., J Adv Prosthodont., 6 nr.6, 2014, p.468.

14. VALINASAB B., RUKOSUYEV M., LEE J., KO J., JUN M.B.G., J Korean Soc Manuf Technol Eng., 24 nr.1, 2015, p.23.

15. DEHURTEVENT M., ROBBERECHT L., BÉHIN P., J Prosthet Dent., 113 nr.1, 2015, p.17.

16.COHEN J., A power primer. Psychological Bulletin., 112 nr.1, 1992, p.155.

17SCHMIDER E., ZIEGLER M., DANAY E., BEYER L., BUHNER M., Europ J Res Method Behavioral Social Sciences, 6, 2010, p.147.

18. PREJMEREAN C., MOLDOVAN M., PETREA C.M., PRODAN D., SILAGHI-DUMITRESCU, L., VASILE, E., FURTOS, G., BOBOIA, S., SILAGHI-DUMITRESCU, R., Mat. Plast., **48**, no. 4, 2011, p.279.

19.DENISSEN H.W., VAN DER ZEL J.M., VAN WAAS M.A.J., Int J Prosth, 12 nr.5, 1999, p.395.

20. LINS L., BEMFICA V., QUEIROZ C., CANABARRO A., J Prosthet Dent., 113 nr.3, 2015, p.205.

21.TINSCHERT J., NATT G., MAUTSCH W., SPIEKERMANN H., ANUSAVICE K J., Oper Dent., 26, 2001, p.367

Manuscript received: 21.12.2015