Effect Bur Velocity on Fracture Surface, Roughness and Morphology of Zirconia Crown and Bridge by Computer Aided Design and Manufacturing (CAD/CAM)

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Effect bur velocity on fracture surface, roughness and morphology of zirconia crown and bridge by computer aided design and manufacturing (CAD/CAM)

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***Abstract*— The Y-TZP has been used in dentistry such as crowns, fixed partial dentures, implants, abutments, and brackets. This paper studied effect cutting speed of bur on fracture surface, roughness and morphology of crowns made of different brands of ’yttria stabilized tetragonal zirconia polycrystals (3- 5 mol % Y) "by "computer aided design and manufacturing techniques. The results SEM of the surface morphology for each brands reveals milling traces and scratching induced by the milling tool also crack and microchips and pores appeared on the surface machining due to densification process. The SEM of the fracture surface morphology revealed the presence plastic deformation ,microchip,twist hackle and defects refers to the direction of crack propagation. The results of fracture resistance for crown shows the fracture force at high cutting speed cutting speed was lower than from low cutting speed Finally, the tool life was found increase with increasing cutting speed.**

***Keywords*— CAD/CAM, crown, bridge, fracture surface, roughness and morphology**

I. Introduction

Zirconia ceramic has been used for a few years in orthodontics for brackets and in prosthodontics for root posts and abutments. Dental ceramics are commonly used as esthetic material for conventional restorations, such as ceramic veneers, single crowns and fixed partial dentures, or implant supported superstructures.The restorative ceramics classified mainly into: (1) feldspar ($KAlSi_3O_8$) porcelain for porcelain-fused-to-meta (PFM) restorations, (2) leucite($KAlSi_2O_6$) -based or lithium disilicate ($Li_2Si_2O_5$) -based ceramics for sintering and heat pressing of ceramics, and (3) alumina (Al_2O_3) or zirconia (ZrO_2) ceramics as machinable ceramics for CAD/CAM systems**[1].**

Y-TZP exhibits exceptional fundamental properties of great interest to bio-medical engineering, such as high strength, fracture toughness, hardness, wear resistance, good frictional and non-magnetic behavior, electrical insulation, low thermal conductivity, corrosion resistance in acids and alkalis, modulus of elasticity similar to steel, and coefficient of thermal expansion similar to iron**[2].** Dental zirconia-based ceramics e.g., 3 mol% “yttrium stabilized tetragonal zirconia polycrystals (3Y-TZPs)”) exhibit excellent mechanical strength and superior fracture resistance due to inherent transformation toughening mechanisms, and they are widely utilized for the fabrication of prosthetic devices. These materials have a wide range of clinical applications, from implant abutments and single-tooth restorations to fixed partial dentures (FPDs) involving several elements[3].Of all the restorative Ceramics,” yttria-stabilized tetragonal zirconia polycrystal (Y-TZP)” is the most robust. There are several variants of Y-TZP, depending on additives and dopants, sintering profiles, and ensuing heat treatments**[4]. “**Computer-aided design (CAD) and computer-aided manufacturing (CAM)” technology systems use computers to collect information, design, and manufacture a wide range of products. With CAD/CAM, parts and components can be designed and machined with precision using a computer with integrated software linked to a milling device **[5].** For dental applications, zirconia is stabilized at room temperature with the addition of 3-5 mol% yttria, this configurations reach high strength (800-1200 MPa) and good fracture toughness (6-15 MPa * $m^{1/2}$).The fracture behavior is strongly influenced not only by fabrication (density, severity, flaws, voids, or cracks), but also by the surface design of the restoration**[6].**

This research aims to fabricate crowns made of from different brands of “yttria stabilized tetragonal zirconia polycrystal (3-5mol%Y-TZP)” by computer aided design and manufacturing techniques and investigate effect of cutting speed on fracture surface, roughness and morphology of crowns as well as bur life.

II. Experimental part

In this work three type of presintered zirconia were employed according to manufacturing procedure: (Vita Zahnfabrik Sackingen consist from yttria stabilized tetragonal zirconia polycrystal,ZrO_2 (3 Y_2O_3 mol%), Kerox dental zirconia and high strength zirconia DD Bio ZW ISO) Germany. Crowns and bridges were machined from presintered zirconia block by CAD/CAM system (full anatomy crown with minimum thickness 0.5 mm).This samples divided to two groups with different cutting speed (100 & 150) m/min. The structures of crown and bridge done with a minimum wall thickness of the core diameter(1mm) and cementation gap approximately 0.04mm thickness, the cement space started at 0.25 mm after complete dental prostheses the samples were fully sintering to 1500 °C for 2 hr. at 8°C/min. The full sintering treatment was accomplished in (ZIRKONOFEN 600 furnace , Zirkon Zahn company).

A. MECHANICAL TESTS

The tests were carried out on samples zirconia after machining by CAD/CAM and sintering to compute mechanical properties such as flexural strength test.

B. SCANNING ELECTRON MICROSCOPE

After completed sintering the morphology of crown, bridge surfaces ,and the morphology of fracture surface was examined directly, by employing SEM (inspect S50 SEM,Japan made).

III.RESULTS AND DISCUSSION

Figures 1 show the relation between roughness values and type of material from Zirconia (three different brands,dental direct block, Kerox dental block & Vita YZ HT block) of the prepared samples using Ra measurement at two different cutting speed. The roughness were tested for side of the samples. It can be noticed that the roughness for the side decreases with increasing the cutting speed. Each fabrication process significantly affected the surface roughness (Ra). The results show surface roughness values for computer-aided design and manufacturing of sintered samples at low cutting speed (100 m/min) without any polishing in the range from 1.145µm up to 1.952 µm while surface roughness values at high cutting speed (150 m/min) from 1.002 µm to 1.476 µm depending on type of material. These result agreement with Yusuke Ito et al show that the surface quality improved as the rotational speed increased **[7].** In cutting speed 100 m/min the best brand was **(Kerox dental block)** have lowest surface roughness , next **dental direct block** have medium and **Vita YZ HT block** have highest surface roughness , but in cutting speed 150 m/min the best brand was **Vita YZ HT block** have lowest surface roughness, next **dental direct block** have medium surface roughness and **Kerox dental block** have lowest surface roughness. In addition to the sintering process has no significant effect of reducing surface roughness of the samples these results agree with other researchers results how state that the surface roughness could not significantly reduce when sintering of the computer-aided design and manufacturing of presintered Y-TZP surface. Sintering it causes "grain coarsening" and residual stresses attributed to the increased surface roughness as well as the increased roughness due to shrinkage related with grain growth and the transformation of "monoclinic to tetragonal phase" **[8].**

To determine the location of the failure, SEM analysis were selected for the morphology of fractured specimens. Figure 2 shows the surface fracture morphology for vita YZ block after bending tested for specimens machined at cutting speeds 100 m/min at different magnification powers. Figure 2a shows details of the fractured area including nucleation of microcracks, arrest lines and micro-chips on the milled surface. Figure 2b reveal cracks ,arrest lines and twist hackle while Figure 2c shows arrest lines and "direction of crack propagation (dcp)".

SEM analysis shows that the fracture origin is situated on the reversed surface to the loading. According to 'weakest link theory' the fracture happens when weakest of defects begin to growth and therefore the flexural strength is robustly affected by changes in population defects in the samples. The ceramics materials are much weaker in "tension" than "compression" and therefore begins to break from the bottom surfaces to the top **[9].**

Figure 3 shows morphology of fracture surface for Vita YZ HT block after bending tested for specimens machined at cutting speeds 150 m/min at different magnification powers. Figure 3a reveals only the plastic deformation was appeared on fracture surface. Figure 3b shows the flaws and pores were observed. Figure 3c revels the "direction of crack propagation (dcp)" as marked by a yellow arrow as well as hackle and wake hackles were detectable.

Figure 4 shows surface fracture morphology for Kerox dental block after bending tested for specimens machined at cutting speeds 100 m/min at different magnification powers. Figure 4a reveals plastic deformation and cracks were appeared on fracture surface. While Figure 4b shows high magnification of power the arrest lines and direction of crack propagation was appeared. Figure 4c shows hackle line and direction of crack propagation. It can notice that fracture starts from the surface opposed to loading. Figure 4c shows the surface fracture morphology for Kerox dental block after bending tested at cutting speeds 150 m/min at different magnification powers. Figure 5 a reveals flaw appeared on surface such as plastic deformation and fine debris. Figure 5b shows arrest lines, wake hackle and the "direction of crack propagation (dcp)". At low magnification power (Figure5c) revealed arrest lines and crack propagated on surface, The fracture begins by the formation of microcracks in the area with surface flaws, then the growth of microcracks and also the propagation weren't straight. This behavior are often related to part transformation throughout crack propagation. The results were according to other researchers **[10].** Figure 6 shows the surface fracture morphology for dental direct block after bending tested for specimens machined at cutting speeds 100 m/min with different magnification powers. Figure 6 a reveals high magnification of power the plastic deformation. Figure 6b shows direction of crack propagation (dcp) and wake hackle was found. Figure 6c revealed the arrest line,"direction of crack propagation (dcp)" and wake hackle line was found at low magnification powers. Figure 7 shows the surface fracture morphology for dental direct block after bending tested for specimens machined at cutting speeds 150 m/min at different magnification powers. Figure 7a reveals the direction of flow of grain during plastic deformation at higher high magnification. Figure 7b shows of "arrest lines", "twist hackle" and the "direction of crack propagation (dcp)". Figure 7c revealed crack propagated on surface fracture and arrest lines at low magnification power. It can be noticed from SEM examinations of the fracture surface the general "direction of crack propagation" as verified by "arrest lines", "hackle", "twist hackle", and "wake hackle". The fracture clearly started from the incisal tip of the influenced zirconia framework and propagated toward the cervical region bridge(three-unit Fixed Dental Prosthesis) since most bridge and framework fractures start from the connector and propagate towards the palatal regions due to bending stresses generated by "occlusal" loading on the "pontic". The results were consistent with other researchers **[11].**

The results of fracture resistance test for crown show mean values of the fracture force of the tested crowns machined at (100-150)m/min cutting speed varied between 2746.6666 N to 2647.3333N. The fracture force at high cutting speed was lower than lower cutting speed but test showed no significant different between two fracture forces. The fracture model and the fracture force did not reveal considerable differences between the tested crowns. The quality of the tested ceramic crowns was lessened by cycling loading and the fracture loading of the tested crowns was sufficiently high to oppose chewing forces in posterior applications. The fracture conduct of a ceramic is firmly influenced defect size (density, severity, flaws, voids or cracks) and manufacture [**5**]. Figure 8 shows the SEM fractographic analysis for dental direct block machined at cutting speeds 100 m/min after fracture tested with different magnification powers. Fractographic analysis reveals flaw appeared on surface such as plastic deformation, arrest line, hackle and the direction of crack propagation (dcp). When the crack moves quickly , these heckles lines are commonly generated.. Figure 9 shows the SEM fractographic analysis for dental direct block machined at cutting speeds 150 m/min after fracture tested with different magnification powers. Fractographic analysis reveals arrest line and fine particles of debris on surface and defects developed on surface fracture such as"arrest line", "hackle" ,"wake hackle" and the "direction of crack propagation (dcp)" is again confirmed by the presence of "wake hackle" .

SEM fractographic analysis revealed in two cases, primary fracture origin was located at the occlusal surface it is known one of the factors affecting stress and fracture resistance is the thickness of the occlusal for all ceramic crowns. The fracture resistance for a monolithic zirconia crown will rise when only a small increase in occlusal thickness **[12].**

III. Conclusions

1. Surface morphology show clearly the cracks, pores ,groove related with plastic deformation and scratching produced by ploughed milled surface by milling tool for three different brands (dental direct block , Kerox dental block and Vita YZ HT block).
2. Decreasing the roughness of the surface when the cutting speed is increase.

3. The fracture force of crown for (dental direct block) decrease when cutting speed increasing and the wear mechanisms observed were twist hackle, hackle , arrest line and dcp defects developed on surface fracture .
4. The fracture clearly start from the incisal tip of the influenced zirconia framework and propagated toward the cervical region bridge.

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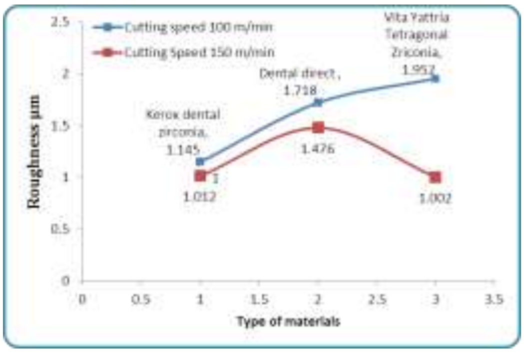

Figures 1: Relation between surface roughness and type of machined material at two different cutting speed.

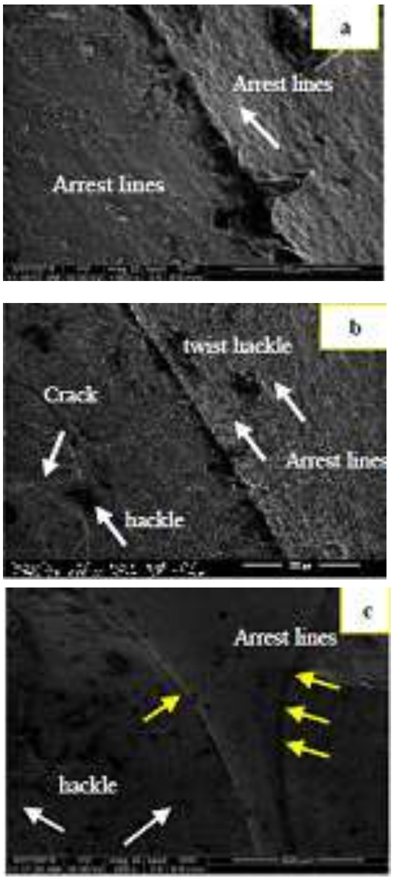

Figure 2: SEM image after a bending test. Fracture surface of the connector zirconia CAD-CAM prosthesis for Vita YZ HT block at 100 m/min.

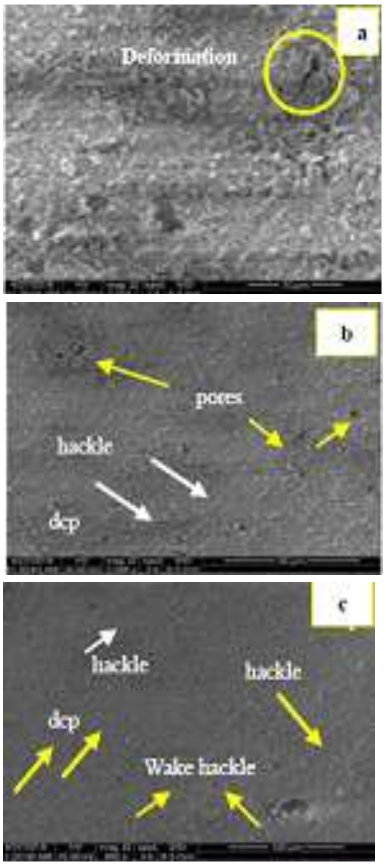

Figure 3: SEM image after a bending test. Fracture surface of the connector zirconia CAD-CAM prosthesis for VitaYZ HT block at 150 m/min .

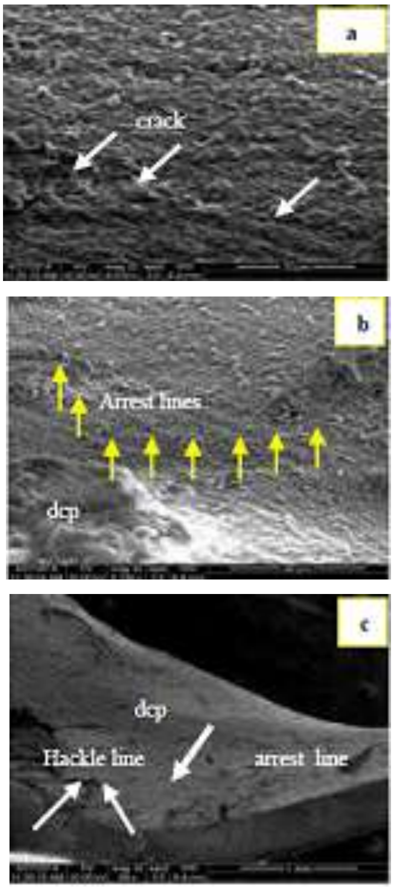

Figure 4: SEM image after a bending test. Fracture surface of the connector zirconia CAD-CAM prosthesis for Kerox dental block at 100 m/min.

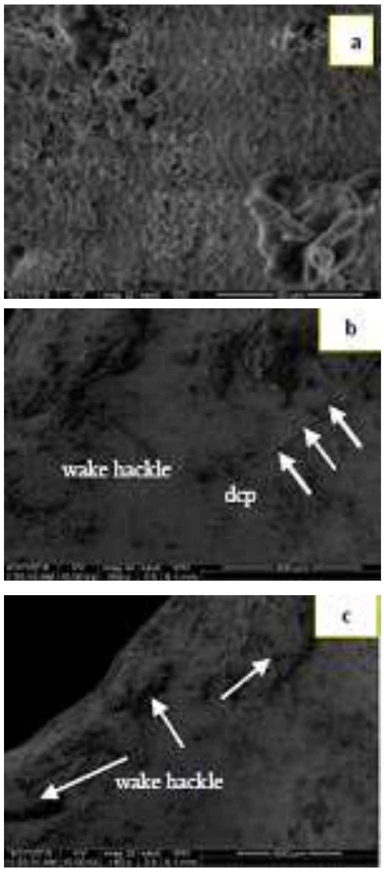

Figure 5: SEM image after a bending test. Fracture surface of the connector zirconia CAD-CAM prosthesis for Kerox dental block at 150 m/min .

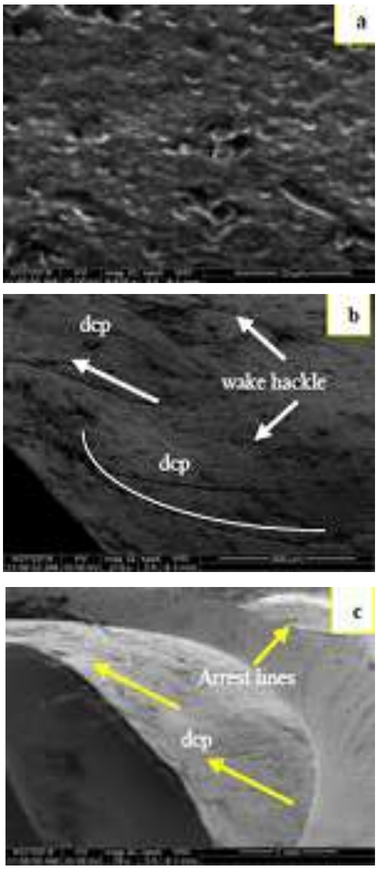

Figure 6: SEM image after a bending test. Fracture surface of the connector zirconia CAD-CAM prosthesis for dental direct block at 100m/min.

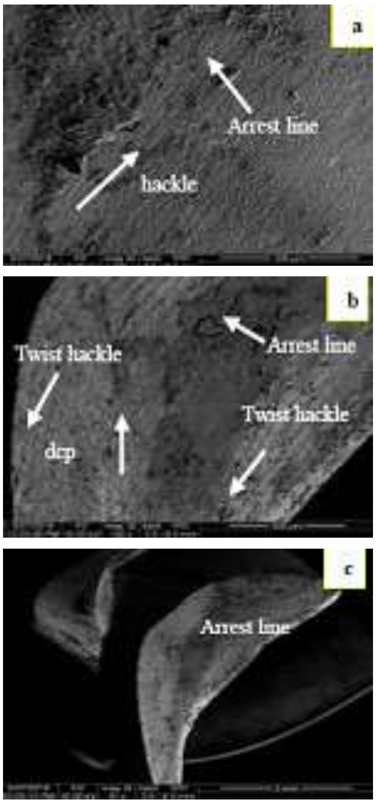

Figure 7: SEM image after a bending test. Fracture surface of ceconnector zirconia CAD-CAM prosthesis for dental direct block at 150 m/min.

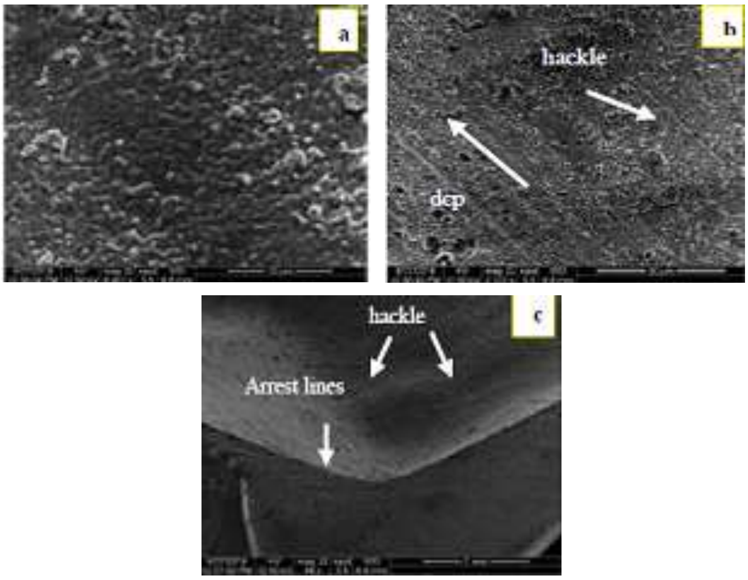

Figure 8: SEM image of fractured zirconia crown for dental direct block machined at 100 m/min.

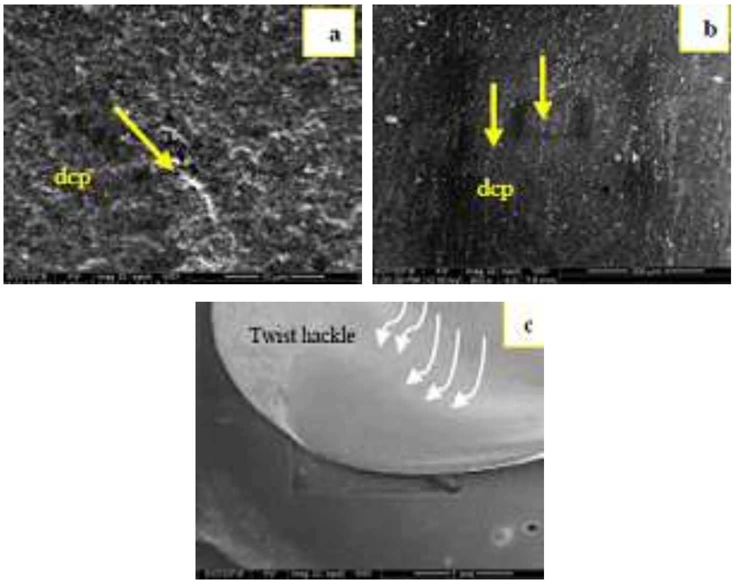

Figure 9: SEM image of fractured zirconia crown for dental direct block machined at 150 m/min .