Different particle-blasting methods used to increase the shear or tensile bond strength of high-translucency zirconia ceramic surfaces

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Abstract

Objectives: To compare the effectiveness of different particle-blasting methods for high-translucency dental ceramic, in regard to the particle size, pressure used and time it takes to fully complete the procedure most effectively, according to the achieved shear and tensile bond strength.
Methods and materials: Analysis of literature was performed by using the PRISMA protocol. The search was done electronically in ScienceDirect, MEDLINE, Cochrane Library and Wiley Online Library databases. The focus question was developed by the PICO (population (P), intervention (I), control (C), and outcome (O)) study design protocol.
Results: Out of 171 records that were screened, 4 articles were included into the qualitative analysis. The results have shown, that the main material, used for particle abrasion, which gives the most effective results in increasing the bond strength of ultra-translucent zirconia ceramic is Al_2O_3. The most effective size of the Al_2O_3 particles varies from 50 to 110 μm. Exposure time of particle-abrasion, which yields the best SBS and TBS results, should be at least 15 seconds. The most effective bonding results to high-translucency ceramic, were achieved when using 0,2-0,3 MPa pressure.
Conclusions: Although there are only 4 articles, and more studies need to be done about the SBS and TBS properties, for high-translucency ceramic, it has been proven, that particle sizes, pressure used, and the time of the procedure have an impact on the final material bond strength.

Key words:

dental, zirconia, high, translucency, surface, treatment, bond, blasting

Introduction

In the recent years of prosthetic restorative dentistry, ceramic restorations became one of the most popular dental prosthesis choices for the vast majority of the patients. According to the recent studies in the US, around 80.2% of all the prosthetic dental restorations that have already been done, were all-ceramic [1]. Due to various options of ceramic materials becoming overwhelming, a lot of research and data analysis of their properties are being done in order to find the most suitable materials for certain clinical situations.

One of the most popular and widely used dental restorative ceramic material is Zirconia ceramic. It is a polycrystalline structure, which occurs in nature only, in conjunction with silicate oxides ($ZrO2 \times SiO2$), and also as a free oxide (ZrO2) [2].

The most common and widely used type of Zirconia in dentistry, is Yttrium-stabilized Tetragonal Zirconia Polycrystalline (3Y-TZP) structure. It shows high biocompatibility, fracture toughness, and exceptional strength, although, the aesthetical results can be insufficient, due to the lack of translucency in 3Y-TZP [3, 4].

Most researches today are trying to improve the 3Y-TZP ceramic by introducing an optically isotropic cubic phase into tetragonal zirconia [4]. This way, they get a 5 mol% yttria-stabilized zirconia polycrystal, also known as 5Y-PSZ, a high translucency zirconia. Although this improves the aesthetical results, by increasing translucency, it also affects clinical implications and physical material properties, such as shear or tensile bond strength [5]. Moreover, when the amount of yttria is increased up to 8% mol, the zirconium is then called ultra-translucent. Although, a clearer classification of different translucency zirconia ceramics is still required [6].

Objective: The aim of this study was to systematically review the most recent studies on differently treated high-translucency dental ceramic surface physical properties, by analyzing and comparing the shear or tensile bond strength and to review the specific ceramic pre-bonding particle-blasting preparation protocols for high-translucency prosthetic dental ceramic.

Material and methods

The aim of this review was to evaluate the possible particle-blasting methods, in order to increase the bonding characteristics of the novel high-translucency (5Y-PSZ) zirconia ceramics surfaces. This article was done according to the systematic review statement [7].

Focused question

The focus question was developed by the PICO (population (P), intervention (I), control (C), and outcome (O)) study design protocol: How can the surface of high-translucency dental ceramics be treated by particle-blasting methods in order to achieve the strongest shear or tensile bond strength?

Search Strategy

Analysis of literature was performed by using the PRISMA protocol. The search was done electronically in ScienceDirect, MEDLINE, Cochrane Library and Wiley Online Library databases. The last date of search was 2020 July 5th and the articles were not older than 5 years old. The keywords “dental; zirconia; high; translucency; surface; treatment; bond; blasting” and their variations were used, which yielded the most results. The references of the papers, that were included, were also investigated, in order to identify any potential additional results.

Selection of studies

The articles were investigated independently by 2 authors. Researchers discussed and compared their selections and matched all the differences through discussion. In the final stage, all of the articles were screened. The exclusion of the articles was done after investigation of titles and abstracts. Analysis was done according to the inclusion and exclusion criteria, to make the decision, whether to include the publication.

Inclusion Criteria

1. Studies were made with high-translucency ceramic;

2. Particle-blasting procedures were described, including the materials that were used;
3. Surface of the material was analyzed after particle-blasting;
4. The shear bond strength and tensile strength of the material was calculated;
5. Articles were not older than 5 years old;
6. Articles were in English.

Exclusion Criteria

1. Studies did not include high-translucency ceramic;
2. No particle-blasting procedure was used;
3. Shear bond strength and/or tensile bond strength were not calculated;
4. The surfaces after particle blasting were not analyzed;
5. Articles, that were older than 5 years old;
6. Articles, that were written in other than English language.

Data extraction

The collection of data was done and summarized in the following fields:

1. Authors and year of publication;
2. P - Population/Problem/Sample size;
3. I – Intervention (describes the intervention, that was done to the samples);
4. C – Comparison (describes the control group samples);
5. O – Outcome (describes, whether the outcomes were successful).

Synthesis of results

All of the results were synthesized, and all of the findings were put into a table format – Table 1.

Results

Study Selection

The first initial data search displayed a total of 429 studies. After applying the 5-year filter, 171 studies were screened for eligibility. Out of those studies, the inclusion and exclusion criteria were applied. 5 studies full texts were analyzed for eligibility. One study was excluded, because only surfaces of the materials were examined, and no bond strength analysis was done [12]. Consequently, 4 studies were included into the qualitative data synthesis, due to their relevance. The flow diagram is shown in Figure 1.

Study characteristics

The data of interest of the studies, is shown in Table 1. The studies were made with high-translucency ceramic. All of them had particle-blasting procedures and their effect to the high-translucency ceramic described clearly. One of the studies measured the tensile bond strength, whereas others measured the shear bond strength.

Quality assessment

The quality assessment showed, that only 1 study should not be raising concerns, regarding the randomization process. The assessment was done using the RoB2 tool. Risk of bias assessment is described in Figure 2.

Qualitative synthesis of results

The studies included in this review showed, that in order to increase the bond strength of high-translucency zirconia material, the most frequently used particles were Al_2O_3 [8-11].

Also, the results of the studies have shown, that the most popular grit size of the Al_2O_3 particles, was either 50 µm or 110 µm, which also concludes, that they produce the most significant results, in regard to an increased bond strength [8-11].

The analysis also revealed, that in Zhao et. al work, the pressure of particle treatment, which was used on the high-translucency ceramic, differed, in comparison, to the regular ceramic. In the high-translucency group, the pressure, which produced the best shear bond strength results, was 0,3 MPa, whereas in the regular ceramic group, the pressure was two times higher 0,6 MPa. Also, in their work, the surface treatment time efficacy was analyzed, and it showed, that for highly translucent ceramic, longer treatment time of 20 seconds increased SBS more in comparison to

Table 1.
Synthesis of results.

Study	Year	Population/ Problem/ Sample size	Intervention	Comparison	Outcome
Zhao et al. [8]	2019	N=312 CAD/CAM blocks (with different amounts of Y_2O_3: group Z – 4-6,5% Y_2O_3, which was used as conventional zirconia samples and group M – 9,28% Y_2O_3, which was used as the highly translucent zirconia samples). 13 random subgroups were formed, with N=12 samples in each group.	N=12 groups received different treatment: 50 μm or 110 μm grit size sandblasting, treatment time – 10s or 20s, and pressure – 0,1MPa, 0,3MPa or 0,6MPa.	1 control group N=12, received no treatment.	SBS of sandblasted specimen groups was higher than in the control group. Larger grain sizes increase SBS significantly in both Z and M group. Highest SBS was achieved at 0,6 MPa pressure for group Z and at 0,3 MPa pressure for group M. Also, in group M SBS increased with treatment time, but for group Z it had no difference.
Aung et al. [9]	2019	3 groups of Y-PSZ ceramic (with different amounts of Y_2O_3: 5-8% HT, 7-10% ST and 8-11% UT), with a total of N=720 specimens. From each group – random N=5 specimens.	Air abrasion Al_2O_3 50 μm at 0 MPa, 0.1 MPa, 0.2 MPa and 0.4 MPa pressure, 20 seconds, distance of 10 mm.	No air abrasion was used on 5 random specimens.	Alumina abrasion at 0,2 MPa provided durable and reliable bonding to Y-PSZ zirconia ceramic. When alumina-blasting pressure was lower, higher or not present, no durable bonding to zirconia ceramic was achieved regardless of using 10-MDP containing adhesives.
Agren et al. [10]	2018	5Y-PSZ 2 groups: ZPA – Zirkonzahn Prettau Anterior ceramic N=16, WCS – Whitepeaks CopraSmile Symphony ceramic N=18.	ZPA air abrasion Al_2O_3 110 μm at 3,5 bar pressure, approx. 2-3 s at distance of 2 cm.	Lithium disilicate E-MAX N=19.	Shear bond strength in ZPA was from 11,1 to 36,7 MPa, which was higher than in the control group - its shear bond strength was from 10,1 to 34,5 MPa.
Yoshida et al. [11]	2019	8 highly translucent zirconia groups, N=8.	Air-abrasion with alumina Al_2O_3 50 μm from 10 mm distance, using 0,1 MPa, 0,15 MPa, 0,2 MPa or 0,3 MPa pressure for 15 s and thermocycling.	1 group of as-sintered specimens.	Air abrasion with 0,2 MPa pressure was the most effective method in increasing the tensile bond strength.

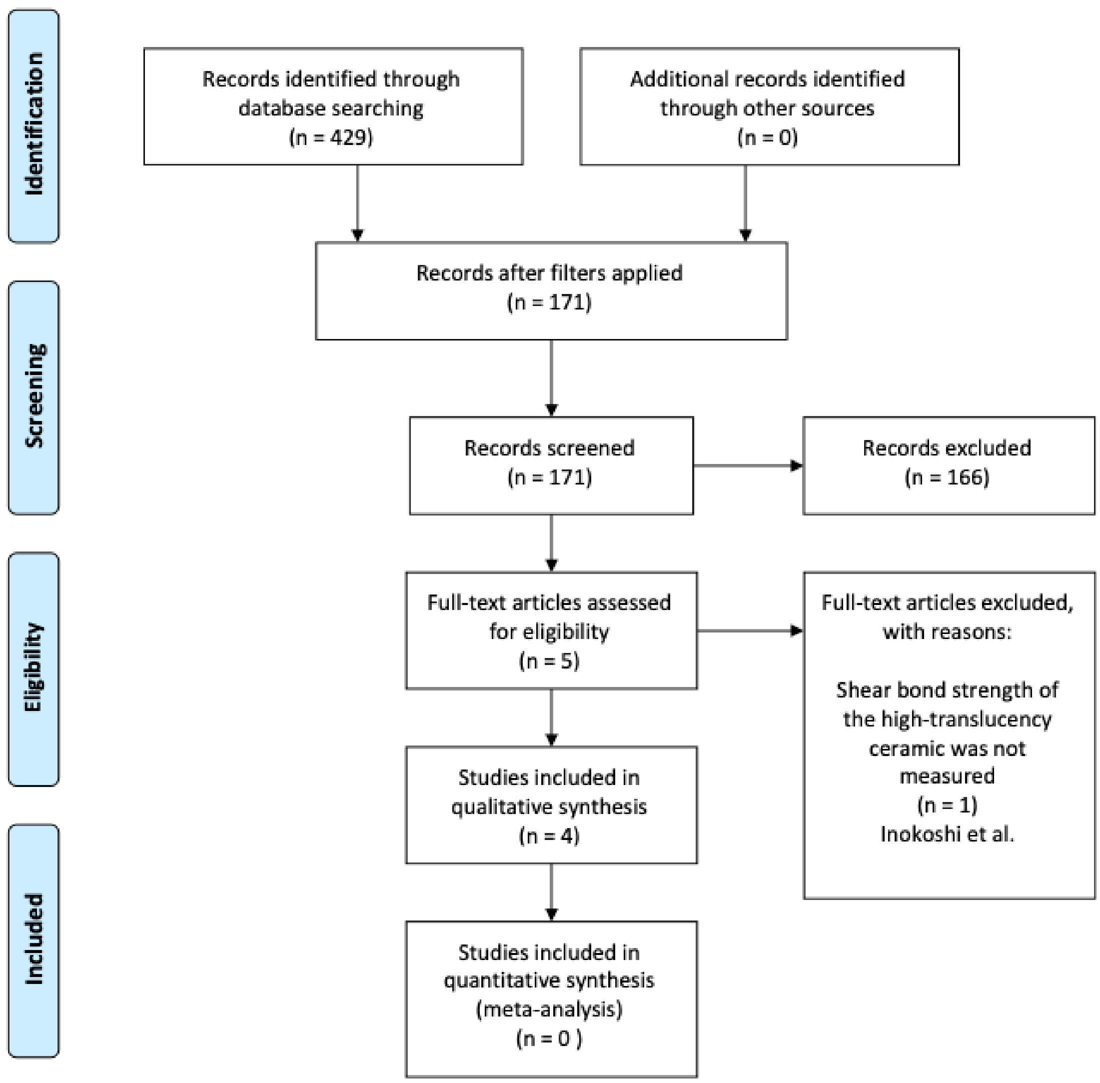

Fig. 1.
PRISMA flow diagram for systematic review

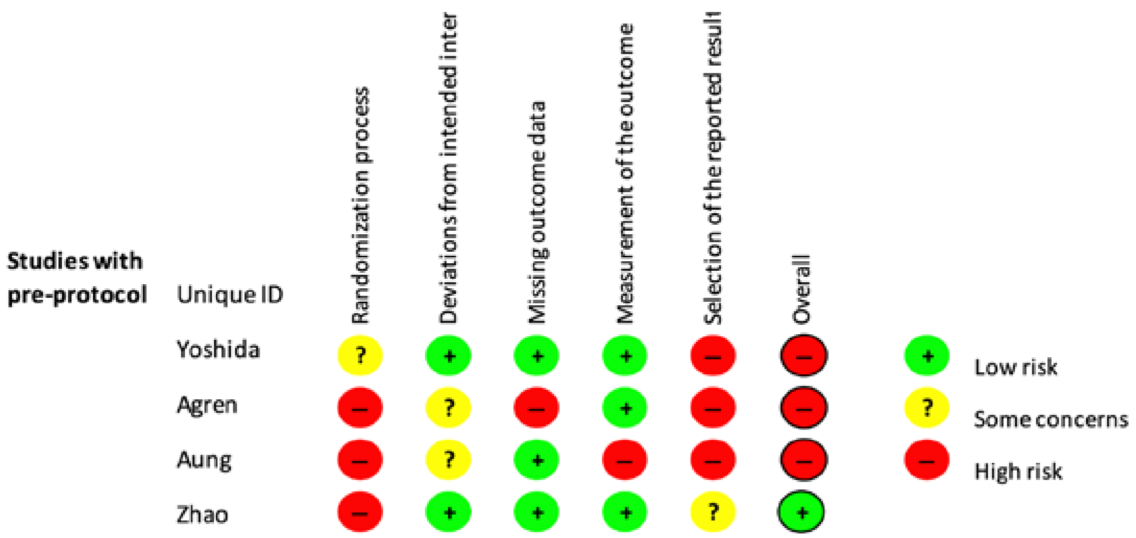

Fig. 2.
Risk of bias assessment

10 second treatment time, whereas regular ceramic was not affected in the same regard [8].

In Aung et. al research, different pressure options were used with Al_2O_3, in order to test, whether, there is an optimal MPa amount to achieve the best high-translucency dental ceramic bonding results. Scientists came to a conclusion, that the best SBS results are obtained, when using 0,2 MPa alumina abrasion pressure, whereas when using a lower, higher, or no abrasion at all, yielded worse results, even when using adhesive materials [9].

Agren at al., have tested 5Y-PSZ ceramic, and compared it to E-Max lithium disilicate, when 110 µm Al_2O_3 abrasion was applied, and the pressure of 3,5 bar was used. It yielded positive results, in comparison to the control group, and the achieved SBS measurements were higher [10].

The study of Yoshida et. al was focused on the tensile bond strength measurement. The high-translucency ceramic underwent 50 µm air abrasion treatment, with 0,1 MPa, 0,15 MPa, 0,2 MPa and 0,3 MPa pressure, for 15 seconds. Also, thermocycling was done after the surface treatment. The analysis has shown, that in comparison to the control group (which consisted of as-sintered specimens), the most significant method, was 0,2 MPa pressure air abrasion, in regard to the increase of tensile bond strength [11].

Discussion

During this systematic review, we have analyzed the literature on the different particle-blasting methods used to increase either the shear or tensile bond strength of high-translucency zirconia ceramic restorations. Our aim was to identify the most effective pre-bonding preparation protocols: most effective pressure, abrasive particle sizes and optimal ceramic exposure time to the particles during the blasting procedures. Only 4 studies were included in this systematic review, due to excluded ones not having the bond strength analysis done or the findings were done on regular, rather than the high-translucency ceramics.

The first study showed positive results in SBS increase, when the particle size was increased during the procedure. Also, it was done on a high number of samples, which was 312, they were also randomly assigned to groups of 12, and the last group was taken as a control group, to compare the effectiveness of the particle abrasion. The finding, which is also very important to the clinicians, is, that during the abrasion procedure, exposure time affects high-translucency ceramic more, than it affects the regular ceramic [8].

A study by Grasel et al. was done on bonding effectiveness when the zirconia is treated with alumina air abrasion (AI) procedure. The findings showed, that also in the regular zirconia ceramic, the AI procedure provided higher SBS values for most of the tested luting systems [12]. Alumina air abrasion is also a very effective in the field of composite restorations. In a study, done by Cura et. al, alumina particle abrasion yielded the highest bond strength when composite resin onlays surfaces were analyzed, and also their roughness showed the highest value in comparison to other particle blasting methods [13]. Also, when using air abrasion as a surface treatment method, it should be noted, that it might affect the ceramic thermally. Hallman et al. concluded a research, in which they analyzed the surface and topography of Y-TZP ceramic affected by silica-coated alumina particles, and came to a result, which concluded, that during the procedure, thermal energy is formed, which melts the surface of the ceramic [14]. Scientists have also claimed, that when using air-abrasion, and aiming for an increased roughness, the best results are obtained, when the zirconia ceramic is still in its green stage, before sintering [15]. Recent additional work done by Cadore-Rodrigues et al. showed, that new materials used for blasting procedures, which have 7% silica in their composition or silica-coated aluminum oxide particles, show better bonding performance to Y-TZP ceramic, after aging procedures [16].

It should be noted, that according to scientist Turp et al. work, the size of the particles, and the duration of air-particle abrasion affects not only the roughness of Y-TZP, but also, the phase transformation [17]. During their experiment, different sized particles were used (30 µm; 50 µm, 110 µm, 250 µm Al2O3), with different application times (5, 15 and 30 seconds), and the test results have reported, that the highest size and longest air-particle abrasion times affect the Y-TZP ceramic roughness the most, although, longer exposure times should be taken into consideration, due to the degradation of the Y-TZP ceramic itself [17]. Also, in Abi-Rached et al. article, considering the abrasion particle sizes application to Y-TZP, it was noted, that for mechanical bonding, 120 µm Al_2O_3 particles were the most promising, out of the other ones tested [18]. The influence of particle sizes during air-abrasion with Al_2O_3 to Y-TZP, was analyzed in a research work, done by Fonseca et al., which revealed, that the 250 µm alumina and the smallest used silica particles did not affect positively, and even decreased the flexural strength of the material, when the other particles (sized 120 µm Al2O3, 120 µm Al2O3+Rocatec Plus) increased the same properties [19]. Additional research for these types of studies is required for high-translucency ceramic, to evaluate the most effective size of particles, during blasting procedures.

In the recent work of Shimoe et al., the results of their study have stated, that when analyzing the bond between indirect composite resin and Y-TZP ceramic, airborne-particle abrasion improves the SBS, although, they state, that the size of the particles or the pressure of the jet is not the primary influencer of this result [20]. Although, when considering the pressure of the airborne-particle abrasion process, Glebowski et al. conducted a research, where titanium surface was abraded with different sized Al_2O_3 particles, analyzing various pressures effectiveness, and their work has concluded, that the highest bond strength results, between the ceramic and titanium, were achieved by using 110 µm Al_2O_3 particles and 0,4 MPa pressure [21]. This shows, that the particle-abrasion can also be used for other dental materials, as a method of choice for increasing the bond strength between them. Although, when considering high-translucency ceramic surface treatment, the best results for the increase in bond strength was 0,2 MPa pressure [11]. Also, according to Aung et. al work, for high-translucency ceramics, the most effective bonding resulted when the pressure of alumina-blasting was also 0,2 MPa [9]. Additional scientifical analyses are required to better understand the most optimal pressure that should be used for high-translucency ceramic, to increase its bond strength optimally.

Conclusions

This systematic review states, that the following conclusions can be drawn:

1. The main material used for particle abrasion which gives the most effective results in increasing the bond strength of high-translucency zirconia ceramic is Al_2O_3.
2. The most effective size of the Al_2O_3 particles varies from 50 to 110 µm.
3. Exposure time of particle-abrasion, which yields the best SBS and TBS results, should be at least 15 seconds.
4. The most effective bonding results to high-translucency ceramic, were achieved when using 0,2-0,3 MPa pressure, although the pressure needs to be monitored thorough the procedure, in order not to damage the ceramic restorations.

References

5. Christensen GJ. Is the rush to all-ceramic crowns justified? The Journal of the American Dental Association 2014, 145(2), 192–194. doi:10.14219/jada.2013.19
6. Piconi C, Maccauro G. Zirconia as a ceramic biomaterial. Biomaterials 1999; 20(1):1-25.
7. Alfawaz Y. Zirconia Crown as Single Unit Tooth Restoration: A Literature Review. J Contemp Dent Pract 2016; 17(5):418-422.
8. Mao L, Kaizer M R, Zhao M, Guo B, Song YF, Zhang Y. Graded Ultra-Translucent Zirconia (5Y--PSZ) for Strength and Functionalities. Journal of Dental Research 2018, 002203451877128. doi:10.1177/0022034518771287
9. Kwon SJ, Lawson NC, McLaren EE, Nejat AH, Burgess JO. Comparison of the mechanical properties of translucent zirconia and lithium disilicate. J Prosthet Dent. 2018; 120(1):132-137. doi:10.1016/j.prosdent.2017.08.004
10. Ghodsi S, Jafarian Z. A Review on Translucent Zirconia. Eur J Prosthodont Restor Dent. 2018;26(2):62-74. Published 2018 May 30. doi:10.1922/EJPRD_01759Ghodsi13
11. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and

meta-analyses: the PRISMA statement. J Clin Epidemiol 2009; 62:1006–1012

12. Zhao P, Yu P, Xiong Y, Yue L, Arola D, Gao S. Does the bond strength of highly translucent zirconia show a different dependence on the airborne--particle abrasion parameters in comparison to conventional zirconia?. J Prosthodont Res 2020; 64(1):60-70. doi:10.1016/j.jpor.2019.04.008
13. Aung SSMP, Takagaki T, Lyann SK, et al. Effects of alumina-blasting pressure on the bonding to super/ultra-translucent zirconia. Dent Mater 2019; 35(5):730-739. doi:10.1016/j.dental.2019.02.025
14. Ågren M, Kou W, Molin Thorén M. Bond strength of surface-treated novel high translucent zirconia to enamel. Biomater Investig Dent 2019; 6(1):35--42. Published 2019 Nov 4. doi:10.1080/26415275.2019.1684200
15. Yoshida K. Influence of alumina air-abrasion for highly translucent partially stabilized zirconia on flexural strength, surface properties, and bond strength of resin cement. J Appl Oral Sci. 2020;28:e20190371. Published 2020 Feb 7. doi:10.1590/1678-7757-2019-0371
16. Grasel R, Santos MJ, Rêgo HC, Rippe MP, Valandro LF. Effect of Resin Luting Systems and Alumina Particle Air Abrasion on Bond Strength to Zirconia. Oper Dent 2018; 43(3):282-290. doi:10.2341/15-352-L
17. Cura M, González-González I, Fuentes V, Ceballos L. Effect of surface treatment and aging on bond strength of composite resin onlays. J Prosthet Dent 2016; 116(3):389-396. doi:10.1016/j.prosdent.2016.02.016
18. Hallmann L, Ulmer P, Reusser E, Hämmerle CH. Surface characterization of dental Y-TZP ceramic after air abrasion treatment. J Dent 2012; 40(9):723--735. doi:10.1016/j.jdent.2012.05.003
19. Martins SB, Abi-Rached FO, Adabo GL, Baldissara P, Fonseca RG. Influence of Particle and Air-Abrasion Moment on Y-TZP Surface Characterization and Bond Strength. J Prosthodont. 2019; 28(1):e271--e278. doi:10.1111/jopr.12718
20. Cadore-Rodrigues AC, Prochnow C, Burgo TAL, et al. Stable Resin Bonding to Y-TZP Ceramic with Air Abrasion by Alumina Particles Containing 7% Silica. J Adhes Dent 2020; 22(2):149-159. doi:10.3290/j.jad.a44151
21. Turp V, Sen D, Tuncelli B, Goller G, Özcan M. Evaluation of air-particle abrasion of Y-TZP with different particles using microstructural analysis. Aust Dent J 2013; 58(2):183-191. doi:10.1111/adj.12065
22. Abi-Rached FO, Martins SB, Campos JA, Fonseca RG. Evaluation of roughness, wettability, and morphology of an yttria-stabilized tetragonal zirconia polycrystal ceramic after different airborne-particle abrasion protocols. J Prosthet Dent 2014;112(6):1385-1391.
23. Garcia Fonseca R, de Oliveira Abi-Rached F, dos Santos Nunes Reis JM, Rambaldi E, Baldissara P. Effect of particle size on the flexural strength and phase transformation of an airborne-particle abraded yttria-stabilized tetragonal zirconia polycrystal ceramic. J Prosthet Dent 2013; 110(6):510-514.
24. Shimoe S, Peng TY, Otaku M, Tsumura N, Iwaguro S, Satoda T. Influence of various airborne-particle abrasion conditions on bonding between zirconia ceramics and an indirect composite resin material. J Prosthet Dent 2019; 122(5):491.e1-491.e9. doi:10.1016/j.prosdent.2019.08.016
25. Golebiowski M, Wolowiec E, Klimek L. Airborne-particle abrasion parameters on the quality of titanium-ceramic bonds. J Prosthet Dent 2015; 113(5):453-459. doi:10.1016/j.prosdent.2014.10.007