Analysis of Internal and Marginal fit of Metal-ceramic Crowns During Processing, Using Conventional and Digitized Technologies

CRISTINA ELENA SAVENCU[1]*, SORIN POROJAN[2], LILIANA POROJAN[1]

[1] V.ictor Babes University of Medicine and Pharmacy Timisoara, Faculty of Dentistry, Department of Dental Prostheses Technology, 9 Revolutiei 1989 Blv, 300041, Timisoara, Romania

[2] Victor. Babes University of Medicine and Pharmacy Timisoara, Faculty of Dentistry, Department of Oral Rehabilitation, 9 Revolutiei 1989 Blv, 300041, Timisoara, Romania

Copings accuracy is an important factor for long-term clinical success of ceramic fused to metal dental restorations. The purpose of the study was to investigate marginal and internal fit of metal-ceramic crowns during processing, using conventional and digitized technologies. Metal copings were produced by Digital light Processing (DLP), invested and casted. Ceramic veneers were overpressed. Internal and marginal fit was measured using silicon replica technique for patterns, casted frameworks and final ceramic fused to metal crowns. Best adaptation was found in resin-pattern group, with small increasing of gap after casting and after ceramic pressing.

Keywords: metal-ceramic crowns, marginal gap, Digital light Processing, computerized milling

Metal-ceramic restorations are still one of the most used in prosthodontic treatment. A ceramic material is applied on a metal framework using a multi-layer sintering process or overpressing the porcelain [1].Conventional lost-wax technique and casting is the most used technique in producing fixed dental restorations and its advantages and long-term success has been proved. But this procedure is also very technique-sensitive, and wax patterns are fragile, prone to distortions, thermal sensitive, have high coefficient of thermal expansion and elastic memory [2, 3]. Other methods to obtain patterns imply self-curing or light-curing resins to exceed shortcomings of wax-patterns, producing stable and precise pieces. However curing shrinkage is the main disadvantage of these materials. In order to overcome these limitations, modern CAD/CAM systems were developed. Subtractive technologies as hard metal milling (HM) and soft metal milling (SM), milling of zirconia, ceramic, composite resin wax or resin for casting patterns and hybrid materials are successfully used for decades in dental field. Limitations on dimensions and complexity of shapes obtained by block cutting led to development of new additive fabrication methods, such as selective laser melting (SLM), selective laser-sintering (SLS), stereo-lithography (SLA), and digital light processing (DLP) [4]. While SLS and SLM can directly produce metal copings and frameworks using a high-temperature laser applied to metal particles, SLA and DLP are used to manufacture models, provisionals, and patterns [5]. Fabrication of metal copings by laser-based technologies is still expensive, due to high price of equipment. 3D printing, on the other hand, is becoming an affordable technology, as the traditional casting is, with increased accuracy and complex internal shape [6].

3D printing laser-based SLA and DLP technologies use a vat of photosensitive liquid resin which is selectively exposed to light and consequently solidifies in thin layers, between 50-200μm, based on a ratio between time and resolution, which stack to create a solid object [7,8]. This procedure is repeated layer by layer, until full object is completely formed. Clinical acceptance and success of restorations obtained by this new method is determined by numerous factors, one of most important for their longevity being adaptability [9].

Marginal gap is an important factor for long-term success of fixed restorations, being responsible for 10% of prosthetic failure, misfit leading to dissolution of luting agent, bacterial infiltration, secondary decay with pulp complications, periodontal disease, gum bleeding, marginal discoloration, ceramic cipping, loss of retention, functional and esthetic failure [3, 4, 10-13]. Literature suggest a range of accepted marginal gaps, from 120 μm suggested by Mclean and von Fraunhoder to 100 μm. In other studies accepted marginal gap varies between 10 μm and 160 μm and internal gap between 81 μm and 136 μm [3,14].

Experimental part

A resin first upper molar was prepared with a chamfer finishing line, an occlusal convergence of axial walls of 6°, and an anatomical reduction of occlusal surface. The prepared tooth was duplicated with silicone (Fegurasil AD Special, Feguramed, Germany). Twenty-four resin specimens were poured (Structur 3, Voco GmbH, Cuxhaven, Germany). These abutments were scanned with D700 3D scanner (3Shape, Copenhagen Denmark), and an anatomic reduced coping design was made with 3Shape software (3Shape, Copenhagen Denmark) (fig. 1).

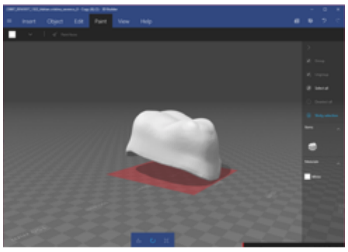

Fig.1. Computer aided design for the coping

STL files were exported to Perfactory 4 Digital Printer P4DDP (EnvisionTEC, Dearborn, Michigan, USA) and twenty-four resin patterns were fabricated from E-Partial Press-E-Cast photosensitive resin, a wax-filled photo-polymer (EnvisionTEC, Dearborn, Michigan, USA). After removing from printer, parts were cleaned with 99% pure Isopropyl alcohol in successive containers with clean alcohol, dried and placed in Otoflash unit (EnvisionTEC, Dearborn, Michigan, USA) for 50 post-processing cycles (fig. 2).

* email: crissavencu@gmail.com; Phone: 0734662519

Fig.2. Printed copings

For fit evaluation silicon replica technique was used [4, 12]. Fit Checker black (GC Corporation, Tokyo, Japan), a silicone for revealing high spots and pressure points was placed between copings and resin duplicated teeth to simulate the luting cement, until set. This thin layer of flowable silicone was embedded between a putty silicone Zetalabor (Zhermack, Badia Polesine, Italy), and a light silicone Oranwash L (Zhermack¸ Badia Polesine, Italy). Silicon replicas were created for each pattern.

After that resin patterns were cleaned with steam and immersed in alcohol, sprued, invested with a phosphate-based investment (Bellavest SH, BEGO, Bremen, Germany), and casted with Wirobond 280 alloy (BEGO, Bremen, Germany), using a vacuum pressure casting machine Nautilus (Bego, Bremen, Germany). After cooling, copings were divested (fig. 3), sandblasted with alumina particles (200 µm, and 75 µm), and finished with suitable burs.

A new set of silicon replicas were made after casting.

Fig.3. Frameworks during divestment

Fig.4. Sprued patterns over metal copings for ceramic overpressing

Copings were cleaned, degreased, and an oxide firing was performed. After that copings were blasted with alumina particles (75 µm), cleaned with steam jet and allowed to dry. Opaquer paste IPS InLine System (Ivoclar Vivadent, Schaan, Principality of Liechtenstein) was applied and opaquer firings were conducted following manufacturers indications. Copings were scanned with D700 3D scanner (3Shape, Copenhagen Denmark), and an anatomic wax-up design of the veneer was made with 3Shape software (3Shape, Copenhagen Denmark). Wax-ups were milled from Harvest ZCAD Wax Press (Harvest Dental Laboratory Products) with a Zenotec (Wieland Dental + Technik GmbH & Co. KG, Pforzheim, Germany) milling machine. Patterns were applied over metal copings, sprued (fig. 4), and invested in a phosphate-based specific investment mass PressVEST Speed (Ivoclar Vivadent, Schaan, Principality of Liechtenstein).

Molds were preheated at 850°C for 75 min and IPS InLine PoM (Ivoclar Vivadent, Schaan, Principality of Liechtenstein) ceramic ingots were pressed using Programat EP 3010 furnance (Ivoclar Vivadent, Schaan, Principality of Liechtenstein). After mold cooling to the room-temperature crowns were divested, finished, cleaned and glazed following manufacturer's instructions.

A new set of silicon replicas were made for final restorations. These silicone ensembles were randomly sectioned in mesio-distal or buccal-oral direction.

The sections were observed and photographed with a hundred microns scale under microscope using Leica DM500 microscope (Leica, Wetzlar, Germania) at 4x magnification.

The gap was measured in nine different positions, corresponding to the following categories: marginal gap (MG), cervical gap (CG), axial internal gap in the middle of axial wall (AG), and occlusal internal gap wall on cusps and in the central fossa (OG) (fig. 5), using this silicone blocks to measure the gap between coping and abutment. Measurements were made with ImageJ software after calibration using the scale from the picture (fig. 6).

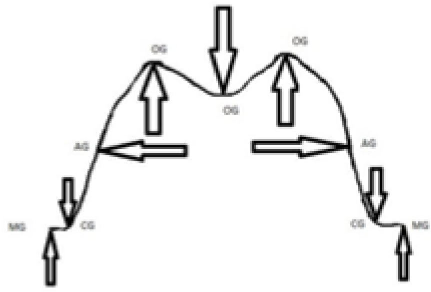

Fig.5. Measurement points.

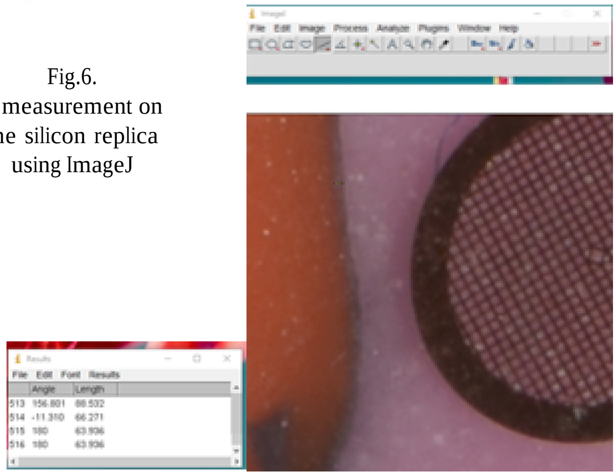

Fig.6. A measurement on the silicon replica using ImageJ

Results and discussions

72 sections (3 groups, 9 sites per crown) were photographed and measured. The mean values for marginal and internal discrepancies measured for each step in technological workflow are presented in table 1. Highest gap values were found for all groups at occlusal level, and no sensible differences between other measured points.

Best adaptation was found in DLP resin-pattern group, with small increasing of gap after casting (+12.28 µm for marginal discrepancy and +7.18µm for internal discrepancy), with no significant differences observed after ceramic pressing (+10.57 µm for marginal discrepancy and 6.01 µm for internal discrepancy), considered as mean values.

The results of this study supports the theory that modern additive technologies can produce rapidly and cost-effective precise and resistant patterns for conventional casting and pressing technique, representing a legitimate alternative to conventional wax-patterns prone to errors and deformations [15].

A widely used method to measure marginal and internal fit of dental crowns consist in sectioning the crown cemented on the abutment. Because it is a destructive method which requires a large number of specimens and because this method cannot be used in clinical practice, it was replaced with silicon replica technique [4]. This in conjunction with image analysis is not the most precise method to asses dental crowns adaptability, but it is a non-destructive method which allows non-invasive and multiple measurements in different stages of manufacturing procedures and it is suitable for clinical use before crown cementation, and it was validated and verified by a considerable number of studies [9, 16]. This technique

Table 1
MEAN VALUES (μm) FOR EACH POINT FOR RESIN PATTERNS (DLP), COPINGS (CST) AND FINAL CERAMIC PRESSED ON METAL CROWNS (POM)

	MG1	CG1	AG1	OG1	OG2	OG3	AG2	CG2	MG2
DLP	81.24	84.37	78.33	87.33	107.40	90.48	80.03	75.45	74.70
CST	98.22	88.06	84.44	91.75	111.08	101.49	90.69	85.03	94.48
POM	92.20	77.00	73.59	92.72	110.89	104.09	92.32	93.38	95.47

Table 2
MEAN VALUES (μm) FOR MARGINAL FIT (MF) AND INTERNAL FIT (IF) FOR RESIN PATTERNS (DLP), COPINGS (CST) AND FINAL CERAMIC PRESSED ON METAL CROWNS (POM)

	MF	IF
DLP	78.94	88.71
CST	91.22	95.89
POM	89.51	94.72

doesn't meet Groten et al proposed requirements to measure minimum 50 points for a single tooth evaluation, who's method consist in measuring marginal gap under microscope on a computer screen. This method has the advantage of multiple measurements in an nondestructive manner, but allows only vertical direction measurements, and offers no indication regarding internal fit [9].

Some researchers suggest that CAD/CAM systems provide consistent results as ceramic fused to metal technique implies use of die spacer to allow space for cement, which in conventional technology can vary due to die consistency, while in digital design this is established and it remains constant [17]. In this study all structures were prepared with an 50μm space for cement.

Some studies reveal differences between buccal and lingual surfaces, while other authors did not find significant differences between different surfaces[17]. In this study, silicone replicas were randomly cut in both mesio-distal and bucco-oral directions to allow measurements on all axial walls, so additional investigations are needed.

All technological steps and all evaluation were performed by the same operator to avoid as much as possible errors.

Conclusions

Within the limitations of this study, the following conclusions can be drawn:

Silicon replica technique in conjunction with image analysis is a non-destructive method which allows non-invasive and multiple measurements in different stages of manufacturing procedures and it is suitable for clinical use before crown cementation.

Best adaptation was found in resin-pattern group, with small increasing of gap after casting and after ceramic pressing. The mean marginal gap was 78.94μm for DLP, 91.22 μm for CST, and 89.51 μm for POM. The mean internal discrepancy was 88.71μm for DLP, 95.89 μm for CST, and 94.72μm for POM with higher discrepancy in occlusal area, but within the clinically accepted range.

Modern additive and subtractive technologies represent a reliable alternative to produce rapidly and cost-effective precise and resistant patterns for conventional casting of dental alloys and ceramic pressing, compared to conventional wax-patterns.

References

1. KIM K.B., KIM W.C., KIM H.Y., KIM J.H., An evaluation of marginal fit of three-unit fixed dental prostheses fabricated by direct metal laser sintering system, Dental materials, 29, 2013, e91-e96
2. FARJOOD E. VOJDANI M., TORABI K., REZA KHALEDI AA., Marginal and internal fit of metal copings fabricated with rapid prototyping and conventional waxing, The Journal of Prosthetic Dentistry, VOL. 117(1), p164-170
3. BHASKARAN E, AZHAGARASAN NS, MIGLANI S, ILANGO T, KRISHNA GP, GAJAPATHI B., Comparative Evaluation of Marginal and Internal Gap of Co-Cr Copings Fabricated from Conventional Wax Pattern, 3D Printed Resin Pattern and DMLS Tech: An In Vitro Study, J Indian Prosthodontic Soc. 2013 Sep;13(3):189-95
4. PARK J.Y., JEONG I.D., LEE J.J., BAE S.Y, KIM J.H., KIM W.C., In vitro assessment of the marginal and internal fits of interim implant restorations fabricated with different methods, The Journal of Prosthetic Dentistry, 116(4), 2016, 536-542
5. KOCAADAODLU H., KILINS H.I., ALBAYRAK H., KARA M., In vitro evaluation of marginal, and occlusal discrepancies in metal ceramic restorations produced with new technologies, The Journal of Prosthetic Dentistry, 116(3), 2016, 368-374
6. NAGIB, R., SZUHANEK, C., MOLDOVEANU, B., NEGRUTIU, M.L., DUMA, V.F., SINESCU, C., BRAD, S., Dimensional Study of Impacted Maxillary Canine Replicas 3d Printed Using to Tipes of Resin Materials, Mat. Plast., **55**, no. 2, 2018, p. 190
7. *** https://formlabs.com/blog/3d-printing-technology-comparison-sla-dlp/
8. STANSBURY J., IDACAVAGE M., 3D printing with polymers: challenges among expanding options and opportunities, Dental materials, 32, 2016, 54-64
9. KIM KB., KIM JH., KIM WC., KIM JH., Three-dimensional evaluation of gaps associated with fixed dental prostheses fabricated with new technologies, Journal of Prosthetic Dentistry, Vol. 112(6), 1432-1436
10. POMPA G., DI CARLO S., DE ANGELIS F., CRISTALLI MP., ANNIBALI S., Comparison of conventional methods and laser-assisted rapid prototyping for manufacturing fixed dental prostheses: an in vitro study, BioMed Research International, Article ID 318097, 7 pages Vofgl.2015
11. NESSE H., UKERVIK ULSTEIN D.M., VAAGE M.M., OTILO M., Internal and marginal fit of cobalt-chromium fixed dental prostheses fabricated with 3 different techniques. Journal of Prosthetic Dentistry, Vol. **114**(5) p 686-92.
12. NG J., RUSE D., WYATT C., A comparison of the marginal fit of crowns fabricated with digital and conventional methods, The Journal of Prosthetic Dentistry, Vol122(3), 2014, 555-560
13. POMPA G., DI CARLO S., DE ANGELIS F., CRISTALLI M.P., ANNIBALI S., Comparison of conventional methods and laser-assisted rapid prototyping for manufacturing fixed dental prostheses: an in vitro study, BioMed Research International
14. GUNSOY S., ULUSOY M., Evaluation of marginal/internal fit of chrome-cobalt crowns: Direct laser metal sintering versus computer-aided design and computer-aided manufacturing, Nigerian Journal of clinical Practice, vol.19(5), P 636-644
15.TALPOS, S., HAJAJ, T., TIMOFTE, C., RIVIS, STREIAN, F., POPA, M., SINESCU, C., NEGRUTIU, M.L., STAN, A., ZAHARIA, C., SZUHANEK, C., IANES, E., PRICOP, M., Implant Surgery Using Bio-compatible Guides, **55**, no. 1, 2018, p. 38
16. TAMAC E., TOKSAVUL S., TOMAN M., clinical marginal and internal adaptation of CAD/CAM milling, laser sintering, and cast METAL CERAMIC CROWNS, Journal of Prosthetic Dentistry, Vol.112(4), P 909-913
17. GONZALO E., SUAREZ MJ., SERRANO B.,LOZANO JFL., A comparison of the marginal vertical discrepancies of zirconium and metal ceramic posterior fixed dental prostheses before and after cementation, Journal of Prosthetic Dentistry, Vol.102(6), P 378-384

Manuscript received: 14.01.2018