ORIGINAL RESEARCH

Evaluation of Physical Changes and Bond Properties of Monolithic Zirconia Following Surface Treatment with Alumina and Synthetic Diamond Particles: A Comparative X-ray Diffraction Analysis

Arshi I Kazi[1], Ramandeep Dugal[2], Pallavi Madanshetty[3], Aamir Z Godil[4], Kashif Y Gandhi[5], Anam M Mukadam[6]

ABSTRACT

Aim: The aim of this study was to compare and evaluate the phase transformation and effect on the bond strength and fracture toughness of monolithic zirconia after surface treatment with alumina and synthetic diamond particles.

Materials and Methods: Forty samples of monolithic sintered zirconia discs (Y-TZP) were divided into two groups of 20 samples each. Group A – air abrasion with alumina particles ($n = 20$); group B – air abrasion with synthetic diamond particles ($n = 20$). Pretreatment phase and posttreatment of each zirconia sample from group A and group B were evaluated using an X-ray diffraction machine. The surface roughness of each zirconia sample was evaluated using a profilometer. Composite discs were fabricated and bonded to the air-abraded surface of each zirconia sample from group A and group B using a dual-cured resin cement, respectively. These samples were mounted in an acrylic block to determine the bond strength of zirconia with resin cement using a universal testing machine. This was followed by a fracture toughness test of the samples using a Vickers indentation hardness tester. The results were subjected to statistical analysis using a t-test, and relevant statistical conclusions were drawn.

Results: The mean ± SD of monoclinic content in group A (alumina particles) and group B (synthetic diamond particles) was $0.82 \pm 0.010\%$ and $0.76 \pm 0.015\%$, respectively. The mean ± SD of surface roughness in group A (alumina particles) and group B (synthetic diamond particles) was 0.507 ± 0.106 and 0.513 ± 0.116 µm, respectively, and the mean ± SD of bond strength in group A (alumina particles) and group B (synthetic diamond particles) was 6.11 ± 1.47 and 6.49 ± 0.83 MPa, respectively. The mean ± SD of fracture toughness in group A (alumina particles) and group B (synthetic diamond particles) was 2.63 ± 0.46 0.5 and 5.70 ± 1.03 MPam$^{0.5}$, respectively. $p < 0.05$ was considered statistically significant.

Conclusion: The distribution of mean monoclinic content was significantly higher in zirconia samples abraded by alumina (Group A) as compared to synthetic diamond particles (Group B). The mean surface roughness and bond strength results were statistically insignificant between both groups. The distribution of mean fracture toughness was significantly higher in group B compared to group A.

Clinical significance: Synthetic diamond particles for air abrasion of Y-TZP can be a promising alternative to alumina as they cause minimal changes in the structural integrity without compromising the bond strength.

Keywords: Air abrasion, bonding, fracture toughness, laboratory research, phase transformation, surface roughness.

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INTRODUCTION

The principal characteristics favoring use of zirconia as a biomaterial are chemical and dimensional stability, mechanical resistance, hardness, and an elastic modulus of the same order as stainless steel.[1,2] Zirconia is the oxidized form of zirconium and can exist in several phases, depending on the temperature. The three phases of zirconia are monoclinic (at room temperature), tetragonal (above 1170°C) and cubic (above 2370°C). Dental zirconia is usually produced by stabilizing zirconia with alloying metal oxides such as yttrium oxide (Y_2O_3, 3 mol%) to produce yttria-stabilized-tetragonal zirconia polycrystal (3Y-TZP). This composition is stable at room temperature. It shows high elastic modulus, flexural strength and fracture toughness.[3–5]

The high fracture toughness of Y-TZP is related to a martensitic-type phase transformation from tetragonal to monoclinic when subjected to mechanical stress. This phase transformation is accompanied by very large shear strain (16%) and volume increase (4%), which generates a field of compressive stress around the crack

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tip that may prevent crack propagation.[6] Apart from the mechanical properties, adhesive cementation of zirconia restoration also plays an important role in achieving its clinical success. Adhesive cementation is necessary to improve retention and marginal adaptation and reduce the possibility of recurrent decay.[7] It has been reported that the clinical success of resin bonding procedures for cementing ceramic restorations depends on the quality and durability of the bond between the ceramic and the resin cement.[8] The zirconia surface is chemically inert; thus, usual ceramic etching techniques that involve the use of 10% hydrofluoric acid gel followed by a silane coupling agent do not promote proper adhesion at Y-TZP substrates. For this reason, establishing a strong and stable bond with resin composite cements has proven to be difficult without a proper zirconia surface treatment.[6] Since zirconia is acid resistant, a durable bond mainly relies on micromechanical interlocking created by surface roughening.[8] Some of the common surface treatment options are grinding, abrasion with diamond rotary instruments, airborne particle abrasion with aluminum oxide or silica-coated aluminum oxide, or any combination of these methods.[9]

Nowadays, Y-TZP surface abrasion with refined alumina (aluminum oxide) particles at a moderate pressure in combination with the use of primers and/or luting resins can be considered the state-of-the-art methodology of bonding to zirconia.[6] Air abrasion aids in the removal of loose contaminated layers, increases the area available for bonding by increasing the surface roughness, improves the micro-mechanical retention of the bonding agent, modifies the surface energy, and improves the wettability of luting materials regardless of the type of resin cement used.[7, 10–13]

Recently, air abrasion with diamond particles has been tried, and studies have shown that synthetic diamond particles improve the shear bond strength of the resin-luting cement and zirconium oxide core more than the alumina particles. This is primarily due to the hardness and particle shape of diamond.[14] These studies have hypothesized that diamond particles, being harder than alumina particles, could have produced a rougher surface on air blasting. The use of air-abrasive particles still raises two main concerns: the possible tetragonal-to-monoclinic phase transformation inducement and the controversial effect on the zirconia strength, since some authors have attributed the zirconia strengthening effect to the air abrasion and others have reported a strength reduction effect related to the possible creation of surface microcracks.[6] One study has also stated that surface treatment using air-abrasive alumina particles reduces the fracture toughness of zirconia.[15] According to the recent literature, the clinically relevant effects on ceramic strength can be avoided if a moderate air abrasion pressure is used.[6]

However, no studies have been carried out to relate the effect of air abrasion of synthetic diamond particles on phase transformation and fracture toughness of zirconia as was previously done for alumina particles. Therefore, this study was undertaken to evaluate the effect of air abrasion of synthetic diamond particles on the phase transformation and fracture toughness of zirconia as compared to that with alumina. This would also provide more insights on which surface treatment increased the bond strength with minimal changes in the structural integrity of zirconia.

Null hypothesis: There is no difference between the bond strength and fracture toughness of monolithic zirconia abraded with alumina and diamond particles.

Source of support: Nil
Conflict of interest: None

MATERIALS AND METHODS

This study was conducted in an *in vitro* set-up. The sample size was determined based on prior literature and pilot studies, ensuring sufficient statistical power to detect significant differences in bond strength between the groups. A total of 40 specimens were made. This number was chosen to accommodate variability in test results and maintain an 80% power at a 5% significance level.

A dental CAD software was used to design zirconia discs of dimensions 10 mm in diameter and 2 mm in height. A Standard Triangle Language file was generated, which was used to mill the zirconia disc samples. Zirconia blanks were fed into the milling machine (3M Lava CNC 500 Milling Machine, USA) and 40 discs of the required dimensions were fabricated, sintered (1600°C for 9 hours) and polished using zirconia finishing burs with a hand-held micromotor.

The samples were divided into two groups containing 20 zirconia discs each.

- Group A – Zirconia disc samples were sandblasted with alumina particles (110 µm).
- Group B – Zirconia disc samples were sandblasted with synthetic diamond particles (30–50 µm).

All the samples of both groups were sandblasted with a standardized method with an air pressure of 0.2 MPa at a 90° angle for 20 seconds at a 10 mm distance. Zirconia samples without visible defects, such as cracks, chipping, or porosities, were included in the study to ensure uniformity and consistency. Samples with any visible defects or pre-existing alterations were discarded and replaced to maintain the integrity and reliability of the experimental data.

The flowchart (Fig. 1) outlines the methodology of this study.

Evaluation of Phase Transformation (Figs 2 and 3)

All zirconia disc samples were tested before and after sandblasting for determining the amount of monoclinic content. The disc was mounted on the stage of the machine and the diffractometer was set at 2θ 24–36°, with a step size of 0.02°/step, 40 mA and 40 KV for the sample. The knife edge attached above was first zeroed and then raised by 1.200 mm to contact the sample, and X-ray diffraction was carried out. The data so obtained was assessed and plotted as a graph using OriginPro 8 (Origin Lab Corporation, US). The graph was then compared with those in the database Personal computer – Powder diffraction file. The same protocol was carried out for the sample obtained after sandblasting in both groups (Figs 2 and 3). The relative monoclinic to tetragonal peak intensity ratio was calculated using OriginPro 8 software for both groups.

Monoclinic phase volume percentage *Vm* was calculated using Toraya et al.'s formula:[16]

$$Vm = \frac{1.311Xm}{1 + 0.311Xm}$$

Vm = Monoclinic phase volume percentage
Xm = Relative monoclinic to tetragonal peak intensity ratio

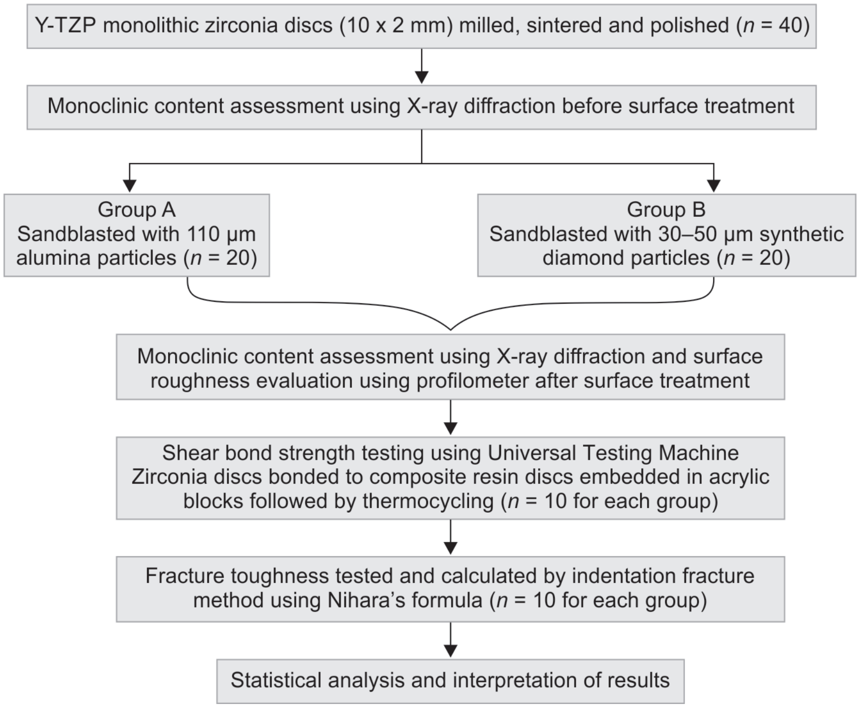

Fig. 1: Workflow of the study

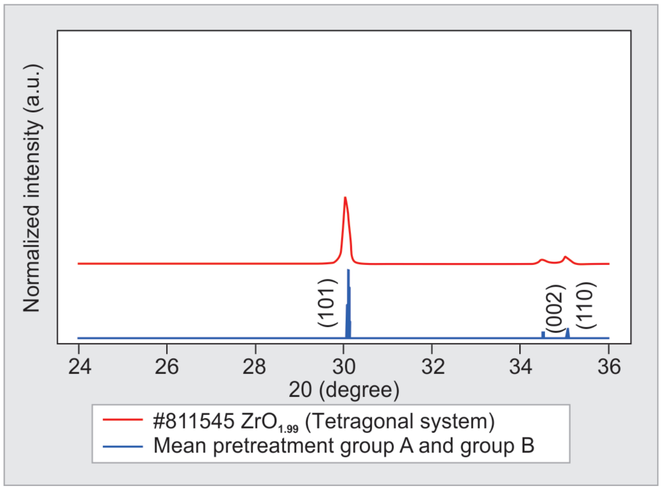

Fig. 2: Mean pretreatment monoclinic content (red) in test samples

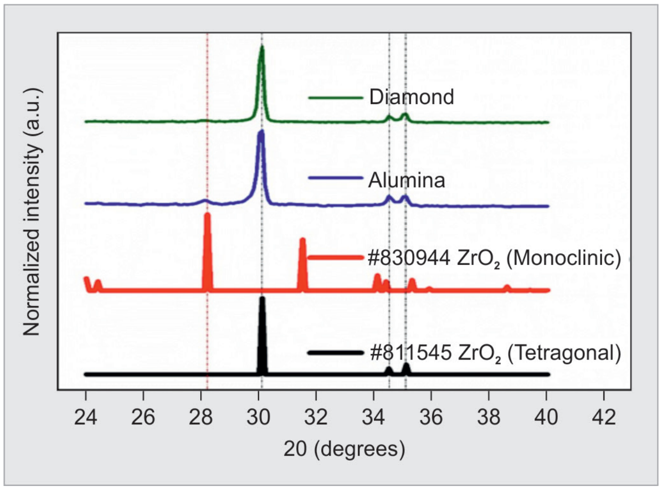

Fig. 3: Monoclinic content after sandblasting in group A (alumina) and group B (synthetic diamond particle)

Evaluation of Surface Roughness

Surface roughness measurement of the specimens was performed with a surface profilometer (Model: SJ 210, Mitututoyo, Japan). The direction of measurement was at a right angle to the direction of abrasion with the stylus speed of 0.5 mm/s and a cut-off length of 1.25 mm. A mean of two observations was recorded for each sample. The error of measurement was determined prior to each series with a surface roughness reference calibration standard.

Evaluation of Bond Strength

Twenty autopolymerizing polymethylmethacrylate resin blocks (Group A $n = 10$; Group B $n = 10$) with composite discs (5×10 mm) were fabricated. The composite discs were pretreated by etching with 37% phosphoric acid gel for 15 seconds, followed by rinsing with water and drying. Monobond N (one component primer, Multilink N, Ivoclar Vivadent, Liechtenstein) was applied with a micro-brush on the bonding surface of zirconia discs for 60 seconds and air-dried to achieve a thin, uniform layer. Resin luting cement – dual cure (Multilink N, self-cure resin-based luting material with light curing option, Ivoclar Vivadent, Liechtenstein) – was dispensed on the center of the zirconia disc sample and luted to the composite disc under a constant load of 10 kgs for 10 minutes using a customized load applicator device. All luted sample assemblies ($n = 10$/group) were stored in distilled water for 24 hours at 37°C, and then they were subjected to a thermocycling regime of 6000 cycles. They were immersed cyclically in water baths between 5°C and 55°C in an automatic thermocycling dipping machine specially

Table 1: Intergroup comparison of mean surface roughness, bond strength, monoclinic content and fracture toughness of test groups

	Group A [Alumina particles] (n = 10)		*Group B [Synthetic diamond particles] (n = 10)*		
Test	*Mean*	*SD*	*Mean*	*SD*	*p-value*
Surface roughness (µm)	0.507	0.106	0.513	0.116	0.905^{NS}
Bond strength (MPa)	6.11	1.47	6.49	0.83	0.493^{NS}
Mean monoclinic content (m%)	0.82	0.010	0.76	0.015	0.001^{***}
Fracture toughness ($MPam^{0.5}$)	2.63	0.46	5.70	1.03	0.001^{***}

Values are mean and SD, *p*-value by independent sample t test. ***$p < 0.05$ was considered to be statistically significant. NS, statistically non-significant

designed for simulation of oral temperature changes with a dwell time of 30 seconds in each bath. The machine was controlled by a programmable logic controller system.

The mounted specimen of each group was stabilized one by one in the universal testing machine (Model no. STS-248, Star Testing System, India) with the help of a metal holder to hold the acrylic block so that the specimen remained stable while testing. The shear bond strength test was performed at the zirconia disc sample and resin cement interface with a crosshead speed of 0.5 mm/min (accuracy of machine ± 1%) until complete debonding occurred and the maximum breaking load was recorded in Newton (N).

Evaluation of Fracture Toughness

Fracture toughness was evaluated for ten samples of each group by the Indentation fracture (IF) method using Nihara's formula:[15]

$K_{IC} = 0.203(c/a)^{-1.5}Ha^{0.5}$
$K_{IC:}$ Fracture toughness value ($MPam^{0.5}$)
H: Vickers Hardness
a: Half of indentation length (µm)
c: Half of crack length (µm)

Using Vicker's Microhardness Tester (Reichert Austria Make), a 100 g load for a dwell time of 20 seconds was applied onto the sandblasted zirconia disc surface to obtain an indentation. The length of the diagonals formed by this indentation was measured, and the hardness number was evaluated using the reference standard: ISO 6507. An initial load of 19.6 N (2 kg) was applied using a universal testing machine (Star Testing System, India, model no. STS-248) with Vickers indenter (diamond) at 136° and increased subsequently until a crack developed on the zirconia disc sample. The load holding time was 20 seconds. Load was increased up to 294 N (30 kg). A visual inspection system (100x magnification) with a geometrical DRO was used for measuring the crack length and the length of diagonals. A mean of two observations was recorded for each sample. The observed values were then substituted into Nihara's formula.

Statistical Analysis

All data collected were tabulated in MS Excel (version 14.0.4734.1000) and subjected to statistical analysis using Statistical Package for Social Sciences (SPSS ver21.0, IBM Corporation, USA) for MS Windows. The study employed an independent sample *t*-test to compare continuous variables (monoclinic content, surface roughness, bond strength, and fracture toughness) between group A and group B. This test was appropriate for independent groups with continuous data assumed to follow a normal distribution. Results were reported as mean ± standard deviation (SD), and a $p \leq 0.05$ was considered statistically significant.

RESULTS

The analysis of the outcomes was conducted as follows (Table 1):

Monoclinic Phase Transformation

- Results: The monoclinic content was significantly higher in group A (alumina particles, 0.82 ± 0.010%) compared to group B (synthetic diamond particles, 0.76 ± 0.015%), with a $p < 0.05$.
- Interpretation: Alumina particles induced a greater degree of phase transformation than synthetic diamond particles, potentially compromising the mechanical integrity of zirconia.

Surface Roughness

- Results: The mean surface roughness was similar between group A (0.507 ± 0.106 µm) and group B (0.513 ± 0.116 µm), with no statistically significant difference ($p \geq 0.05$).
- Interpretation: Both abrasives produced comparable surface roughness, indicating that the particle type did not significantly impact the textural alteration of zirconia surfaces.

Bond Strength

- Results: The mean bond strength was slightly higher in group B (6.49 ± 0.83 MPa) compared to group A (6.11 ± 1.47 MPa), but the difference was not statistically significant ($p > 0.05$).
- Interpretation: Synthetic diamond particles provided equivalent bond strength to alumina particles, confirming their potential as an alternative abrasive material for surface preparation.

Fracture Toughness

- Results: The mean fracture toughness was significantly higher in group B (5.70 ± 1.03 MPa) compared to group A (2.63 ± 0.46 MPam^0.5), with a $p < 0.05$.
- Interpretation: Zirconia samples treated with synthetic diamond particles exhibited improved fracture toughness, indicating their ability to maintain structural integrity under stress better than alumina-treated samples.

DISCUSSION

Air abrasion with alumina is the most commonly used technique for the surface treatment of zirconia restorations.[16–18] Alumina, being less ductile than zirconia, having larger-sized grains and higher surface hardness, makes air-abrasion more effective.[19] It has been found that alumina abrasives in the range of 50–110 µm have exhibited increased long-term shear bond strength significantly.[14] They provide an ideal contribution to surface roughness with limited monoclinic phase development.[20]

In 2000, Sen et al. used an alternative air abrasion material, diamond particles, to increase the surface roughness and surface area of the glass-infiltrated aluminous oxide ceramic surface.

Although the particle size of the diamond particle was small, more roughness was observed with the diamond particles as compared to Al_2O_3 particles of larger size. The hardness of the diamond particles was stated as a reason for the following outcome.[21] In another study carried out by Kulunk et al., air abrasion with 30–50 µm synthetic diamond particles showed higher bond strength values between adhesive resin cement and zirconia core. However, they did not report a significant difference in the bond strength after sandblasting larger-sized Al_2O_3 (110 µm) particles compared to smaller-sized synthetic diamond particles (30–50 µm). SEM in their results showed that the synthetic diamond particles were geometric and angular, whereas Al_2O_3 particles were sharper and amorphous. Hardness and particle shape of synthetic diamond particles were responsible for increased abrasive efficiency in spite of their lower size.[14]

According to Mohs' scale, the hardness of alumina and synthetic diamond abrasives are 9 and 10, respectively. The surface hardness of zirconium oxide is 8.5, making it a more ductile material than these abrasives. The hardness of the abrasive particle affects the shear bond strength of the resin-luting cement and the surface topography of zirconium oxide more as compared to the size of the abrasive particle.[14] Since the mean surface roughness values were not statistically significant between both groups of the present study, their corresponding shear bond strength values were also not statistically significant under identical experimental conditions. Thereby, concluding that air abrasion of monolithic zirconia with alumina particles of size 110 µm and synthetic diamond particles of size 30–50 µm resulted in statistically insignificant surface roughness and bond strength values.

When 3Y-TZP is subjected to external stresses due to grinding, abrasion or polishing, tetragonal-monoclinic phase transformation occurs, which results in a local volumetric increase, thereby initiating compressive stresses.[22] These compressive stresses may either develop on the ground surface or in the vicinity of the crack tip, preventing further propagation of the crack. For the crack to propagate, it must overcome these compressive stresses, which explains the increased fracture toughness of zirconia compared to other ceramics. The process of transformation toughening occurs when the zirconia particles are in their metastable tetragonal form and on the verge of transformation. The metastability of the transformation process is dependent on various factors such as the composition, size, shape of the zirconia particles; the type and amount of the stabilizing oxides; and the interaction of zirconia with other phases.[22–24]

Polycrystalline zirconia containing a high content of metastable tetragonal phase shows high strength, high fracture toughness ($K_{IC} = 6–9$), and small grain size. At a low concentration of tetragonal phase <30%, there is a rapid decrease in strength accompanied by a rapid increase in grain size. These results are explained by means of a stress-induced phase transformation in the metastable tetragonal phase.[25] Studies have shown that the process of surface treatment of zirconia may affect the surface stress state and indirectly affect aging. Also, early aging or excessive temperature increase during surface treatment may cause reversal of phase transformation, monoclinic-tetragonal phase. The overall thickness of the monoclinic transformed layers depends on the severity and rate of loading.[26] This possibly leads to easy crack propagation and reduced strength of zirconia.[5,27] Air particle alumina abrasion does create surface damage and, under humid conditions, may allow slow crack growth and failure of the zirconia in the long run.[5]

In the current literature, very limited data has been published regarding the phase transformation caused by air abrasion of synthetic diamond particles on monolithic zirconia. The X-ray diffraction results in this study before air abrasion of the zirconia samples revealed a pure tetragonal form of zirconia. However, after air abrasion, a significant increase in the monoclinic phase was observed in both groups. These results were similar to observations reported by Kosmač et al. and Curtis et al. where air particle alumina abrasion produced a greater thickness of the monoclinic (m) phase when compared to diamond-grounded specimens. However, in their study the samples were ground with diamond burs unlike this study where the samples were air abraded.[28,29] Curtis et al. and Fonseca et al. observed that airborne-particle abrasion promoted phase transformation, and the percentage increase in the monoclinic phase was directly proportional to the size of the particles.[28,30] This observation is concurrent with the present study, as zirconia samples abraded with 110 µm alumina particles show more monoclinic content than those abraded with 30–50 µm synthetic diamond abrasives.

Phase transformation before bonding is undesirable as it reduces the toughness of the outer layers, making them brittle. Thus, dental practitioners need to be cautious when altering the surfaces of sintered zirconia.[26] Zhang et al. explored the effect of sandblasting on the long-term strength of Y-TZP and reported that the damage introduced into the ceramic undersurfaces due to sandblasting caused further reductions in strength levels by 20–30% under cyclic loading. They concluded that Y-TZP crowns sandblasted with alumina (50 µm) could cope with masticatory forces up to 400 N, despite some strength degradation associated with the introduction of larger flaws.[31] In a study carried out by Özcan et al., all types of abrasives increased the monoclinic phase of the zirconia sample. They further concluded that deposition of 50 µm alumina produced more surface roughness but decreased the biaxial flexural strength of the tested zirconia. Damage caused from air-abrasion was almost equivalent to 1 N indentation pressure. They suggested that topography after air-abrasion resembles edge-shaped grooves, which was responsible for strength degradation.[32] Varied observations were reported by Karakoca and Yilmaz, who concluded that the biaxial flexural strength of the Y-TZP materials decreased after grinding and significantly increased after sandblasting. They also stated that the low monoclinic content of sandblasted groups may lead to further weakening of the material, resulting in unexpected failures in the long run.[33]

Since zirconia is a brittle material, fractures are of the biggest concern in the masticatory environment. Due to a lack of evidence in literature over the correlation of monoclinic content and the fracture toughness of zirconia, the fracture toughness of the zirconia samples in both groups after air abrasion was evaluated. The mean fracture toughness values observed in this study of group A (alumina particles) was 2.63 ± 0.46 $MPam^{0.5}$. This value is higher than that reported by Paes et al., who observed a mean fracture toughness value of 1.41 $MPam^{0.5}$ after sandblasting zirconia with 50 µm alumina particles.[6] In a recent study by Rai et al., fracture toughness values of different translucent zirconia ceramics ranged from 2.39 to 9.86 $MPam^{0.5}$. They observed that high sintering temperature along with the increased dwelling time made the grain size larger and increased the number of micropores, resulting in a material with reduced mechanical properties but better translucency.[34]

Abrasion of densely sintered zirconia ceramic for roughening purposes can be detrimental and compromise the mechanical properties of zirconia. The progress of the transformation, which can lead to grain pullout and surface degradation from the applied oral stresses, leading eventually to the failure of restoration. El-Korashy and El-Refai noted in their results that the presence of greater monoclinic content after different surface treatments yielded higher fracture toughness values.[15] A contrasting inference can be derived from this study: An increase in the content of the monoclinic phase yields lower fracture toughness values. Guzzato et al. stated that microcracking and strength degradation may result from an excessive amount of transformed monoclinic phase and can lead to slow crack growth, thereby justifying the results of this study.[35]

Transformation toughening is not the only mechanism that can be responsible for increased fracture toughness. Other factors, such as microcrack toughening, crack field void formation, and contact shielding mechanisms that induce some sort of crack closure and crack deflection, could be some reasons for increased fracture toughness.[15]

The fracture toughness values of zirconia are also influenced by the content of the stabilizing oxides (yttria), their grain size and the processing method and the influence of these factors on the porosity and metastability of the tetragonal grains.[35]

Higher blasting pressures and larger abrasive particles lead to more extensive t m phase transformation. Moreover, flaws, pits, micro-cracks, melting of the surface, embedding of abrasive particle fragments into the ceramic surface, debris, grain pull-out and plastic deformation occur due to the impact of air abrasion.[36,37] Hence, sandblasting of intaglios with smaller abrasives has been recommended as larger abrasives produced visible surface defects.[38]

Since the samples and experimental conditions in both groups were identical, it is understood that the shape, hardness and size of the abrasive particles play an important role in determining the phase transformation and fracture toughness of zirconia. Moreover, larger sizes of alumina particles were used in this study compared to synthetic diamond particles. Therefore, the microcracks formed due to alumina sandblasting might be deeper, and the tensile stresses generated by these cracks would have been greater than the compressive stresses induced by phase transformation, leading to reduced fracture toughness of the zirconia samples in group A.

On the other hand, zirconia samples sandblasted with synthetic diamond particles due to their geometric shape and smaller size would have led to the formation of small microcracks. Additionally, as previously described, smaller-size synthetic diamond abrasives led to less phase transformation. Low monoclinic content at the abraded surface increased the fracture resistance of the zirconia disc, thereby reducing the crack propagation.

It is clinically important to choose an abrasive that causes the least phase transformation of sintered zirconia. Phase transformation is a one-time phenomenon and not repeatable, which can either occur before the cementation of the prosthesis during the laboratory procedures like milling, grinding, abrasion and polishing or intraorally due to mechanical stresses generated by the contact of the crown surface with the opposing dentition. Ideally, phase transformation is undesirable, but intraoral phase transformation is inevitable. However, phase transformation that occurs during the laboratory procedures can be controlled. Surface treatment of Y-TZP prostheses before bonding causes the phase transformation to occur extraorally. Thus, forming monoclinic content at the treated surfaces, compromising their toughness, and eventually making them brittle. These prostheses, once cemented, cannot undergo re-sintering and cause reversal of phase transformation, leaving behind the transformed monoclinic layer as it is. Hence, they are unable to sustain occlusal loads in the long run, with marked reduction in their longevity. In order to obtain high strength of zirconia restorations, a pure tetragonal phase with stabilizing oxides is essential. If the phase transformation has already occurred extraorally, it will not re-occur intraorally again when the prosthesis is under functional load. This will prevent the transformation toughening mechanism to act intra-orally, leading to crack propagation and early failure of the restoration under load.

Further studies with surface X-ray diffraction and SEM analysis of the Y-TZP surfaces after air abrasion with alumina and synthetic diamond particles can provide more conclusive results. Bond strength analysis of other resin cements on zirconia surfaces abraded with synthetic diamond particles needs more investigation. Also, phase transformation with different sizes of synthetic diamond particles needs to be evaluated.

CONCLUSION

Extraoral surface treatment of monolithic zirconia restorations with any abrasive results in the formation of a monoclinic surface. This compromises their toughness and eventually makes them brittle. Therefore, dental practitioners need to be cautious when altering the surfaces of these materials after sintering. In this study, it was observed that air abrasion of zirconia by synthetic diamond particles leads to less phase transformation, justifying increased fracture toughness and providing equivalent surface roughness and bond strength to that abraded with alumina particles. Hence, synthetic diamond particles for air abrasion of Y-TZP can be a promising alternative to alumina as they cause minimal changes in the structural integrity without compromising the bond strength.

Clinical Significance

Synthetic diamond particles for air abrasion of Y-TZP can be a promising alternative to alumina as they cause minimal changes in the structural integrity without compromising the bond strength.

Limitations

This study has certain limitations that warrant consideration. Firstly, as the study was conducted in an *in vitro* setting, the direct correlation of the findings to the clinical environment remains uncertain. Secondly, the use of disc-shaped specimens, rather than actual crowns, may not fully replicate clinical scenarios. Lastly, the results are specific to the use of a single type of cement, a particular size, and pressure of abrasive particles, thereby limiting the generalizability of the findings to other materials or clinical conditions.

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