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COMPARATIVE EVALUATE THE SURFACE PROPERTIES OF ZIRCONIA AFFECTED BY SIMULATED CHAIRSIDE GRINDING PROCESS USING DIFFERENT ABRASIVE AGENTS

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Abstract

Aim: The aim of the present study was to assess the change in physical properties (surface roughness,surface hardness and phase transformation) after surface grinding of zirconia by using three commerciallyavailable abrasives.

Materials and Methods: Thirty sintered zirconia specimens were prepared and divided into three groupsnamely Group M (grinded using Mani Dia diamond bur standard grit), Group T (grinded using Tri Hawkdiamond bur coarse grit) and Group P (grinded using Predator carbide bur). A customised assembly wasused to follow a standardised protocol for surface grinding. The surface roughness, surface hardness andphase transformation were recorded before and after the grinding procedure.

Statistical Analysis Used: ANOVA and Bonferroni post hoc test were used to assess the values obtainedafter the testing the surface roughness and surface hardness.

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Results: The results of the present study revealed the average values of change in surface roughness asGroup M (0.44 μm) and Group T (1.235 μm) and Group P (-0.88 μm). The average values of change insurface hardness were Group T (19.578 HV), Group M (46.722 HV) and Group P (36.429 HV). The changein surface hardness was not statistically significant. There was no phase transformation seen after thegrinding procedure.

Clinical Significance: Carbide burs along with copious water irrigation when used to grind zirconia intraorallyproduces has a polishing effect, minimal change in hardness & no phase transformation. The presentstudy advocates the use of carbides for chair-side grinding of zirconia.

Key Words: Carbides, chairside grinding, zirconia

INTRODUCTION

The increasing demand for aesthetics has led to metal-freerestorations becoming the material of choice for fixed dentalprostheses.[1-3] Metal-ceramic restorations, though the goldstandard for restoration of teeth have known drawbacks suchas compromised aesthetics and the possibility of delaminationof the ceramic overlying the metal.[4] One of the most recentadditions to the family of all ceramic materials is zirconia.Zirconia is a polycrystalline ceramic material. This polymorphexists in three phases-monoclinic phase (M), tetragonalphase (T), and the cubic phase (C). The tetragonal phaseshows the most optimum physical and mechanical properties.[5]

However, in the presence of stresses, the tetragonal crystalsundergo a phasic transformation to the weaker monoclinicphase. This martensitic phase transformation induces a 3–4%volumetric expansion of the crystal inducing internal stresseseventually making the material prone to fracture. The additionof a stabilizing agent yttrium oxide to zirconium

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dioxide leadsto the formation of Y-TZP.[6] This yttrium content of 3–5%maintains the stability of zirconia in the tetragonal phasethereby reducing the amount of phase transformation.[7]

Zirconia has been reported to have superior mechanicalproperties among all ceramic restorations.[8] It exhibits doublethe fracture toughness and bending strength as compared to theother ceramics.[9] This material fulfils the prerequisites of anideal restorative material due to its excellent physical propertieswhich include high strength, translucency, colour stability, andsuperior biocompatibility.[10,11]In spite of the excellent properties of zirconia, the surfacegrinding ofzirconia for occlusal adjustments can result in arelatively rough surface of the restoration, which may causesevere wear of opposing enamel.[12] A smooth surface of therestoration is necessary to avoid the plaque accumulation,gingivitis, periodontitis, wear of antagonist's tooth and othercomplications that can lead to the failure of restoration.[13]Grinding zirconia decreases its flexural strength and fractureresistance.[14] However, many a times, it is not possible to avoidgrinding during routine clinical or laboratory procedures. Thishas led to the development of newer materials that minimize,if not prevent any damage to the zirconia surface.

Newer instruments are being fabricated to improve theefficiency of grinding at the same time reducing the illeffects of the grinding procedure. Investigators have reportedthe effects of various grinding procedures on the surfaceproperties of Y-TZP ceramics in the previous studies.[15-23]Kosmac et al. and Iseri et al. documented a decrease in thestrength of zirconium oxide after grinding procedure.[15,18]Preis et al. reported an increase in surface roughness afterdental adjustments, which can subsequently be improved usinga polishing kit.[19] Xu et al. reported an improvement in thestrength of zirconia on fine grinding with diamond points.[24]

The residual surface compressive layers introduced during thegrinding procedure strengthens the zirconia considerably.[25]However, severe grinding process introduces deep surface flawswhich are difficult to remove and act as stress concentrators.[26]The studies have also reported a phase transformation fromthe tetragonal (T) to the monoclinic (M) phase due to thesuperficial modifications.[20,21]The design and cutting efficiency of instruments used forsurface grinding procedure can also affect the surface properties.

Comparison between the various grinding tools that can be usedfor surface grinding has been reported in the past. Ferrari andConti concluded that tungsten carbides had a better finishingpotential as compared to diamond points.[23] Ercoli et al. inhis study demonstrated the superior performance of carbidesin comparison to diamond points. He concluded that duringthe cutting process carbides require less load and advancesfaster within the substrate.[27] Carbides at high speed producea very smooth surface.[28] Hotta et al. assessed the durabilityof tungsten carbide and concluded that the damage to theblades increases the machining time, but this increase couldbe acceptable for a polishing effect.[29] Despite having a bettercutting efficiency of carbides, the studies in the past have notdocumented their effect on zirconia.

This study evaluated the effect of different commercially availablegrinding tools such as tungsten carbides and diamond points ofvarying grit sizes, after surface grinding of zirconia restorations.The changes in physical properties (surface roughness, hardness,and phase transformation) were assessed.

The null hypothesis studied was that surface roughness, surfacehardness, and phase transformation are not influenced by thegrain size and design of commonly used commercially availableand zirconia-specific abrasive agents.

MATERIALS AND METHODS

Thirty specimens of zirconia (3M™ ESPE™ Lava™,St. Paul, Minnesota, United States) were cut into the blocks ofdimensions 15 mm length × 10 mm width × 3 mm thicknessat the presintered stage and smoothened with silicon carbidegrinding paper #400, #600, and #1000 (3M 101 Q Wetordry,3M). The prepared specimens were then sintered. They weredivided into three groups with ten specimens per group. Therequired area for testing was marked [Figure 1].

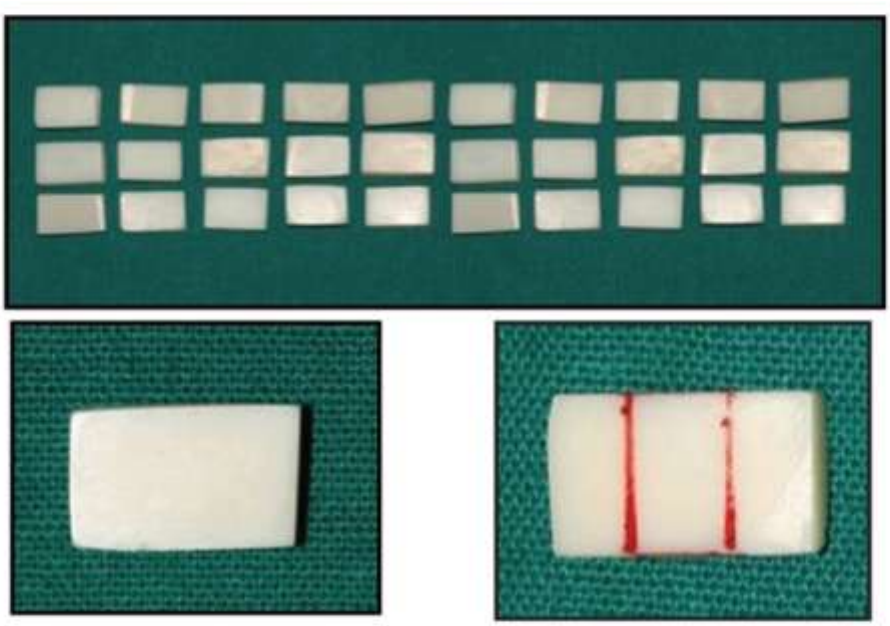

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Figure 1: Specimens and the tested area marked

The specimens were ground using the standard protocol describedlater. The specimens in Group T underwent grinding with adiamond point bur (198-018 C, 1.8 D × 8.0 L; Coarse grit, TriHawk, Morrisburg, Ontario, Canada) [Figure 2], Group M withanother diamond point bur (Standard grit, size 106–125, ManiDia burs, Mani, Inc., Tochigi, Japan) [Figure 3] and Group P withcarbide burs (Predator Turbo PR 3T, 1/10 D × 4.0 L, PrimaDental, United Kingdom) [Figure 4], respectively.

Figure 2: Tri Hawk diamond bur, coarse grit

Figure 3: Mani diamond bur, standard grit

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Figure 4: Predator carbide bur

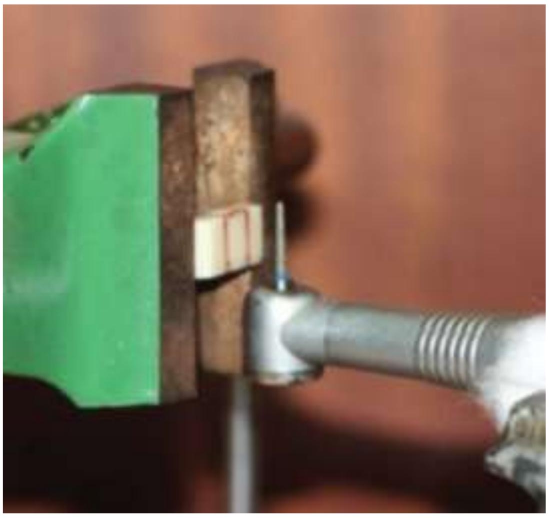

Figure 5: Customized assembly used for grinding of the zirconiaspecimens

A customized assembly was designed to mount both thehandpiece and the specimens [Figure 5]. The handpiece wasclamped on a flat platform which could slide sideways. Anotherclamp to stabilize the specimen was attached to the assembly.Burs inserted in the handpiece were oriented approximatelyparallel and positioned in contact with the specimen. Stabilizingboth the components ensured a constant load application.Specimens removed from assembly were cleaned and air driedbefore testing. The chairside grinding procedure was simulatedusing the three different burs as per the manufacturer'sinstructions. The grinding procedure was the first carried outfor Group T, then Group M, and Group P respectively, usingthe standardized protocol as described by Preis et al.[19] Eachsample was ground for 10 s.

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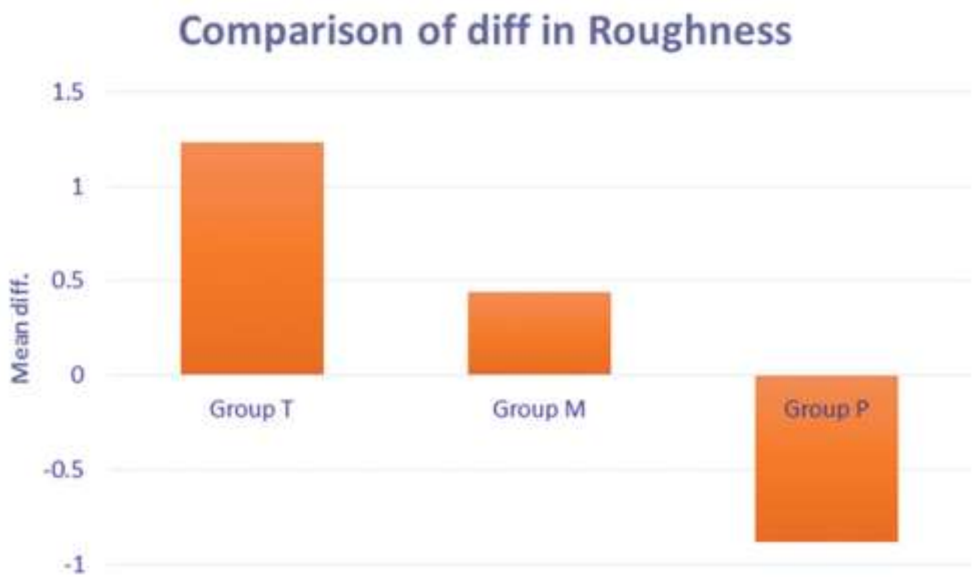
The pretreatment surface roughness Ra (arithmetic averageroughness) analysis was carried out for all thirty specimens fromthe three groups by means of a profilometric contacts surfacemeasurement device (Perthometer SP6, Feinpruf-Perthen,Mahr, Gottingen, G; 2 measurements per specimen;LT = 1.7 mm/0.25 mm, velocity 0.1 mm/s, 2 µm diamondindenter). Pretreatment surface hardness analysis was done for allthe samples using the Vicker's Microhardness Tester (ReichertAustria Make, Sr. No. 363798, using load: 100 g).

After wear simulation, the surface roughness Ra and surfacehardness were determined.Phase transformation of zirconia was investigated by X-raypowder diffraction technique (Bruker, D8 Advance) usingCuKα (1.54) X-rays. The diffraction profiles were acquiredin the 2 ϴ range from 20° to 80°, where ϴ is the angle ofreflection with the step size of 0.03 and scan rate of 0.6 s/step.The relative amount of phase transformation for the specimenswas determined as described by Karakoca and Yilmaz.[21]

RESULTS

Average values of change in roughness were 1.235 µm,0.44 µm, and −0.88 µm for Groups T, M, and P, respectively.Statistical analysis was carried out using the average values ofchange in roughness [Graph 1]. Surface roughness Ra valuesshowed a statistically significant difference between thegroups ($P < 0.001$). Grinding of the sintered zirconia specimenssignificantly increased Ra in Group T and Group M, whereasthe same procedure caused a reduction in the Ra for Group P.



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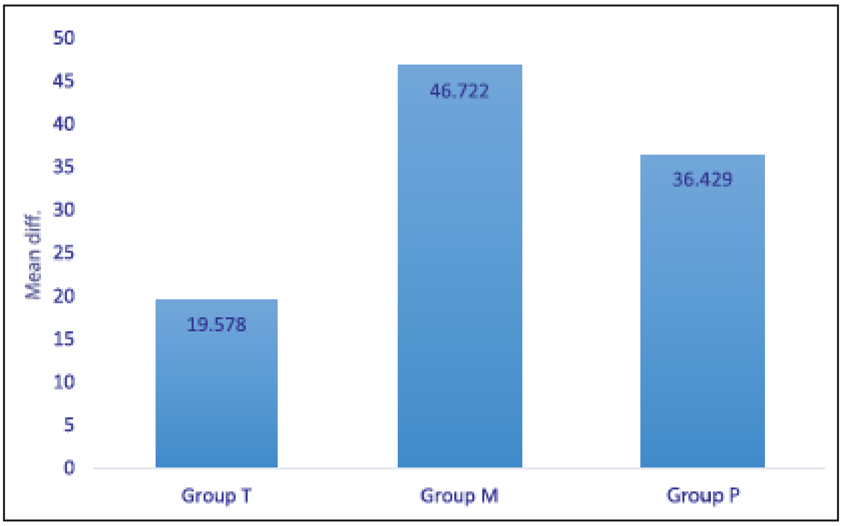
Graph 1: Average values of change in surface roughness



Graph 2: Average values of change in surface hardness

The one-way ANOVA demonstrated differences in themean values (P < 0.001), and the Bonferroni post hoctest revealed statistically significant differences among thegroups (P < 0.001).Similarly, average values of change in hardness were 19.578 HV,46.722 HV, and 36.429 HV for Groups T, M, and P,respectively. Statistical analysis was carried out using the averagevalues of change in hardness [Graph 2]. The one-way ANOVAdemonstrated differences in the mean values (P < 0.020), andthe Bonferroni post hoc test did not reveal any statisticallysignificant differences among the groups (P > 0.05).

The X-ray diffraction pattern and analysis of the peaks of thecontrol specimen confirmed tetragonal crystalline phase. Aftersurface manipulation with the abrasives, the intensity of thepeaks in specimens of Group P, M, and T decreased in thatorder. As compared to the sintered state, the ground specimenspresented asymmetrical broadening of the tetragonal peak andincrease of full width at half maximum. The least distortionof the peaks was observed in Group P as indicated in thegraph [Figure 6]. The grinding procedure had no significanteffect on the relative amount of tetragonal zirconia in all thegroups.

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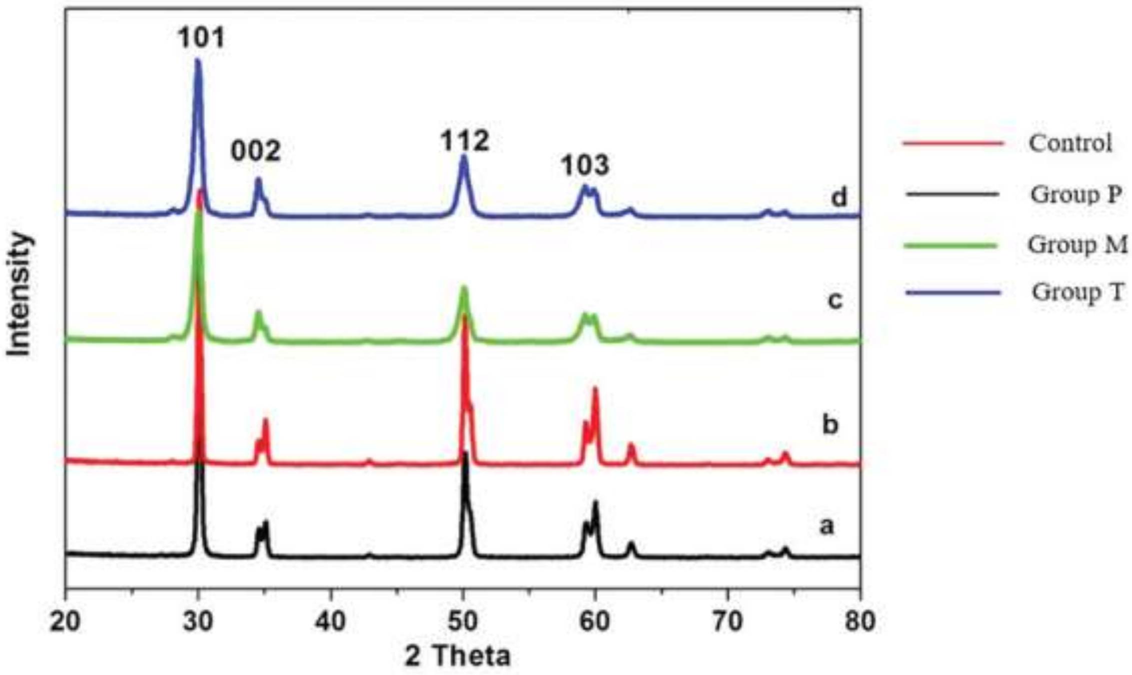

Figure 6: X-ray diffraction pattern following grinding of specimens

DISCUSSION

Chairside adjustment of a restoration is a standard protocolfollowed by clinicians for establishing optimal occlusalcontacts. Following such adjustments, the restoration shouldbe reglazed or mechanically polished to restore the surfacesmoothness.[30] However, reglazing is not always convenient orpossible. Therefore, the use of polishing is recommended torestore the surface finish and properties.[20]Advancements in material science and excellent physicalproperties have made zirconia, a popular alternative totraditional metal or PFM restorations for fixed dentalprostheses.[9]

Although zirconia meets the requirement of a prostheticmaterial, it has a disadvantage of causing irreversible wearof the antagonist tooth.[13] This process of wear also resultsin an increase in the surface roughness and loss of glaze ofthe restoration.[20] The surface smoothness of a restoration isessential to avoid complications such as plaque accumulation,gingivitis, periodontitis, and wear of antagonist tooth.[15] Asstudied by Bollen et al., surface roughness higher than 0.2 μmwill lead to bacterial adhesion, plaque maturation, and increasedthe risk of caries.[30] The rough surface of zirconia will causemore wear of the opposing tooth and also compromise theclinical performance of the restoration; hence, a polishedzirconia surface is preferred.[19,31,32]

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The previous studies show that reglazing the restoration afterchairside adjustments are necessary.[33] While others show thatmechanical polishing of the restoration can help restore thesurface properties.[21]In this study, the authors carried out a comparison betweendiamond points and carbide burs. Diamond points wereused (Mani Inc., Japan) as they are the most common abrasivesclinicians use to grind zirconia chairside. The high hardness ofzirconia necessitates the use of these coarse diamond rotaryinstruments.[32] Carbides are known to have a high cuttingefficiency at high speed.[34] Hence, these were chosen in thestudy. A commercially available zirconia-specific abrasivewas also used to study its effect on the zirconia surface incomparison to the popularly used burs described above.

Surface grinding usually leads to an increased surfaceroughness.[35,36] The results of this study indicated an increasein the surface roughness in Group T (1.235 μm) andGroup M (0.44 μm). The mean Ra value obtained for GroupT (1.235 μm) was more than that of Group M (0.44 μm). Thegrit size of the diamonds used in Group T was much coarseras compared to the one used in Group M thereby causing agreater surface roughness. As studied by Okhuma et al. largerthe grit size of diamond, more will be the grinding depth.[37]Coarse grinding introduces surface and subsurface flaws causinggrain pull out and strength degradation.[14] The results obtainedin this study were similar to previously reported studies.[31,38,39]

Güngör et al. studied the effects of surface treatment onzirconia and observed highest surface roughness in specimenswhich were ground using diamond rotary instruments (100 μmgrain size). They concluded that surface grinding was anabrasive surface treatment. It results in removing a greateramount of material and higher level of stress generation.[38]

Ramos et al. reported an altered micromorphological patternafter grinding zirconia ceramic. They stated that the grit sizeof diamond disks affected the surface roughness values. Lowersurface roughness values were observed with small grit sizediamond disks. Fine grit instruments have a large numberof grains and less distance between them, which results ingreater number of scratches which are close to each otherthereby creating a more homogeneous surface.[39]

Hmaidouchet al. reported a significant increase in surface roughnessafter coarse grinding. After polishing of the same specimen,smooth surface was obtained that was comparable to untreatedglazed zirconia surfaces. This was possible due to the removalof weakly attached surface grains and elimination of thegrinding trace lines. They concluded that polished surfaceswere better than glazed surfaces and produce less wear on theopposing enamel.[31] In

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this study, the high surface roughnessin Group T and Group M could be attributed to the grit sizeof the diamond points, with a higher grit size leading to deepersurface flaws.

The Ra value obtained for Group P (−0.88 μm) showeda decrease in surface roughness and had a polishing effect.This could be explained by the 8-bladed toothed geometryof the carbide which caused a polishing effect on thezirconia specimens. Carbides have a shearing action on thecutting substrate, whereas diamond points have an abrasiveaction.[34,40-42] Carbides have blades with slight negative rakeangle and 90 degrees edge angles. The clearance faces are eithercurved or have two faces to provide a low clearance angle nearthe edges and greater clearance space ahead of the followingblade.[34] As studied by Hotta et al., damage to the blade of acarbide bur increases with increase in machining time, but thebur could yet be acceptable for polishing.[29]

The result of the surface hardness values obtained indicateda reduction in the hardness of the zirconia in all the threegroups. Group M (46.722 HV) showed the highest reduction,whereas Group T (19.578 HV) showed the least reduction. Thedifference was statistically significant. This is in agreement withOkhuma et al. and Siegel.[37,40] They stated that heat generatedduring grinding process caused destruction and exfoliation ofdiamonds. Hence, the larger grit size of diamonds in Group Tcompared to that in Group M grinds the zirconia specimensfaster and efficiently, causing less change in surface hardness.The values of change in hardness obtained for Group P werenot statistically significant when compared to Group T andM. These findings are in agreement with those of Trainiet al. and Pittayachawan et al.[22,43] Traini et al. reported ahigher value of hardness for machined surfaces than for finepolished surfaces while a lower value of hardness for coarsepolished surface. They used silicone wells green-coarse gritand silicone wells yellow–super-fine grit (Edenta AG, Dental

Rotary Instruments, AU/SG, Switzerland) at 10,000 rpm togrind zirconia specimens. The reported differences betweenthese were statistically insignificant.[22]Pittayachawan et al.reported an increased hardness value of machined specimens ascompared to polished specimens. The specimens were groundedsequentially with 300, 500, 800, and 1000 grade siliconcarbide papers (Struers, UK). The specimens were polishedwith a DP-suspension (Struers, UK) containing polycrystallinediamond (Struers, UK) of size 9 μm and 3 μm for 10 minat a polishing machine speed of 150 rpm. The difference inhardness between these two groups tested was statisticallyinsignificant.[43]

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The X-ray diffraction pattern of the ground specimens showeda reduction in the peaks in all the three Groups T, M, andP, respectively as compared to the peaks seen in the control.The grinding procedure did not have any distinct influenceon the phase transformation of specimens in this study. Phasetransformation did not take place as the surface treatment wasnot effective enough to initiate a T→M transformation, but a lowamount of monoclinic phase was observed due to grinding.[44]The broadening of the tetragonal peaks could be due to thelattice distortion of the crystalline structure of zirconia.[19]

The results obtained in this study were similar to previouslyreported studies.[21,35,39,45]Karakoca and Yilmaz studied thephase transformation after grinding and sandblasting of Y-TZPand reported that grinding has no significant influence on thephase transformation.[21] Lee et al. studied the effect of differentgrinding burs on physical properties of zirconia and reporteda small amount of monoclinic phase in all experimentalgroups. They believed that the increase in local temperaturedue to excessive grinding and sparks could be the possiblereason for inducing a reverse phase change to the tetragonalphase.[35] Similarly, in this study, some amount of latticedistortion was seen which could be due to the excessive heatand sparks generated while grinding the surface. Continuouscopious water irrigation was able to control the amount ofheat generated. Ramos et al. reported that grinding promoteda higher monoclinic phase in the test group than the controlgroup. This test group underwent a heat treatment that induceda reverse transformation of the monoclinic phase achievinga monoclinic phase content similar to that of the controlgroup. They related the transformation rate to the grain size,larger the grain size lower will be the stability.[39] Lava zirconia(Lava Frame, 3M ESPE) which was the same brand used inthe present study, is known to have large grain size, thus greaterpossibility of the phase transformation.

The results of phasetransformation of this study are in agreement with that ofRamos et al. Juy et al. in their study, stated that the monoclinicphase induced was transformed back to the tetragonal phasedue to the increase in temperature of the surface undergoing thegrinding procedure.[46] Other studies also reported a decreasein the monoclinic phase due to reverse phase transformationby heat generation on excessive grinding.[46,47]Thus, the results obtained in the above study showed that thenull hypothesis was rejected for surface roughness and surfacehardness, whereas accepted for phase transformation.

CONCLUSION

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Within the limitations of this study, it may be concluded thatcarbides used for abrasion of the zirconia had a polishingeffect on the zirconia surfaces. Diamond points abradedand roughened the zirconia surface, resulting in surfaces thatrequired further finishing, and polishing. The use of thezirconia-specific diamond bur seems questionable as this studyshows that carbides have the potential to be used with greaterefficiency on zirconia surfaces. There was a reduction in thehardness of the zirconia when all the different abrasives wereused, though this reduction was not statistically significant.

No phase transformation was observed following abrasion ofzirconia with either diamond points of different coarseness andcarbide burs. Thus, this study advocates the use of carbides forchairside grinding of zirconia.

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