Abstract: Purpose: Two important factors in dental prosthesis are making an accurate impression and producing a suitable cast which represents the exact relationship between prepared tooth and oral structures. This study, aimed to investigate the effects of different combinations of impression and pouring materials on marginal and internal adaptation of premolar zirconia crowns.

Material and Methods: Forty maxillary premolars were prepared considering round shoulder finish line. The impressions were made either by additional (Panasil) or condensation (Speedex) silicon, and poured by two different types of gypsum materials (Siladent or GC gypsum) (N=10). Zirconia crowns were fabricated using a CAD-CAM system. The crowns were cemented, and the samples were cut in bucco-lingual direction. Marginal and internal gaps were measured by stereomicroscope (×25).

Results: The mean marginal gaps for Panasil-Siladent, Panasil-GC, Speedex-Siladent, and Speedex-GC were 141 μm, 143 μm, 131 μm, and 137 μm respectively. The internal gaps were 334 μm, 292 μm, 278 μm, and 257 μm respectively. The independent T-Student test showed no significant differences in average marginal or internal gap among various impression and gypsum materials or their interactions (p>0.05). Two-way ANOVA test showed no significant differences in maximum marginal or internal gap among various impression and gypsum materials and their interactions (p>0.05).

Conclusion: The present study revealed no statistically significant difference in marginal/internal gap among crowns prepared using different combinations of impression-pouring materials evaluated.

Keywords: Dental restoration; Gypsum; Internal gap; Impression material; Marginal gap.

Resumen: Introducción: Dos factores importantes en la prótesis dental son hacer una impresión precisa y la producción de un modelo adecuado que represente la relación exacta entre el diente preparado y las estructuras orales. Este estudio, tuvo como objetivo investigar los efectos de diferentes combinaciones de materiales de impresión y vertido sobre la adaptación marginal e interna de coronas de circonio premolar. Material y Métodos: Se prepararon cuarenta premolares maxilares considerando la línea de meta del hombro redondo. Las impresiones se realizaron con silicio adicional (Panasil) o
de condensación (Speedex) y se vertieron con dos tipos diferentes de materiales de yeso (yeso Siladent o GC) (N = 10). Las coronas de zirconio se fabricaron utilizando el sistema CAD-CAM. Las coronas se cementaron y las muestras se cortaron en dirección buco-lingual. La brecha marginal e interna se midió con estereomicroscopio (×25).

**Resultados:** Las brechas marginales medias para Pansil-Siladent, Panasil-GC, Speedex-Siladent y Speedex-GC fueron de 141μm, 143μm, 131μm y 137μm, respectivamente. Las brechas internas fueron 334μm, 292μm, 278μm y 257μm, respectivamente. La prueba de T-Student independiente no mostró diferencias significativas en la brecha marginal o interna promedio entre varios materiales de impresión y yeso o sus interacciones (p>0.05). La prueba ANOVA bidireccional no mostró diferencias estadísticamente significativas en la brecha marginal/interna entre las coronas preparadas con diferentes combinaciones de materiales de impresión y vertido evaluados.

**Conclusión:** El presente estudio no reveló diferencias estadísticamente significativas en la brecha marginal/interna entre las coronas preparadas con diferentes combinaciones de materiales de impresión y vertido evaluados.

**Palabra Clave:** Restauración dental; Yeso; Brecha interna; Material de impresión; Brecha marginal.

**INTRODUCTION.**

Although digital procedures changed many criteria in routine dental practices, making an accurate oral impression and fabricating an accurate cast, still play important roles in accurate prosthesis fabrication.

The poured impression should record the accurate details of the prepared tooth and the precise relation to surrounding structures. Nowadays, silicone elastomers (either condensation or additional) are among the most prevalent impression materials used for dental or implant impressions in a variety of situations.

However, the impression material is not the only factor that affects the recording of accurate details, another factor to consider is the pouring material. Different types of dental gypsums are available that can be classified based on ISO-6873 into five main types:

- type I- impression plaster,
- type II- pouring plaster,
- type III- pouring stone,
- type IV- high strength and low expansion die stone,
- type V- high strength and high expansion gypsum.

Type IV is the most prevalent type in pouring accurate cast and die. The compatibility of pouring and impression materials, and the compensation potential of gypsum for dimensional changes of impression material, along with the porosity, strength, accuracy, and stability of pouring material are important factors on the final results. There has been a continuing controversy in the literature about the compatibility of impression and pouring materials (Table 1).

The material compatibility could affect the accuracy and durability of the final end-result. Marginal and internal adaptation of dental prosthesis are among the most important factors that affect long-term prosthesis success, and reflect the accuracy of the fabrication process.

Increased marginal discrepancy will increase the possibility of cement exposure to oral fluids, and that will enhance microleakage, cement solubility, recurrent caries, and periodontal problems. Marginal adaptation is defined as the discrepancy between prepared finish-line and the restoration margin, and could be classified as vertical, horizontal, and absolute marginal gap, or over/under extension according to Holmes et al. The routinely investigated absolute gap is measured from the margin of restoration to the cavosurface angle of the prepared tooth finish line. The internal adaptation, on the other hand, affects the retention, resistance, and mechanical support of restorations.

According to the lack of adequate research and controversial results on the role of applied material compatibility on the marginal and internal preciseness of zirconia crowns, it seems necessary to consider and investigate this subtle but important factor.

This study aimed to investigate the effect of four combinations of impression/pouring materials on the accuracy of final end-result: marginal and internal adaptation of zirconia crowns fabricated by computer assisted technology (CAD-CAM). The null hypotheses were that there are significant differences in marginal and also internal gaps of fabricated zirconia crowns between different combinations of impression/pouring materials.
MATERIALS AND METHODS.

The study protocol was approved by the institutional ethics committee (IR.JSUMS.REC.1394-056); all patients gave their informed consent for use of the extracted teeth, and the study was performed considering the ethical standards of the revised Helsinki Declaration.

Forty maxillary premolar teeth were selected among intact, caries and restoration-free premolars extracted for orthodontic purposes. The teeth were kept in a sealed container in saline and diluted bleach for 24 hours. Afterwards, the teeth were inserted into acrylic blocks along their long axis.

Tooth preparation was made by diamond burs (Jota AG, Hirschensprungstrasse, Switzerland) considering 2mm occlusal reduction, 12 degrees of taper, and round shoulder finish-line with 1.5mm depth; the prepared surfaces were polished. All the preparations were performed by a prosthodontist. The teeth were randomly divided into two groups of 20 samples according to the impression materials used for impression making. Twenty impressions were made by additional silicone (putty fast and extra light consistency, Polyvinylsiloxane, Panasil, Kettenbach GmbH & Co. KG, Eschenburg, Germany), and 20 by condensation silicone (Putty and light consistency, Condensation silicone, Speedex, Coltene/Whaledent co, Altstätten, Switzerland) using a two-stage method.

Each group was randomly divided to two subgroups (n=10) to be poured by two different type IV dental gypsums: Siladent gypsum (Marmoplast N, Dr. Böhme & Schöps GmbH, Goslar, Germany), or GC gypsum (GC Fujirock EP, GC America Inc, Patterson dental, Saint Paul, America) hour after impression making. The casts were scanned (D810 3shape Trios, Copenhagen, Denmark); pre-sintered high translucent zirconia crowns (DDcubeOne, Dental direkt GmbH, Spenge, Germany) were milled by milling machine (CORiTEC 350i, imes-icore GmbH, Eiterfeld, Germany), and sintered in long program up to 1450o C for 16 hours according to

Figure 1. Absolute marginal adaptations by direct observation with a stereomicroscope (×25).

A: The samples were cross-sectioned bucco-lingually, ready to be directly evaluated under stereomicroscope. B: Stereo microscope photograph from cross-sectioned samples. C: Cement thickness measurements are provided in different zones.

Figure 2. Schematic drawing of different internal and marginal gaps measured in this study.
**Table 1.** Main results from studies evaluating impression and pouring materials compatibility.

| Study | Impression materials used | Pouring materials used | Conclusion |
|-------|---------------------------|------------------------|------------|
| Morrow et al.⁹ | Alginate:  
  Alginate Compound  
  DP Elastic Compound  
  Jeltrate  
  Kalginate | Gypsum:  
  DiKeen  
  Glastone  
  Stone  
  True-Stone  
  VelMix | Di-Keen was more compatible with impression materials than other stones.  
 Jeltrate was more compatible with dental stones than other impression materials.  
 The Di-Keen-Jeltrate combination was the most compatible combination, but not statistically better than DiKeen-DP, and VelMix-Jeltrate combinations. |
| Owen et al.⁹ | Alginate:  
  Blueprint Rapid  
  Colourgel  
  GC Fast-set Technicol  
  GC Vericol Aroma  
  Kalginate, fast-set  
  err Alginate, fast-set  
  S.S. White, normal set  
  Zelgan Green, fast-set  
  Zelgan Pink, normal-set | Gypsum:  
  EPI  
  Yellow stone (Kaffir D)  
  Kerr Ortho stone  
  Peaeh stone  
  Plaster of Paris  
  Vel-Mix (50:50 mixture of plaster of Paris and yellow stone) | Results obtained varied: Sometimes producing marked improvement in surface quality of subsequent gypsum casts was identified |
| Butta et al.¹⁰ | Additional silicones:  
  Examix-NDS  
  Doric-ES Flo-Light  
  Panasil Contact Plus  
  Extrude Wash  
  President Plus Jet | Type IV gypsum:  
  SilkyRock  
  Fuji Rock  
  Suprastone  
  Vel-Mix | Different impression materials showed different compatibility with different Type IV gypsums:  
 Super stone made 88% of completely reproduce casts |
| Chang et al.¹¹ | Alginate:  
  Algiace Z  
  Cavex  
  Jeltrate  
  Silicone:  
  Aquasil LV  
  Coltex fine  
  Exaflex  
  Regula  
  Take1 | Gypsum:  
  MG crystal rock  
  super hard stone  
  MS plaster | Same accuracy  
 More roughness in alginate than silicone  
 Alginate cannot replace silicone rubber base |
| Vadapalli et al.¹² | Polyvinyl-siloxane:  
  Impergum  
  Polyether: aquasil | Gypsum | In dry conditions both materials performed almost equally  
 In moist conditions Aquasil performed better than Impregum |
| Santini et al.¹³ | Addition silicone:  
  Exaflex Vinyl | Type III Gypsum:  
  Heraeus Kulzer Moldadur Dental Stone  
  Type IV Gypsum:  
  Heraeus Kulzer Die Stone Peach | Type IV gypsum was more compatible with addition silicone than type III gypsum |
manufacturer instructions. Cement space was set at 30 microns, started 1mm from the finish line. No adjustment was necessary for either of the groups, and sitting was confirmed by two independent expert observers for each crown.

Each crown was cemented on the tooth abutment by dual-cure resin cement (Panavia F2, Kuraray Noritake Dental Inc, Okayama, Japan). Twenty four hours later, each tooth-crown complex was sectioned using Mecatome (Mecatome T210, Presi GmbH, Angonnes, France) in the mid mesio-distal dimension on the line connecting buccal to palatal cusp tip. Absolute marginal and also internal adaptations were evaluated by direct observation under stereomicroscope (x25) (Figure 1).

### Table 2. Descriptive information on marginal adaptation of evaluated groups (All the measurements are in µm).

| Marginal gap | Panasil+Siladent | Panasil+GC | Speedex+Siladent | Speedex+GC |
|--------------|-----------------|------------|-----------------|------------|
|              | Buccal          | Lingual    | Buccal          | Lingual    |
| Mean (SD) µm | 132.74          | 149.85     | 178.36          | 108.18     |
|              | (58.61)         | (63.31)    | (82.21)         | (54.74)    |
| Max          | 230.99          | 247.08     | 293.86          | 222.22     |
| Min          | 68.71           | 64.33      | 52.63           | 30.7       |

### Table 3. Descriptive information on internal adaptation of evaluated groups (All the measurements are in µm)

| Group          | Internal gap | Mid Buccal- µm | Buccal Cusp- µm | Central Fossa- µm | Lingual Cusp- µm | Mid Lingual- µm |
|----------------|--------------|----------------|-----------------|-------------------|------------------|-----------------|
| Panasil+Siladent | Mean (SD)    | 128.06 (47.21) | 568.21 (279.08) | 298.34 (70.56)    | 581.70 (279.08)  | 94.29 (85.68)   |
|                | Max          | 513.16         | 1095.18         | 372.30            | 937.55            | 328.95          |
|                | Min          | 17.54          | 301.05          | 124.22            | 216.72            | 21.93           |
| Panasil+GC     | Mean (SD)    | 75.58 (63.49)  | 455.55 (150.07) | 342.02 (43.05)    | 452.25 (156.82)   | 139.47 (66.66)  |
|                | Max          | 236.84         | 672.44          | 431.45            | 678.95            | 232.46          |
|                | Min          | 30.70          | 188.80          | 301.16            | 168.73            | 57.02           |
| Speedex+Siladent | Mean (SD)   | 90.79 (45.19)  | 444.85 (114.67) | 370.15 (133.27)   | 386.09 (183.62)   | 101.75 (37.54)  |
|                | Max          | 162.28         | 601.26          | 609.05            | 667.74            | 153.51          |
|                | Min          | 30.70          | 267.07          | 210.25            | 110.44            | 35.09           |
| Speedex+GC     | Mean (SD)    | 80.26 (66.35)  | 431.53 (110.05) | 340.38 (71.62)    | 353.56 (126.21)   | 79.38 (25.52)   |
|                | Max          | 201.75         | 614.97          | 426.10            | 599.23            | 118.42          |
|                | Min          | 13.16          | 321.09          | 225.85            | 209.28            | 43.86           |

### Table 4. Internal and marginal gaps in different combination of impression materials and pouring stone (All the measurements are in µm)

| Index          | Impression | Gypsum | Minimum | Maximum | Mean     | Std. Deviation |
|----------------|------------|--------|---------|---------|----------|---------------|
| Marginal gap (µm) | Panasil    | Siladent | 66.52   | 190.79  | 141.30   | 44.18         |
|                 |            | GC     | 63.60   | 220.03  | 143.27   | 48.93         |
|                 | Speedex    | Siladent | 99.42   | 165.94  | 131.50   | 24.21         |
|                 |            | GC     | 84.07   | 182.75  | 137.01   | 30.93         |
| Internal gap (µm) | Panasil    | Siladent | 198.33  | 533.68  | 334.12   | 107.76        |
|                 |            | GC     | 166.80  | 371.14  | 292.98   | 63.30         |
|                 | Speedex    | Siladent | 156.47  | 378.83  | 279.12   | 77.68         |
|                 |            | GC     | 180.60  | 356.82  | 257.02   | 56.96         |
Marginal measurements were made three times in buccal and lingual finish lines for each sample, and the mean quantity was reported as a marginal gap in each side. For internal adaptation, five measurements were made for each sample in mid-buccal, mid-lingual, buccal and lingual cusp tips, and central fossa (Figure 2).

The results were analyzed using two-way ANOVA, and independent T-test.

RESULTS.

Table 2 and Table 3 summarize descriptive analyses for marginal and internal gaps respectively; Table 4 presents the effect of different combinations of impression and pouring materials on marginal and internal gaps.

The results confirmed that neither the impression material type (\(p=0.512\)), nor the gypsum type (\(p=0.760\)) had a significant effect on marginal adaptation of zirconia crowns, and the interaction between impression material and gypsum type also had no significant effect on marginal adaptation (\(p=0.885\)).

Internal adaptation showed the same pattern of results; neither the impression material type (\(p=0.077\)), nor the gypsum type (\(p=0.213\)) had significant effect on internal adaptation of zirconia crowns, and the influence of interaction between impression material and gypsum type was not significant (\(p=0.705\)).

The statistical analyses of maximum measurements by two-way ANOVA showed that maximum quantity of marginal gap of different groups was not affected significantly by impression materials (\(p=0.342\)), or gypsum types (\(p=0.338\)).

The impression material (\(p=0.080\)), or type of pouring material (\(p=0.051\)) also had no significant effects on maximum internal adaptations. Even the interaction between these two varieties caused no significant change in maximum marginal (\(p=0.742\)), or maximum internal (\(p=0.161\)) adaptation of zirconia crowns.

DISCUSSION.

Different factors affect success and longevity of restorative treatments; among them, the adaptation of prosthesis may play a special role. Marginal adaptation is the decisive factor in probability of occurrence of caries and periodontal problems. Internal adaptation, on the other hand, determines stability and retention of the prosthesis that might be even more important in special situations of short abutment, or higher bite forces. The fabrication steps are critical factors in the accuracy of laboratory made restorations.

Wide range of routinely used impressions and pouring materials, and their interactions are among pivotal issues to be considered. Elastomeric impression materials are the most prevalent materials used in every-day prosthetic practices. Condensation and additional silicones are still applied frequently despite significant improvements in digital dentistry. After impression making, the impression might be poured in the lab to have a precise model for restoration fabrication. Any incompatibilities or negative interactions between impression and pouring materials could negatively affect the result and cause inaccuracy in fabricated product despite all the efforts made in the fabrication steps. The materials tested in the present research (condensation or additional silicone as impression materials and two types of pouring gypsums) are among the most prevalent materials used in prosthetic practices; however, their interactions caused no significant difference in restorations’ marginal and internal adaptations, and the null hypothesis was rejected.

The clinically acceptable marginal gap is considered 120μm according to Mclean et al., and less than 150μm according to Jemt et al. Different studies have reported the marginal gap of 10 to 160μm in CAD-CAM milled zirconia copings, and 11 to 58μm in full zirconia restorations. The marginal adaptations in the present study were not in a clinically acceptable range according to Mclean criteria except for lingual surface of either impression material poured by GC gypsum. However, according to the Jemt criteria, all the marginal gaps were clinically acceptable except for the buccal margins of either impression materials poured by GC gypsum. This result is not confirmed by other studies that evaluated marginal gap in zirconia crowns; however, the role of conventional impression making and cast pouring may significantly change the in-vitro results obtained, as well as the method of gap measurement, the cement space, the fabrication system accuracy, and the preparation design, as well as the sintering technique. Generally, the accuracy of milling in lingual finish line was more than buccal side. The difference between the milled material thickness and volume could justify this finding; since, thicker material could more successfully compensate for milling subtle inaccuracy.
Application of direct preparation scanning or impression scanning might provide completely different results. There is no consensus on the clinically acceptable internal gap. However, the internal gap should provide a uniform and adequate cement space, while not compromising retention and resistance. In the groups evaluated in the present study, the internal gaps were generally higher for occlusal surfaces (buccal/lingual cusp tips, and central fossa). The increased occlusal gap compared to other surfaces has been reported by several studies irrespective of the fabrication method employed.

This result could be attributed to the more complex occlusal anatomic design, the possibility of more interferences in the occlusal surface according to computer milling mechanism, or intensified effects of axial/marginal interferences in occlusal section of the restoration. When it comes to conventional impression and cast pouring, all these factors might play a more relevant role, since the dimensional changes of conventional materials will affect the restoration adaptation.

Considering the axial surfaces, all the internal measurements were under the 120µm described by McLean et al., except the mid buccal values in Panasil+Siladent, and midlingual measurements in the Panasil+GC groups; both made by additional silicone impression. This could be covered by more dimensional stability of additional silicone that prevent material expansion outward from the tooth mold and results in smaller die compared to what is made by condensation silicone impression. Although each coping was milled after the scanning of related die, but, the die size might affect the milling accuracy considering the milling bur size and scanning limitations.

The result emphasizes the importance of creating space for low-consistency additional silicone wash covering the high-consistency material, and providing a thicker die spacer for the die poured from additional silicone impressions, compared to those poured from condensation silicone.

The wide range of standard deviations could be explained by finger pressure used for crown cementation. Although tried to be uniform and applying even pressure, the possibility of incorrect insertion or uneven pressure possibly due to the lack of opposite and adjacent teeth as insertion guides could not be ruled out. The same wide range was also shown in the Coli et al., and Kokubo et al., studies. This result emphasizes the importance of attention to the insertion accuracy in clinical practice.

However, the purpose of this study was to evaluate the effect of material interaction on marginal/internal adaptation that was shown to be statistically non-significant.

There are other factors that potentially influence restorations’ marginal/internal adaptation, namely tooth preparation design, cement type, restoration fabrication procedure, position and number of points evaluated, and the measurement method employed. The present study evaluated natural teeth and used milled zirconia crowns to imitate a clinical situation, however, the adaptation measurements were made only in two aspects. Further studies considering other combinations of materials, other measurement methods, and evaluating the materials interaction effects in full arch restorations are suggested.

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REFERENCES.

1. Miyazaki T, Hotta Y, Kuni J, Kuriyama S, Tamaki Y. A review of dental CAD/CAM: current status and future perspectives from 20 years of experience. Dental materials journal 2009; 28(1):44-56.

2. Erdemir U, Sancaklı HS, Sancaklı E, Eren MM, Ozel S, Yucel T, Yıldız E. Shear bond strength of a new self-adhering flowable composite resin for lithium disilicate-reinforced CAD/CAM ceramic material. J Adv Prosthodont. 2014; 6(6):434-43.

3. Kumar V, Aaran H. Evaluation of effect of tray space on the accuracy of condensation silicone, addition silicone and polyether impression materials: an in vitro study. J Indian Prosthodont Soc. 2012; 12(3):154-60.

4. Soganci G, Cinar D, Çağlar A, Yagız A. 3D evaluation of the effect of disinfectants on dimensional accuracy and stability of two elastomeric impression materials. Dent Mater J. 2018; 37(4):675-84.

5. Tango RN, Souza DL, da Silva LH, Sato TP, Borges AL, de Carvalho PC. Effect of the mixing on the dimensional stability of dental stones. Braz Dent Sci. 2018; 21(4):432-6.

6. Harris PE, Hoyer S, Lindquist TJ, Stanford CM. Alterations of surface hardness with gypsum die hardeners. J Prosthodont Dent. 2004; 92(1):35-8.

7. Anusavice KJ, Shen C, Rawls HR, editors. Phillips’ science of dental materials. Elsevier Health Sciences. 2012; Chapter 2.

8. Morrow RM, Brown JR CE, Stansbury BE, deLorimer JA, Powell JM, Rudd KD. Compatibility of alginate impression materials and dental stones. J Prosthodont Dent. 1971; 25(5):556-66.

9. Owen CP. An investigation into the compatibility of some irreversible hydrocolloid impression materials and dental gypsum products: Part I. Capacity to record grooves on the international standard die. J Oral Reabil. 1986; 13(1):93-103.

10. Butta R, Tredwin CJ, Nesbit M, Moles DR. Type IV gypsum compatibility with five addition-reaction silicone impression materials. J Prosthodont Dent. 2005; 93(6):540-4.

11. Chang YC, Yu CH, Liang WM, Tu MG, Chen SY. Comparison of the surface roughness of gypsum models constructed using various impression materials and gypsum products. J Dent Sci. 2016; 11(1):23-8.

12. Vadapalli SB, Atluri K, Putcha MS, Kondreddi S, Kumar NS, Tadi DP. Evaluation of surface detail reproduction, dimensional stability and gypsum compatibility of monophase polyvinylsiloxane and polyether elastomeric impression materials under dry and moist conditions. J Int Soc Prev Community Dent. 2016; 6(4):302.

13. Santini E, Octarina O. Compatibility of Types III/IV Gypsum with Addition Silicone Impression Material. Sci Dent J. 2019; 3(1):17-22.

14. Holmes JR, Bayne SC, Holland GA, Sulik WD. Considerations in measurement of marginal fit. J Prosthodont Dent. 1989; 62(4):405-408.

15. Faot F, Suzuki D, Senna PM, da Silva WJ, de Mattias Sartori IA. Discrepancies in marginal and internal fits for different metal and alumina infrastructures cemented on implant abutments. Eur J Oral Sci. 2015;123:215-219.

16. Tuntiprawn M, Wilson PR. The effect of cement thickness on the fracture strength of all-ceramic crowns. Aust Dent J. 1995;40:17-21.

17. Zeltner M, Sailer I, Mühlemann S, Özcan M, Hämmeler CH, Benic GI. Randomized controlled within-subject evaluation of digital and conventional workflows for the fabrication of lithium disilicate single crowns. Part II: marginal and internal fit. J Prosthodont Dent. 2017;117(3):354-62.

18. Boitelle P, Mawussi B, Tapie L, Fromentin O. A systematic review of CAD/CAM fit restoration evaluations. J Oral Reabil. 2014;41(11):853-74.

19. Guess PC, Vagkopoulou T, Zhang Y, Wolkewitz M, Strub JR. Marginal and internal fit of heat pressed versus CAD/CAM fabricated all-ceramic onlays after exposure to thermo-mechanical fatigue. J Dent. 2014; 42(2):199-209.

20. White BT, Long TE. Advances in Polymeric Materials for Electromechanical Devices. Macromol Rapid Commun. 2019;40(1):1800521.

21. Al-Atyaa ZT, Majeed MA. Comparative Evaluation of the Marginal and Internal Fitness of Monolithic CAD/CAM Zirconia Crowns Fabricated from Different Conventional Impression Techniques and Digital Impression Using Silicone Replica Technique (An in vitro study). Biomed Pharmacol J. 2018;11(1):477-90.

22. McLean, J.W. and Von Fraunhofer, J.A. (1971) The estimation of cement film thickness by an in vivo technique. British Den J. 131:107-111.

23. Jemt T, Hjalmarsson L. In vitro measurements of precision of fit of implant-supported frameworks. A comparison between “virtual” and “physical” assessments of fit using two different techniques of measurements. Clin Implant Dent Relat Res 2012;14(1):e175-82.

24. Boitelle P, Mawussi B, Tapie L, Fromentin O. A systematic review of CAD/CAM fit restoration evaluations. J Oral Reabil. 2014;41:853-74.

25. ArRejaie A, Alalawi H, Al-Harbi FA, Abualsaud R, Al-Thobity AM. Internal fit and marginal gap evaluation of zirconia copings using microcomputed tomography: an in vitro analysis. Int J Periodontics Restorative Dent. 2018;38:857–63.

26. Saab RC, da Cunha LF, Gonzaga CC, Mushashe AM, Correr GM. Micro-CT analysis of Y-TZP copings made by different CAD/CAM Systems: marginal and internal fit. Int J Dent. 2018;2018:5189767.

27. Ahmed WM, Abdallah MN, McCullagh AP, Wyatt CCL, Troczynski T, Carvalho RM. Marginal discrepancies of monolithic zirconia crowns: the influence of preparation designs and sintering techniques. J Prosthodont. 2019;28:288– 98.

28. Cunali RS, Saab RC, Correr GM, Cunha LFD, Ornaghi BP, Ritter AV, Gonzaga CC. Marginal and Internal Adaptation of Zirconia Crowns: A Comparative Study of Assessment Methods. Braz Dent J. 2017;28(4):467-473.

29. Güngör MB, Doğan A, Bal BT, Nemli SK. Evaluation of marginal and internal adaptations of posterior all-ceramic crowns fabricated with chair-side CAD/CAM system: an in vitro study. Acta Odontologica Turcica. 2018; 35(1):1-8.

30. Carbajal Mejía JB, Yatani H, Wakabayashi K, Nakamura T. Marginal and Internal Fit of CAD/CAM Crowns Fabricated Over Reverse Tapered Preparations. J Prosthodont. 2019; 28(2):e477-84.

31. Anunmana C, Charoenchitt M, Asvanund C. Gap comparison between single crown and three-unit bridge zirconia substructures. J Adv Prosthodont. 2014; 6(4):253–258.

32. Paul N, K.N RS, M.R D, S S, M.B R. Marginal and internal fit evaluation of conventional metal-ceramic versus zirconia CAD/CAM crowns. J Clin Exp Dent 2020; 12(1):e31-7.

33. Kubo Y, Nagayama Y, Tsurita M, Ohkubo C, Fukushima S, Vult von Steyern P. Clinical marginal and internal gaps of In-Ceram crowns fabricated using the GN-I system. J Oral Reabil 2005;32:753–8.
34. Kokubo Y, Tsumita M, Kano T, Sakurai S, Fukushima S. Clinical marginal and internal gaps of zirconia all-ceramic crowns. J Prosthodont Res 2011; 55(1):40-43.

35. Birnbaum NS, Aaronson HB. Dental impressions using 3D digital scanners: virtual becomes reality. Compend contin educ dent 2008; 29(8):494.

36. Veresa GK, Dimova C, Miloseva J. Analysis of the dimensional stability of elastomeric silicone impression materials. In Book of abstracts, International Symposium at Faculty of Medical Sciences 2015; 29 (1): No. 1.

37. Coli P, Karlsson S. Fit of new pressure-sintered zirconium dioxide coping. Int J Prosthodont 2004;17:59–64.