Conventional impression *vs* intraoral scanner for CAD/CAM partial restorations

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SUMMARY

Purpose. The purpose of this study was to compare the effectiveness of the digital workflow in producing indirect milled restorations starting from a conventional impression technique and from an intraoral digital scanner. In our study we evaluated the accuracy of indirect partial restorations made of zirconia and lithium disilicate, with the two impression techniques.
Material and methods. Three first permanent molars with regular anatomy, on which MOD cavities for indirect restorations have been prepared, have been selected for the experimental models. For each experimental model, four impressions have been taken with the conventional technique, poured with hard plaster and scanned in a dental laboratory, and four impressions have been taken with the digital intraoral scanner. From each digital file two SLA epoxy resin models were 3D printed and two indirect restorations, one out of lithium disilicate and one out of zirconia, for a total of 48 models and 48 restorations.
Each restoration was tried on the corresponding SLA model and then seated in the master cavity on the original tooth. Each seated restoration was photographed on a stand for repeatability in order to measure and compare gaps at the cervical margin between restoration and tooth. All datas were recorded and undergone statistical analysis.
Results. For lithium disilicate restorations a mean marginal gap of 114.12 ± 88.82 µm has been detected for samples obtained with a conventional impression technique and of 33.55 ± 42.83 µm for samples obtained with a digital impression technique.
For zirconia restorations a mean marginal gap of 182.58 ± 76.56 µm has been detected for samples obtained with a conventional technique and of 114.52 ± 46.86 µm for samples obtained with a digital technique.
Conclusions. Within these experimental conditions, the digital impression technique produced better restorations in terms of marginal adaptation than the conventional impression technique. Moreover, for both techniques has been observed a substantial difference in the marginal adaptation of the two compared materials, with a better performance of lithium disilicate than zirconia. A fully digital workflow, with the limitations of an *in vitro* simulation, appears to increase the degree of reliability of CAD/CAM workflows.

Key words: dental ceramics, indirect partial restorations, digital and conventional impression techniques, marginal adaptation, CAD/CAM.

Introduction

In recent decades, the dental sector has been subject to profound changes dictated both by a scientific and technological progress and by a greater demand for aestetics by patients.

The introduction in the dental field of digital technologies, together with a progressive improvement in adhesive techniques and materials, has made it possible to achieve less invasive operations, aimed to reach the clinical goal of ensuring a better preservation of healthy dental tissue. The workflow through CAD/CAM (Com-

puter Aided Design/Computer Aided Manufacturing) systems and the ever-increasing spread of digital impression devices, is one of the greatest innovations in the dental sector of the last decades.
In the field of restorative and prosthetic dentistry, the taking of an impression is a crucial moment because the success of the restoration or the prosthetic device created, depends on its precision (1-3). A prosthetic or conservative indirect restoration with an unsatisfactory marginal adaptation will predispose to the onset of secondary caries, marginal microleakages, plaque accumulation and inflammation of the periodontal tissues (4).
Modern conventional impression compounds do have excellent chemical properties and an expert and rigorous technique allows an excellent adaptability to different clinical situations (5-7).
The conventional impression technique is complex as it can be affected by several variables: the operator, the clinical situation, the presence of undercuts, voids and deformations due to fluid contamination or elasticity of the material. Therefore, the conventional impression technique is claimed to be less standardizable than the digital intraoral impression (8, 9).
All mentioned variable in the conventional technique can lead to inaccuracies that can affect the quality of the impression, resulting in inaccuracy of the plaster model and therefore of the final restoration. Nevertheless, it is well known that, in accordance with the instructions of the material manufacturer and the protocols, the conventional technique has provided and still provides excellent results.
The digital technique on the other hand, involves the use of an intraoral scanning device that records the morphology of the dental tissues (10) directly generating a virtual 3D model and avoiding the physical reproduction phase of the plaster model.
The digital impression allows a standardization of operating procedures by reducing the number of different steps prior to the generation of a virtual 3D model. The use of an intraoral digital scanner results in a lower risk of error diminishing the variables described above (10-12). It also makes it possible to drastically reduce the number of clinical steps needed to carry out the restoration, thus significantly affecting operating times and costs. Despite the numerous positive aspects of this technique, it is not free of potential disadvantages as an irregular deposition of dust on surfaces (for devices that need it), incorrect scanner placement, insufficient data acquisition or inadequate cavity preparation, which makes it difficult for the beam of light emitted by the scanner to penetrate in small spaces such as inside a gingival sulcus (13, 14).
The main objective of modern restorative and prosthetic dentistry techniques is to obtain an optimal result at the lowest biological price possible (14-16). This attitude, aimed to save all the healthy dental tissue, must guide any tooth preparation stage and should represent the first choice, when we talk about treatments complying with biology (17).
The use of indirect partial restorations such as inlays, onlays and overlays, consents the achievement of this objective in many ways: allowing a better supervision of occlusal contacts and contact areas (18, 19), a reduction in polymerization stress compared with a direct restoration with composite resin (19-21), a correct distribution of occlusal forces and an excellent aesthetic performance in full compliance with the surrounding soft tissues (20, 22-24).
Indirect partial restorations can be made of composite or ceramic material, and the mechanical strength of the material is a fundamental parameter for their success, especially when used in restoring the elements of the posterior regions (19, 25).
Another important aspect to consider is the onset of mandibular temporal disorders (TMD) (26) due to occlusal interferences. Several studies have demonstrated that the use of occlusal adjustment might prevent the development of TMD and the exacerbation of its symptoms (27-29).
The modern ceramic materials, thanks to their excellent aesthetic performance, which allows them to simulate the optical properties of enam-

el and dentine, and also thanks to their properties (30, 31), represent one of the most successful choices for functional and aesthetic restorations (32).
The dental ceramics are divided into etchable and non-etchable and classified according to their microstructure in glassy ceramics, polycrystalline ceramics and glassy ceramics containing crystalline component (30).
The lithium disilicate is a glassy, etchable ceramic with high clinical performances in manufacturing veneers, indirect partial restorations and single crowns on front and rear elements. Due of its mechanical strength, lithium disilicate finds no indication for extended fixed prostetics like bridges (30, 33).
Zirconia is a non-etchable polycrystalline ceramic with a higher flexural and fracture resistance than most of all the other ceramic materials available on the market (33). Both materials, lithium disilicate and zirconia, are milled ceramics used for CAD/CAM production but differ in the production processes after milling.
The precision of the milling phase of the ceramic materials is influenced by the number of axes of the milling machine: 5-axis devices are, in fact, more accurate than those with 4 axes (34).
The purpose of this work was to verify in the *in vitro* simulation system, the degree of accuracy of indirect, zirconia and lithium disilicate restorations made with a CAD/CAM technology, by comparing the two impression techniques - the conventional and the digital one.

Materials and methods

For this study three permanent maxillary first molars with regular anatomy extracted for periodontal reasons have been selected.
Each tooth was mounted on a pink acrylic resin base to simulate the typical gum color and shape, along with a second molar and a second premolar to reproduce a realistic clinical situation of a posterior region.
This setup was made to recreate the real complexities of an impression taking because of the presence of other teeth in contact with the prepared tooth.
Three master models have been created and named *master model A, B, C*.
A Mesio-Occluso-Distal (MOD) cavity for indirect restorations (Figures 1, 2, 3) has been created on each master model by an expert operator. Cavities were prepared with high-speed diamond burs, medium and fine grain, with a divergent angle of 6° and a rounded angle between the floor and the axial wall. Each cavity had a minimum depth of 3 mm in the central area and a maximum of 6 mm in the mesial and distal boxes.

Figure 1
Mesio-Occluso-Distal (MOD) cavity for indirect restorations. Sample A.

Figure 2
Mesio-Occluso-Distal (MOD) cavity for indirect restorations. Sample B.

Figure 3
Mesio-Occluso-Distal (MOD) cavity for indirect restorations. Sample C.

The prepared master models were always kept in acqueous solution in order to avoid dissecation prior to or after impressions.
For each experimental model four impressions using the conventional technique and four impressions using the digital technique have been taken. Each impression has been used for the production of a lithium disilicate inlay IPS e.max® CAD (IvoclarVivadent) and an extra translucent zirconia (Zircodent - Orodent) inlay, for a total of 48 restorations to be analyzed.
For the taking of the conventional silicone impressions, four acrylic resin individual perforated impression trays were prepared for each master model (a total of 12 impression trays). The impression taking has been carried out using a two-component, mono-phase technique and two polyvinyl-siloxanes in 50 ml cartridges with different degrees of viscosity: Aquasil Ultra Rigid Regular set Smart Wetting® Impression Material (Dentsply) with heavy viscosity (ISO 4823) and Aquasil Ultra LV Regular set Smart Wetting® Impression Material (Dentsply) with light viscosity (ISO 4823). The extrusion system used was the Dentsply Caulk cartridge dispenser with its mixing tips.
The heavy material was placed on the impression tray then the light material was put on both the heavy material and in the cavity on the master model and kept in place respecting the setting time indicated by the manufacturer.
For the digital impression technique, we used a Trios 3Shape, which is a digital intraoral scanner based on laser confocal microscopy technology. For each master model four digital scans have been made, for a total of 12 STL files.
Both the conventional impressions and the STL files related to master model scans have been sent to the reference dental lab.
From each conventional impression, an extra hard stone model (Fuji Rock EP Type IV) has been produced, which has subsequently been scanned with an extraoral scanner (InEos X5 Sirona), thus creating another 12 STL files to enter the digital workflow.
For each STL file, have been produced a pair of light cured, epoxy resin (Accura® XM247) SLA models (Stereo Lithography Apparatus) with a digital printer (3D System IPro8000), reproducing the only sample element on which the MOD preparation has been applied. The SLA models have been made with 0.05 mm thick layer applications and each layer has been cured with UV laser beam. At the end of each application, each SLA model has been subject to a further laser light curing cycle for the complete solidification of the outer surface.
For each STL file the restoration has been planned and the milling parameters have been set. The milling of lithium disilicate restorations has been carried out with a four-axis Vhf N4 device, while the milling of zirconia restorations has been carried out with a five-axis Vhf K5 device.
Lithium disilicate restorations have been made with IPS e.max® ceramic (IvoclarVivadent), milled in a partial crystallization state, so that it can be easily worked with CAD/CAM systems. The dimensional compaction of 0.2%, which takes place during the completion of the crystallization process has been considered.
After the milling, the baking process has been completed to reach a total crystalline state, in which the structure has 70% of lithium disilicate crystals ($Li_2Si_2O_5$), immersed in a glass matrix and in which the typical biaxial resistance of 360MPa is achieved. The protocol has considered a firing temperature of 850°C, which has been achieved with a monitored heat increase of

30°C per minute and maintained for 10 minutes. Finally, a slow cooling up to 700°C and a subsequent cooling with a turned-off device has been carried out.
Zirconia restorations have been milled from extra translucent zirconia discs (Zircodent by Orodent) with a final biaxial endurance of 1200 MPa. Starting from an ambient temperature, the sintering protocol used after the milling process has considered a heat increase of 10°C per minute up to 300°C and of 5°C per minute up to the final sintering temperature of 1500°C, which has been maintained for 60 minutes. After this time, monitored cooling has been carried out with a heat decrease of 7°C per minute up to 750°C and then of 20°C per minute up to 250°C. Once the 250°C have been reached, a cooling with an open furnace at ambient temperature has been carried out.
Given the willingness to evaluate differences in the degree of reliability between direct and semi-direct digital workflows, it has been decided not to carry out any adjustment of the restorations.
For analysis of the marginal adaptation, after the elimination of the adjacent elements, a photographic acquisition has been carried out under standardized conditions of the mesial and distal walls of each restoration.
Each restoration was tested on the corresponding SLA model and then seated in the master model for evaluation of gaps at cervical margin (Figure 4 a, b). Each restoration, seated in the relative master model, was then photographed in mesial and distal view and the resulting 192 images were then elaborated and measured using Autodesk® AutoCAD® 2018 software. Three measuring points have been identified on each cervical margin. Two points corresponded to the extremes of the cervical margin and a middle point between the first two. All measured gaps were recorded and compared for statistics.

Results

For lithium disilicate restorations a mean marginal gap of 114.12 ± 88.82 μm has been detected for samples obtained with a conventional impression technique and of 33.55 ± 42.83 μm for samples obtained with a digital impression technique.
For zirconia restorations a mean marginal gap of 182.58 ± 76.56 μm has been detected for samples obtained with a conventional technique and of 114.52 ± 46.86 μm for samples obtained with a digital technique (Figure 5).

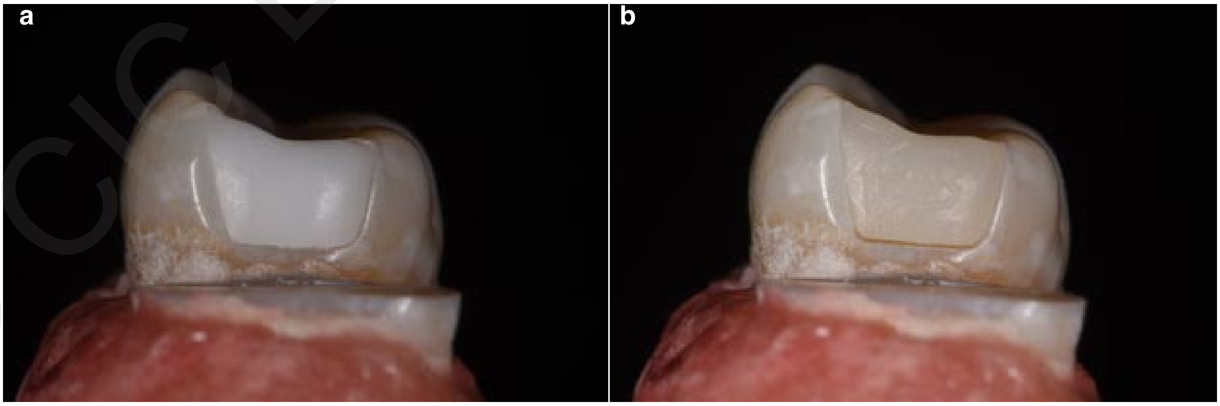

Figure 4
a) Zirconium indirect restoration, seated in the relative master model. b) Lithium Disilicate indirect restoration, seated in the relative master model.

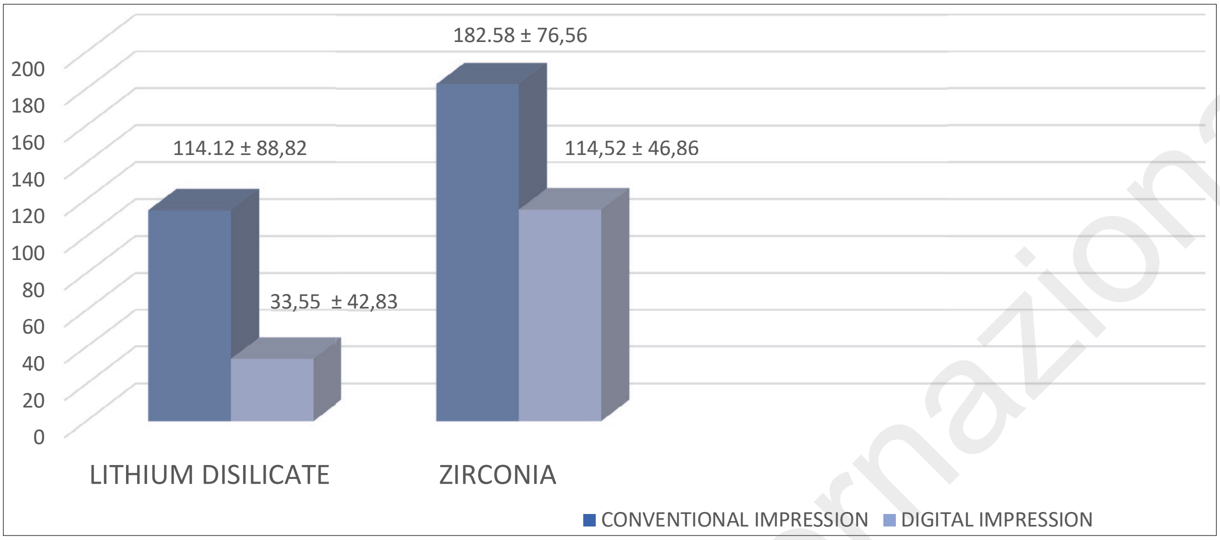

Figure 5
Mean of marginal gap (μm) on master model.

Discussion

Data analysis subjects that in almost all samples the digital impression technique produced restorations with a better marginal adaptation than the conventional impression technique.
The impression technique used was certainly a variable that could influence the final result.
The conventional technique has probably been affected by the many variables that characterize its workflow, contributing to the production of restorations with a higher mean marginal gap than those achieved with the digital technique. These ones on the other hand, due to their easy standardization and to the fewest steps required, have resulted in restorations with a better marginal adaptation and with much lower standard deviation. Comparing the two tested different ceramic materials, lithium disilicate restorations performed better than zirconia. This result is in agreement with what is reported in literature (30, 32, 33, 35, 36), even if lithium disilicate restorations were milled with a four axis when zirconia with a five axis CAM device. The better performance of the lithium disilicate was not related to the impression technique or the different digital workflows but it must be related to the milling phase and probably even more to the final heat treatment that is performed on the material.
SLA 3D models are not sufficiently precise to test the fitting of a milled restoration and are probably not compatible with the clinical standards required in prosthetic dentistry.

Conclusion

In determining the success of an indirect partial restoration made from ceramic material, several variables are involved. The precision and accuracy of the impression are crucial parameter since the whole digital production workflow will be affected with the risk of producing a final restoration with poor fitting or precision.
The digital technique, compared to the conventional technique, behaved significantly better in terms of marginal adaptation of the restoration, as it is subject to fewer variables, and this is in accordance with what is reported in literature (1, 2, 12). At the same time, it is possible to observe that different milled ceramics can produce dif-

ferent results in terms of marginal adaptation thus to their clinical performances.
Based on the outcomes of this study, lithium disilicate in a CAD/CAM workflow has generated in almost all samples better marginal adaptation levels than those obtained from zirconia (37). This leads to the conclusion that a fully digital workflow starting with a high precision intraoral scanning device reduces effectively the processing phases resulting in fewer potential errors. A deep knowledge of the characteristics of the restorative material and of all the workflow is a crucial part of the clinical restorative planning and final success in producing high precision indirect restorations.

References

1. Ender A, Mehl A. Full arch scans: conventional versus digital impressions. An in-vitro study. Int J Comput Dent. 2011;14 (1):11-21.
2. 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.
3. Rhee YK, Huh YH, Cho LR, Park CJ. Comparison of intraoral scanning and conventional impression techniques using 3-dimensional superimposition. J Adv Prosthodont. 2015;7(6):460-67.
4. Park JY, Bae SY, Lee JJ, Kim JH, Kim HY, Kim WC. Evaluation of the marginal and internal gaps of three different dental prostheses: comparison of the silicon replication technique and three-dimensional superimposition analysis. J Adv Prosthodont. 2017;9(3):159-69.
5. Hamalian TA, Nasr E, Chidiac JJ. Impression materials in fixed prosthodontics: Influence of choice on clinical procedure. J Prosthodont. 2011;20:153-60.
6. Perakis N, Belser UC, Magne P. Final impressions: a review of material properties and description of a current technique. Int J Periodontics Restorative Dent. 2004;24(2):109-17.
7. Spoto G. Dental Materials Teachers and Prosthetic Laboratory Technologies of Italian Universities: Odontostomatologic Materials and Technologies. Ariesdue. 2013.
8. Samet N, Shohat M, Livny A, Weiss EI. Clinical evaluation of fixed partial denture impressions. J Prosthet Dent. 2005;94(2):112-17.
9. Storey D, Coward TJ. The Quality of Impressions for Crowns and Bridges: An assessment of the work received at three commercial dental laboratories, assessing the quality of the impressions of prepared teeth. Eur J Prosthodont Restor Dent. 2013;21(2):53-7.
10. Gjelvold B, Chrcanovic BR, Korduner EK, Collin-Bagewitz I, Kisch J. Intraoral Digital Impression Technique Compared to Conventional Impression Technique. A Randomized Clinical Trial. J Prosthodont. 2016;25(4):282-87.
11. Tortiglione L, De Franco M, Bosetti G. The Prosthetic Workflow in the Digital Age. Int J Dent. 2016;(3):1-7.
12. Seelbach P, Brueckel C, Wöstmann B. Accuracy of digital and conventional impression techniques and workflow. Clin Oral Investig. 2013;17(7):1759-64.
13. Kim JH, Kim Kim, Kim SH, Kim WC, Kim HY, Kim JH. Quantitative evaluation of common errors in digital impression obtained using a LED blue light in-office CAD/CAM system. Quintessence internationals. 2015;46(5):401-7.
14. Munich C, Ori G. The optical impression in the prosthesis. Italian Committee for the Coordination of Scientific Dentistry Societies. 2017.
15. Tundo GR, Sbardella D, Ciaccio C, De Pascali S, Campanella V, Cozza P, Tarantino U, Coletta M, Fanizzi FP, Marini S. Effect of cisplatin on proteasome activity. J Inorg Biochem. 2015 Dec;153:253-258.
16. Libonati A, Marzo G, Klinger FG, Farini D, Gallusi G, Tecco S, Mummolo S, De Felici M, Campanella V. Embryotoxicity assays for leached components from dental restorative materials. Reprod Biol Endocrinol. 2011 Oct 6;9:136. doi: 10.1186/1477-7827-9-136.
17. Bottacchiari S. Composite inlays. Structural, periodontal and endodontic aspects. 2016. Quintessence editions.
18. Fuzzi M, Rappelli G. Survival rate of ceramicinlays. J Dent. 1998;26(7):623-26.
19. Morimoto S, Rebello de Sampaio FBW, Braga MM, Sesma N, Özcan M. Survival rate of resin and ceramic inlays, onlays and overlays: a systematic review and meta-analysis. J Dent Res. 2016;95(9): 985-94.
20. Nikolopoulou F, Loukidis M. Critical review and evaluation of composite/ceramic onlays versus crowns. Dentistry. 2014;4(9):261.
21. Shor A, Nicholls JI, Philips KM, Libman WJ. The fatigue load of teeth was restored with bonded direct composite and indirect ceramic inlays in MOD class II cavity preparations. Int J Prosthodont. 2003;16(1):64-9.
22. Hamdy A. Effect of full coverage, endocrowns, onlays, inlays restorations on fracture resistance of endodontically treated molars. J Dental and Oral Health. 2015.
23. D'Amario M, De Angelis F, Vadini M, Marchili N, Mummolo S, D'Arcangelo C. Influence of a repeated preheating procedure on mechanical properties of three resin composites. Oper Dent. 2015 Mar-Apr;40(2):181-9. doi: 10.2341/13-238-L.
24. Ballesio I, Angotti V, Gallusi G, Libonati A, Tecco S, Marzo G, Campanella V. Durability of adhesion between an adhesive and post-space dentin: Push-out

evaluation at one and six months. International Journal of Adhesion and Adhesives. 2012;38:75-8.
25. Gallusi G, Galeano P, Libonati A, Giuca MR, Campanella V. Evaluation of bond strength of different adhesive systems: Shear and Microtensile Bond Strength Test. Oral Implantol (Rome). 2009 Oct;2(4):19-25. Epub 2010 May 25.
26. Tecco S, Mummolo S, Marchetti E, Tetè S, Campanella V, Gatto R, Gallusi G, Tagliabue A, Marzo G. sEMG activity of masticatory, neck, and trunk muscles during the treatment of scoliosis with functional braces. A longitudinal controlled study. J Electromyogr Kinesiol. 2011 Dec;21(6):885-92.
27. Ottria L, Candotto EV, Guzzo F, Gargari M, Barlattani A. Temporomandibular joint and related structures: anatomical and histological aspects. J Biol Regul Homeost Agents. 2018. Jan-Feb;32(2 Suppl.1):203-7.
28. Ottria L, Lauritano D, Guzzo F, Gargari M, Barlattani A. Anatomic relationship between temporomandibular joint and middle ear. J Biol Regul Homeost Agents. 2018. Jan-Feb;32(2 Suppl.1):209-12.
29. Ottria L, Candotto EV, Guzzo F, Gargari M, Barlattani A. TMJ's capsule histological and macroscopical study: relationship between ligamentous laxity and TMI disfuctions. J Biol Regul Homeost Agents. 2018 Jan-Feb;32(2 Suppl.1): 213-26.
30. Kelly JR, Benetti P. Ceramic materials in dentistry: historical evolution and current practice. Aust Dent J. 2011;56(1):84-96.
31. Türk AG, Sabuncu M, Ünal S, Önal B, Ulusoy M. Comparison of the marginal adaptation of direct and indirect composite inlay restorations with optical coherence tomography. J Appl Oral Sci. 2016;24(4):383-90.
32. Srinivasa Raju Datla, Rama Krishna Alla, Venkata Ramaraju Alluri, Jithendra Babu P, Anusha Konakanchi. Dental Ceramics: Part II - Recent Advances in Dental Ceramics. American Journal of Materials Engineering and Technology. 2015;3(2):19-26.
33. Giordano R, McLaren EA. Ceramic overview: classification by microstructure and processing methods. Compend Contin Educ Dent. 2010;31(9):682-84, 686, 688 passim; Quiz 698,700.
34. Park JI, Bae SY, Lee JJ, Kim JH, Kim HY, Kim WC. Evaluation of the marginal and internal gaps of three different dental prostheses: comparison of the silicone replica technique and three-dimensional superimposition analysis. J Adv Prosthodont. 2017;9(3):159-69.
35. Marrelli M, Puja A, Palmieri F, Gatto R, Falisi G, Gargari M, Caruso S, Apicella D, Castelli C, Nardi GM, Paudano F, Tatullo M. Innovative approach for the in vitro research of biomedical scaffolds designed and customized with CAD-CAM technology. Int J of Immunopathol and Pharmacol. 2016;29(4):778-83.
36. Sannino G, Germano F, Arcuri L, Bigelli E, Arcuri C, Barlattani A. Cerec CAD-CAM chairside system. Oral and Implantology. 2014;7(3):57-70.
37. Gargari M, Ottria L, Morelli V, Benli M, Ceruso FM. Conservative Zirconia-Ceramic bridge in front teeth. Case report. Oral and Implantology. 2014;vol. VII (No 4):93-8.

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