ORIGINAL RESEARCH

A Comparative Evaluation of the Wear of Natural Tooth Opposing Three Different CAD-CAM Ceramics: An *In Vitro* Study

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Abstract

Purpose: This *in vitro* study was carried out to compare the wear of opposing natural teeth caused by zirconia, resin nanoceramic restorations, and polymer-infiltrated ceramic network (PICN).

Materials and methods: A total of 12 disk-shaped samples measuring 10 × 2 mm were milled from each of the following blanks–Zirconia disc (3M™ Lava™ Plus), Lava™ Ultimate computer-aided design and computer-aided manufacturing (CAD/CAM) blocks, and VITA ENAMIC® CAD/CAM blocks. The samples were grouped as group I—zirconia ($n = 12$), group II—resin nanoceramics ($n = 12$), and group III—PICN ($n = 12$). A total of 36 freshly extracted maxillary premolars were collected and allocated to three groups ($n = 12$ each). The extracted teeth were weighed and scanned for prewear. The disc samples were subjected to a two-body wear test against the natural teeth in a two-body wear machine for 10,000 cycles, and readings were recorded. The teeth were again weighed and subjected to postwear scans. The one-way analysis of variance (ANOVA) was done to find the significant difference among groups, and *post hoc* Bonferroni's test was done for intergroup comparisons.

Results: The results revealed that there was a statistically significant difference ($p = 0.001$) in all three groups. The maximum amount of wear was seen with zirconia (0.2912 ± 0.151 mm) followed by resin nanoceramic (0.1345 ± 0.017 mm) and PICN (0.1233 ± 0.007 mm). The maximum amount of weight loss was seen with zirconia (0.0100 ± 0.0048 gm), followed by resin nanoceramic (0.0037 ± 0.0037 gm), and the least amount of weight loss was seen in PICN (0.0017 ± 0.0009 gm).

Conclusion: PICN displayed the least volumetric loss of the opposing natural teeth (both according to the weight and change in linear dimension), followed by resin nanoceramic and zirconia. In the case of bruxers, hybrid ceramics can be considered good alternatives to zirconia.

Keywords: Hybrid ceramics, Polymer-infiltrated ceramic network, Resin ceramics, Resin nanoceramics, Wear.

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Introduction

Dental practice has become increasingly dependent on computer-aided design and computer-aided manufacturing (CAD/CAM) in the last couple of decades. Since the introduction of digitalization tools/scanners in the past few years, software and milling devices have improved significantly.[1] Fixed prostheses produced by CAD/CAM have shown acceptable clinical outcomes over the years. A variety of materials have been used to fabricate these prostheses, including metals and ceramics. Among the two, ceramics have become much more popular because of the superior esthetic properties they offer.[2]

The ceramic block material for CAD/CAM applications is now available in a wide range of compositions and properties. Wear resistance and hardness are important characteristics of dense ceramics like zirconia. Due to this high wear resistance, zirconia crowns cause excessive wear in the opposing natural tooth. A number of authors have demonstrated that ceramic substrates tend to wear down human enamel more abrasively than other substrates.[3–7] This has become a major disadvantage of ceramic crowns. This disadvantage needs to be reduced or eliminated while retaining the other desirable properties. It would therefore be valuable to have a ceramic restorative material that provides good strength without increasing enamel wear.[8]

Recently, a polymer-infiltrated ceramic network (PICN) material and composite resin nanoceramic blocks have been launched as substitutes for dense ceramics. In addition to offering the lower brittleness and superior fracture resistance of polymers, these new CAD/CAM materials offer the esthetic properties of glass ceramics.[9]

The manufacturing process of PICN involves two steps. Initially, a coupling agent is used to condition a porous presintered feldspar ceramic. By capillary action, a cross-linking polymer (ultra direct

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memory access, tetraethylene glycol dimethyl ether, dibenzoyl peroxide) is then infused into the porous ceramic network structure. A PICN material was subsequently obtained by heat-induced polymerization.[10] Unlike traditional ceramic blocks, composite resin nanoceramic blocks are made from polymeric materials reinforced with ceramic filler particles. A significant improvement in their mechanical properties can be attributed to the process of industrially fabricating these blocks at high temperatures and under high pressure, which results in a higher volume fraction filler and higher conversion rates (85%).[11]

The mechanical properties of these hybrid ceramics have been compared with lithium disilicate glass ceramics, and it has been found that the two newer CAD/CAM ceramics (PICN and resin nanoceramics) have improved mechanical properties.[2,12] However, not much evidence exists regarding the wear caused in the opposing natural tooth by these materials when compared to popularly marketed ceramics like zirconia.

Therefore, this *in vitro* study was to compare the wear of opposing natural teeth caused by zirconia, resin nanoceramic restorations, and PICN. The null hypothesis was that there would be no difference in the wear of opposing natural teeth due to zirconia, resin nanoceramic restorations, and PICN.

Materials and Methods

The study was done in a dental college and research center in the region of Western Maharashtra. The Ethical Committee clearance number for the study is MCES/EC/563/2019, dated, 8th November 2019. The methodology for the study is divided into the following steps.

Preparation of Specimens and Sampling

Tinkercad® software (Autodesk, San Francisco, United States of America) was used to design the stereolithography (STL) file for disc specimens. A three-dimensional (3D) model of a disc measuring 10 mm in diameter and 2 mm in thickness was created in STL format. This file was then sent to the milling machine for milling. A total of 36 disc-shaped samples (12 samples/group) of 10 mm diameter and 2 mm thickness were milled with the help of a CAD/CAM device from each of the following blanks—Zirconia disc (3M™ Lava™ Plus High Translucency Zirconia, 3M, Saint Paul, Minnesota, United States of America), Lava™ Ultimate CAD/CAM blocks (3M, Saint Paul, Minnesota, United States of America) and VITA ENAMIC® CAD/CAM blocks (VITA Zahnfabrik, Bad Säckingen, Germany).

The obtained disc samples were divided into three groups—group I, zirconia ($n = 12$); group II, resin nanoceramics ($n = 12$); and group II, PICN ($n = 12$) (Figs 1A to C). Samples without visible defects were only included in this study. Samples with visible defects were discarded and replaced with new ones.

Collection of Extracted Teeth

A total of 36 freshly extracted maxillary premolars, which were indicated for orthodontic extraction, were collected and allocated to three groups (12 each). Unrestored, fully developed, and caries-free tooth with the patient's consent/assent was used in the study. Attrited, carious, nonvital, restored, and root canal-treated teeth were excluded from the study.

The tooth was then cleaned under running water and normal saline. A metal index measuring 20 × 20 × 25 mm was used to embed the tooth in a self-cure self-polymerizing acrylic block (DPI RR, Mumbai, India). Cold cure polymer and monomer were proportioned and mixed in a silicone cup as per the manufacturer's recommendation. Acrylic material was transferred to the metal index, and the tooth was embedded into it and held until the acrylic material went to the stiff stage (Fig. 2).

Wear Testing of Opposing Teeth

Contrast spray (Easy Scan contrast spray, Alphadent, Seongnam-si, Korea) was sprayed on the extracted tooth before placing it in the extraoral 3D scanner. The mounted extracted tooth was then placed inside the extraoral laboratory scanner (Dental Wings, DWOS, 3Series scanner, Montreal, Canada) (Fig. 3A). The prewear scanned image of the 3D object was obtained in STL format. After scanning the tooth samples, they were placed on a weighing machine, and the weight of each sample was noted in grams

The mounted extracted tooth was placed onto the upper holder of a two-body wear machine. The ceramic disc (zirconia, resin nanoceramic, or PICN) was placed on the lower holder of the two-body wear machine. A total of 5 kg of the constant load was applied to the cusp tips and ceramic discs (Fig. 3B). A 10,000-cycle friction test was performed on these specimens. As part of the test, artificial saliva was sprayed between the extracted tooth sample and the disc surface at specified intervals to simulate oral conditions.

After completion of 10,000 cycles of wear, the tooth was again sprayed with contrast spray to prepare it for postwear extraoral 3D scanning. The mounted extracted tooth was placed inside the extraoral laboratory scanner, and the scanned image of the 3D object was again obtained in STL format.

Now both the prewear and the postwear 3D object STL files were exported to a software (Geomagic® Control X™ 64 Bit Build version 2018, Copyright© 3D Systems, Senningerberg, Luxembourg) and superimposed for comparison of prewear and postwear (Figs 4A to C). The difference between prewear and postwear 3D scans was calculated, and the amount of wear that occurred was determined.

After scanning, the tooth samples were placed on the weighing machine again, and the weight of each sample was noted. The difference between the pre and postwear test weights of each

Figs 1A to C: Milled discs measuring 10 × 2 mm: (A) Zirconia; (B) Resin nanoceramic; (C) Polymer infiltrated ceramic network sample was considered as the amount of wear that occurred in the tooth.

Statistical Analysis

The data on the continuous variable was presented as mean and standard deviation (SD). The ANOVA was done to find the significant difference among groups, and *post hoc* Bonferroni's test was done for intergroup comparisons. The *p*-values of <0.05 are considered statistically significant. All the hypotheses were formulated using two-tailed alternatives against each null hypothesis (hypothesis of no difference). The entire data was statistically analyzed using Statistical Package for the Social Sciences (SPSS) (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, New York, United States of America—IBM Corp.) for Microsoft Windows.

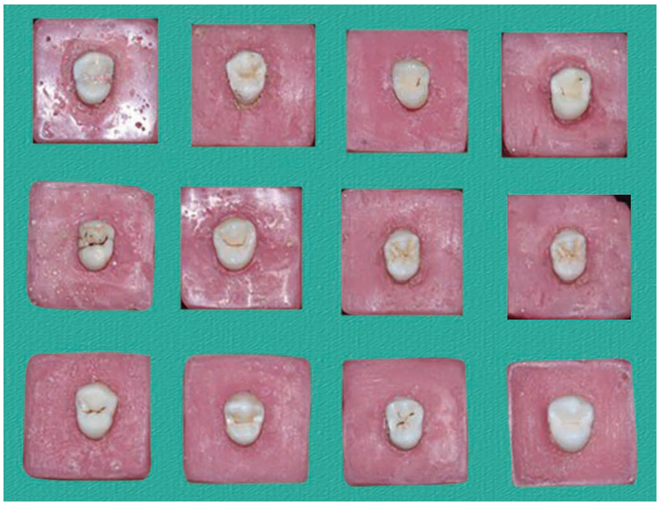


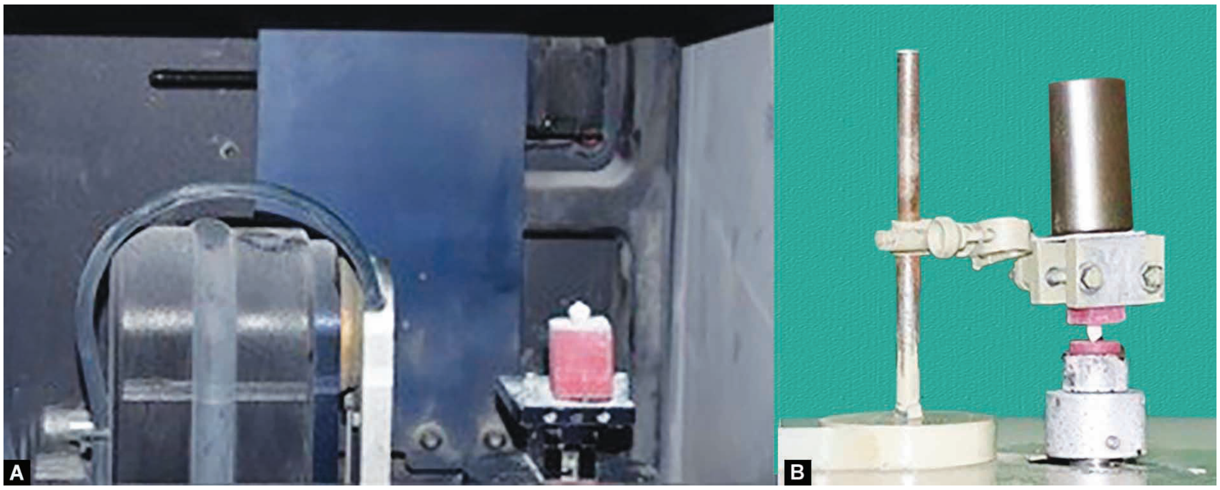
Fig. 2: Extracted maxillary premolars embedded in acrylic blocks

Results

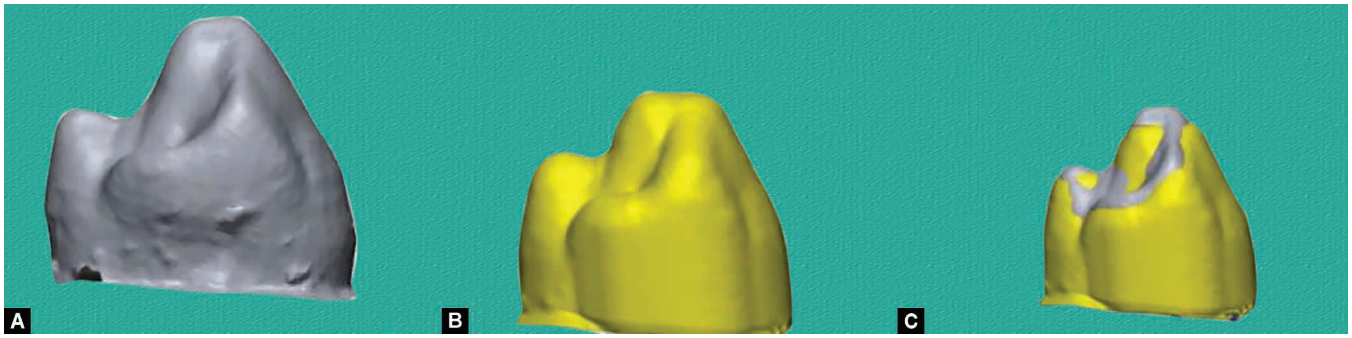
Comparison of Weight Loss before and after Wear Cycle

The results revealed that there was a statistically significant difference ($p = 0.001$) in weight loss among all three groups. The maximum amount of weight loss was seen with zirconia group I (0.0100 ± 0.0048 gm), followed by resin nanoceramic group II (0.0037 ± 0.0037 gm), and the least amount of weight loss was seen in PICN group III (0.0017 ± 0.0009 gm) (Table 1).

A pairwise comparison of the difference in weight loss between the zirconia group and the resin nanoceramic group was statistically significant ($p = 0.001$). The difference in weight loss between the zirconia group and the PICN group was also statistically significant ($p = 0.001$). The difference in weight loss between the resin nanoceramic group and the PICN group was insignificant ($p = 0.344$) (Table 2).



Figs 3A and B: (A) Extracted tooth placed inside the extraoral laboratory scanner; (B) Extracted tooth placed onto the upper holder while disc sample was placed on the lower holder of a two-body wear machine



Figs 4A to C: (A) Prewear scan; (B) Postwear scan; (C) Two scans overlapped

Comparison of Change in Tooth Height before and after Wear Cycle

The results revealed that there was a statistically significant difference ($p = 0.001$) in all three groups. The maximum amount of wear was seen with zirconia group I (0.2912 ± 0.151 mm), followed by resin nanoceramic group II (0.1345 ± 0.017 mm), and the least amount of wear was seen in PICN group III (0.1233 ± 0.007 mm) (Table 3).

A pairwise comparison of wear revealed that difference in wear between the zirconia group and the resin nanoceramic group was statistically significant ($p = 0.001$). The difference in wear between the zirconia group and the PICN group was also statistically significant ($p = 0.001$). The difference in wear between the resin nanoceramic group and the PICN group was insignificant ($p = 0.948$) (Table 4).

According to the results, zirconia caused the highest volumetric loss (both in weight and in linear dimension) of the opposing tooth among the three groups, while PICN displayed the least amount of volumetric loss.

Discussion

Several innovations have come up in esthetic restorative materials. One concern about the CAD/CAM blocks in the past was their monochromatic appearance. However, with the new advances in manufacturing technology, a wide variety of blocks with superior esthetic qualities is now available. Polychromatic leucite-reinforced ceramic blocks, lithium disilicate glass-ceramic blocks, feldspar fine-particle ceramic blocks, and reinforced resin-ceramic blocks are among the esthetic restorative material options that are available.[13]

The recently introduced hybrid CAD/CAM ceramic materials have multiple advantages over other materials. In addition to improving machinability, an easier intraoral repair is ensured with light polymerized restoratives, and postmilling firing is not required, which speeds up production. Indications of hybrid ceramic materials include veneers, inlays, onlays, crowns, and small anterior and posterior bridges.[14]

In the oral cavity, wear is characterized by a progressive loss of anatomical form. The etiology of this process can be physiological or pathological.[15] To preserve normal function and occlusal harmony, it is essential to choose the right restorative material. There are a number of factors that affect enamel wear, including physical characteristics such as hardness, frictional resistance, and fracture toughness, as well as microstructural characteristics like porosity and crystalline structure, and surface roughness of the restoration.[16]

In the current study, zirconia caused the highest volumetric loss (both in weight and in linear dimension) of the opposing tooth among the three groups. PICN displayed the least amount of volumetric loss, according to this study. The null hypothesis that there would be no difference in the wear of opposing natural teeth due to zirconia, resin nanoceramic restorations and PICN is rejected.

The lower wear caused by PICN and resin nanoceramic materials can be explained by the fact that the composite resins incorporated in these hybrid ceramics have Young's modulus similar to that of dentin.[11] Furthermore, the hardness and fracture toughness of these hybrid ceramics are lower than that of conventional ceramics.

Table 1: Comparison of weight loss (in gm) among three groups

Groups	*Mean*	*SD*	*F value*	*p-value*
Zirconia	0.0100	0.0048	17.683	0.001*
Resin nanoceramic	0.0037	0.0037		
PICN	0.0017	0.0009		

*Indicates significance at $p \leq 0.05$

Table 2: Pairwise comparison of weight loss before and after the wear cycle

Material pair		*Mean difference*	*p-value*
Zirconia	Resin nanoceramic	0.0063	0.001*
Zirconia	PICN	0.0083	0.001*
Resin nanoceramic	PICN	0.0020	0.344

*Indicates significant at $p \leq 0.05$

Table 3: Comparison of change in dimension among three groups (by 3D scanning method)

Groups	*Mean*	*SD*	*F value*	*p-value*
Zirconia	0.2912	0.151	13.658	0.001*
Resin nanoceramic	0.1345	0.017		
PICN	0.1233	0.007		

*Indicates significant at $p \leq 0.05$

Table 4: Pairwise comparison of tooth height before and after the wear cycle

Material pair		*Mean difference*	*p-value*
Zirconia	Resin nanoceramic	0.1567	0.001*
Zirconia	PICN	0.1679	0.001*
Resin nanoceramic	PICN	0.1112	0.948

*Indicates significant at $p \leq 0.05$

Additionally, they have lower concentrations of crystal phase when compared to conventional ceramics. All these factors contribute to the lower wear of enamel caused by this hybrid ceramics.[17]

The soft polymeric matrix of polymer-based restorative CAD/CAM materials wears away due to abrasion, which exposes filler particles.[18] Also, biting forces apply stress at the filler-matrix interface throughout the polymer restoration. If stresses exceed the bond strength between the resin matrix and filler particles, they may cause subsurface cracks and subsequent loss of the material, along with the loss of singular, superficial filler particles. As compared with composites, dental ceramics have a different mode of wear. As ceramics are brittle, they wear by fracturing, causing them to get rougher and releasing wear fragments, increasing the wear of opposing enamel.[19]

The results obtained in this study are in agreement with results obtained by Lawson et al.,[20] and Ludovichetti et al.[21] Kamel et al.[22] reported PICN to be the most antagonist-friendly among three tested ceramic materials, namely translucent zirconia, lithium disilicate, and hybrid ceramic (PICN). According to a study done by Xu et al.,[23] on the wear behavior of VITA ENAMIC® and tooth enamel, it was determined that Enamic had a significantly lower wear resistance than enamel. The hardness of the enamel reported by Chun et al.[24] is 274.8 VH, by Ludovichetti et al.[21] for VITA ENAMIC® is 200 VH, and by Mormann et al.[25] for translucent zirconia is 1300 VH. Lower hardness values of the hybrid ceramics, when compared to zirconia, can be attributed to lower wear caused by them.[22] The tendency of brittle chipping in dense ceramics such as zirconia might be another reason for causing more wear of the opposing tooth. By resharpening the edges of the particles, brittle chips formed by the abrasive process can further increase wear. Brittle chips formed during the abrasive process can cause resharpening of the edge of the particles with a further increase in the wear rate.[16]

The difference in antagonist enamel wear between the two hybrid ceramics can be credited to the difference in their genetic structures. Resin nanoceramics contain silica particles of 20 nm, zirconia particles of 4–11 nm, and agglomerated nanosized particles of silica and zirconia, all embedded in a highly cross-linked polymer matrix with an approximately 80% ceramic load.[26] On the other hand, PICN material consists of two interpenetrating ceramic-polymer networks. Capillary action is used to infiltrate a polymer into a porous presintered ceramic network.[10] As a consequence of the structural differences between the two hybrid ceramic materials in the present study, the amounts of wear caused by them vary.

Conclusion

Within the limitations of this study, it can be concluded that PICN displayed the least volumetric loss of the opposing natural tooth, followed by resin nanoceramic and zirconia. In the case of bruxers, hybrid ceramics can be considered good alternatives to zirconia.

References

1. van Noort R. The future of dental devices is digital. Dent Mater 2012;28(1):3–12. DOI: 10.1016/j.dental.2011.10.014
2. Davidowitz G, Kotick PG. The use of CAD/CAM in dentistry. Dent Clin North Am 2011;55(3):559–570. DOI: 10.1016/j.cden.2011.02.011
3. Rupawala A, Musani SI, Madanshetty P, et al. A study on the wear of enamel caused by monolithic zirconia and the subsequent phase transformation compared to two other ceramic systems. J Indian Prosthodont Soc 2017;17(1):8–14. DOI: 10.4103/0972-4052.194940
4. Wiley MG. Effects of porcelain on occluding surfaces of restored teeth. J Prosthet Dent 1989;61(2):133–137. DOI: 10.1016/0022-3913(89)90360-0
5. Mahalick JA, Knap FJ, Weiter EJ. Occusal wear in prosthodontics. J Am Dent Assoc 1971;82(1):154–159. DOI: 10.14219/jada.archive.1971.0018
6. Seghi RR, Rosenstiel SF, Bauer P. Abrasion of human enamel by different dental ceramics in vitro. J Dent Res 1991;70(3):221–225. DOI: 10.1177/00220345910700031301
7. Lee A, Swain M, He L, et al. Wear behavior of human enamel against lithium disilicate glass ceramic and type III gold. J Prosthet Dent 2014;112(6):1399–1405. DOI: 10.1016/j.prosdent.2014.08.002
8. Stawarczyk B, Keul C, Eichberger M, et al. Three generations of zirconia: from veneered to monolithic. Part II. Quintessence Int 2017;48(6):441–450. DOI: 10.3290/j.qi.a38157
9. Fasbinder DJ. Material matters: a review of chairside CAD-CAM restorative materials. J Cosmet Dent 2018;34(3):64–74.
10. Della Bona A, Corazza PH, Zhang Y. Characterization of a polymer-infiltrated ceramic-network material. Dent Mater 2014;30(5):564–569. DOI: 10.1016/j.dental.2014.02.019
11. Coldea A, Swain MV, Thiel N. Mechanical properties of polymer-infiltrated-ceramic-network materials. Dent Mater 2013;29(4):419–426. DOI: 10.1016/j.dental.2013.01.002
12. Elsayed A, Yazigi C, Kern M, et al. Mechanical behavior of nano-hybrid composite in comparison to lithium disilicate as posterior cement-retained implant-supported crowns restoring different abutments. Dent Mater 2021;37(8):e435–e442. DOI: 10.1016/j.dental.2021.03.015
13. Harsono M, Simon JF, Stein JM, et al. Evolution of chairside CAD/CAM dentistry. Tex Dent J 2013;130(3):238–244. PMID: 23734548.
14. Marchesi G, Piloni AC, Nicolin V, et al. Chairside CAD/CAM materials: current trends of clinical uses. Biology (Basel) 2021;10(11):1170. DOI: 10.3390/biology10111170
15. Smith BG, Bartlett DW, Robb ND, et al. The prevalence, etiology and management of tooth wear in the United Kingdom. J Prosthet Dent 1997;78(4):367–372. DOI: 10.1016/s0022-3913(97)70043-x
16. Oh WS, DeLong R, Anusavice KJ. Factors affecting enamel and ceramic wear: a literature review. J Prosthet Dent 2002;87(4):451–459. DOI: 10.1067/mpr.2002.123851
17. Bajraktarova-Valjakova E, Korunoska-Stevkovska V, Kapusevska B, et al. Contemporary dental ceramic materials, a review: chemical composition, physical and mechanical properties, indications for use. Open Access Maced J Med Sci 2018;6(9):1742–1755. DOI: 10.3889/oamjms.2018.378
18. Bayne SC, Taylor DF, Heymann HO. Protection hypothesis for composite wear. Dent Mater 1992;8(5):305–309. DOI: 10.1016/0109-5641(92)90105-l
19. Kunzelmann KH, Jelen B, Mehl A, et al. Wear evaluation of MZ100 compared to ceramic CAD/CAM materials. Int J Comput Dent 2001;4(3):171–184. PMID: 11862884.
20. Lawson NC, Bansal R, Burgess JO. Wear, strength, modulus and hardness of CAD/CAM restorative materials. Dent Mater 2016;32(11):e275–e283. DOI: 10.1016/j.dental.2016.08.222
21. Ludovichetti FS, Trindade FZ, Werner A, et al. Wear resistance and abrasiveness of CAD-CAM monolithic materials. J Prosthet Dent 2018;120(2):318.e1–318.e8. DOI: 10.1016/j.prosdent.2018.05.011
22. Kamel MA, Hasan MR, Hashem RM. Assessment of wear of three CAD/CAM ceramics against natural tooth structure in a chewing simulator (in vitro study). Egypt Dent J 2019;65(1):403–416.
23. Xu Z, Yu P, Arola DD, et al. A comparative study on the wear behavior of a polymer infiltrated ceramic network (PICN) material and tooth enamel. Dent Mater 2017;33(12):1351–1361. DOI: 10.1016/j.dental.2017.08.190
24. Chun KJ, Choi HH, Lee JY. Comparison of mechanical property and role between enamel and dentin in the human teeth. J Dent Biomech 2014;5(1): 1758736014520809. DOI: 10.1177/1758736014520809
25. Mörmann WH, Stawarczyk B, Ender A, et al. Wear characteristics of current aesthetic dental restorative CAD/CAM materials: two-body wear, gloss retention, roughness and Martens hardness. J Mech Behav Biomed Mater 2013;20:113–125. DOI: 10.1016/j.jmbbm.2013.01.003
26. Duarte S, Sartori N, Phark JH. Ceramic-reinforced polymers: CAD/CAM hybrid restorative materials. Curr Oral Health Rep 2016;3(3):198–202. DOI: 10.1007/s40496-016-0102-2