Evaluation of hardness and fracture toughness of feldspathic porcelain by various surface finishing techniques - an *in vitro* study

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CERTIFICATE

Certified that this dissertation **"EVALUATION OF HARDNESS AND FRACTURE TOUGHNESS OF FELDSPATHIC PORCELAIN BY VARIOUS SURFACE FINISHING TECHNIQUES - An *in vitro* Study"** is the work of **Dr.G. KHALID.,** postgraduate student of M.D.S., Branch VI- Prosthodontics, RAGAS Dental College & Hospital, Chennai, during the period of 2002-2005.

This Dissertation is submitted to THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY, in Partial fulfillment for the Degree of **Master of Dental Surgery in Branch VI- Prosthodontics.**

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INTRODUCTION

Porcelain is widely used in dental practice as material of choice for an individual jacket crown, Porcelain fused to metal restoration in crown and bridge prosthodontics and also as laminate veneers in cosmetic dentistry.

In either use of porcelain application the main advantage are its biocompatibility natural appearance and high resistance to wear and chemical inertness. The Dental porcelain is essentially a boro silicate of feldspathic glass, which may or may not contain dispersed crystalline metallic oxide component. Metal ceramics which are popularly used in pronthodontics are characterized by their refractive nature, hardness, susceptibility to clinical fracture and chemical inertness.

Metal ceramic restoration have metal substructures fused over with ceramic veneer that is mechanically and chemically bonded. The first ceramic layer is opaque; it masks the dark metal oxide. The opaque is covered by slightly translucent body porcelain, which is veneered with a more translucent enamel. Later the strong life like appearance of the completed metal ceramic restoration results from a surface glaze, formed as an additional firing after the dental restoration has been trimmed and shaped before the final fit of the crown.

Even though porcelain is considered superior to all types of restorative materials used in Prosthodontics its main disadvantages are brittleness, lesser edge strength, high hardness resulting in more impact to the opposing teeth during mastication and also abrasion of enamel of the natural opposing and adjacent teeth. To a certain extent these physical properties of porcelain can be also be altered by modifying the technology of application of porcelain to suit the requirement of the restoration, but the finishing and polishing of porcelain restoration are considered as an essential procedure for the final fit. There are viewers who also feel that finishing and polishing of porcelain restoration is considered satisfactory with usage of conventional polishing systems such as polishing cups, disks and with porcelain polishing pastes. However the usual method of producing the surface gloss is by the application of glazes on the surface of porcelain.

Glazes are generally colourless porcelain, low fusing and possessing fluidity at high temperature. They fill small surface porosities and irregularities and when fired are meant to create the external glossy appearance of porcelain restorations. The other method is producing surface finish and glossy appearance is by self-glaze method.

The natural glaze or self-glaze refers to the process in which the restoration is fired to the temperature that is usually equal to or higher than the original firing temperature.

The porcelain which is used as metal ceramic restorative material should have adequate strength, hardness, formable to the required shape, biocompatible, resistant to the oral environment, abrasive resistance and should be able to obtain the required colour and translucency.

For dental application hardness of ceramic, similar to that of enamel is desirable to minimize the wear of the resulting ceramic restoration and reduce the wear damage that can be produced on enamel by the ceramic restoration. The susceptibility to brittleness leading to fracture is a drawback particularly when flaws and tensile stress co-exist in the same region of the ceramic restoration. Nevertheless the porcelain restoration should have glossy surface finish with whatever the procedure is followed, either by glazing or by conventional surface finishing and polishing. Moreover the micro roughness or inadequate surface finish is considered as a health hazard due to accumulation of food as mentioned by Nasser Barghi, Lee Alexander and Robert A. Draughn[9].

It is also considered that the surface flaws induced at the time of surface finish leads to brittleness and reduces the flexural strength, micro hardness and thereby reducing the fracture toughness values also, however it is mandatory and essential that high surface finish with an increase in esthetic value is achieved by the method of polishing and glazing, In spite of knowing fully well, that the minor micro roughness is definitely produced during the finer trimming and with the application of polishing materials.

Considering these facts a study has been taken up to evaluate few of the physical properties such as micro hardness and fracture toughness to the various methods of finishing and polishing such as conventional usage of polishing materials on porcelain, glazing with vitreous materials and also auto glazing.

REVIEW OF LITERATURE

Dental ceramics is an inorganic compound with non metallic properties typically consisting of oxygen and one or more metallic or semi metallic elements such as aluminium, calcium, lithium, magnesium, potassium, silicon, sodium, tin, titanium and zirconium that is formulated to produce the whole or as a part of a ceramic based dental prosthesis

Dental ceramics may consist primarily of glasses porcelain, glass ceramic or highly crystalline structures. Of all the types of dental porcelain used feldspathic porcelain are a ceramic composed of glass matrix face and one or more crystalline faces such as leucite K2O Al2O3 4SiO2.

It is considered as the most durable esthetic material impervious to oral fluids, biologically compatible, chemically indestructible in most environments, more resistant to corrosion and abrasion than plastic and does not react with most liquid, gases, alkalis and acids. Ceramic also remains stable over longtime periods

During the past decade several new ceramic materials and techniques have been developed. However inception of ceramic usage dates back to more than more than 10,000 years ago (i.e. Stone age) wherein Craftsmen of this era used rocks that could be shaped into tools and artifacts by a process called flaking,

Dechamant 1789 French dentist patented the first porcelain tooth material. Duchateau 1774 advocated for denture use improved mineral paste teeth in England, However, this baked compound was not used to produce individual teeth because there was no effective way at that time to attach the teeth to a denture base material.

Fonzi 1808, an Italian dentist, invented a "terrometallic" porcelain tooth that was held in place by a platinum pin or frame. Planteau 1817, a French dentist, introduced porcelain teeth to the United States and Peale 1822, an artist, developed a baking process in Philadelphia for these teeth.

Stockton 1825 began the commercial production of porcelain teeth. Ash 1837 in England developed an improved version of the porcelain tooth. Plaff 1756 in Germany developed a technique to make impressions of the mouth using plaster of Paris but it was not until 1839 that the invention of vulcanized rubber allowed porcelain denture teeth to be used effectively in a denture base. The nephew of Stockton in 1844 founded the S.S. White Company, and this led to further refinement of the design and the mass production of porcelain denture teeth.

Dr. Charles Land 1903 introduced one of the first ceramic crowns to dentistry. He described a technique for fabricating ceramic crowns using platinum foil matrix and high-fusing feldspathic porcelain. These crowns exhibited excellent aesthetics, but the low flexural strength of porcelain resulted in a high incidence of failures,

Since then, feldspathic porcelains with reliable chemical bonding have been used in metal-ceramic prostheses. Unfortunately feldspathic porcelain has been too weak to use reliably in the construction of all ceramic crowns without a cast metal core or a metal foil coping

Weinstein 1962 have made major breakthroughs responsible for the long-standing superb aesthetic performance and clinical survivability of metal-ceramic restorations. The patents described about formulations of feldspathic porcelain that allowed systematic control of the sintering temperature and thermal expansion coefficient and components that could be used to produce alloys that bonded chemically to and were thermally compatible with feldspathic porcelains.

Vita Zahnfabrik in 1963 developed the first commercial porcelain. Subsequently more versatile Ceramco porcelain was developed that led to thermal expansion behavior, which allowed porcelain to be used safely with a wider variety of alloys.

McLean and Hughes 1965[29] reported a significant improvement in the fracture resistance of porcelain crowns, however their work have shown drawbacks when a dental aluminous core ceramic consisting of a glass matrix containing between 40 and 50-wt% ALO, was used. The resulting material showed translucency (opaque, chalky-while appearance) of the aluminous porcelain core material, unacceptable high failure rate when used for molar crown & bridge because of the large sintering of the aluminous porcelain core material excellent marginal adaptation was difficult to achieve. This has resulted in the limited use of aluminous porcelain crowns for the restoration of maxillary anterior crowns and when no other ceramic product is available.

Adair and Cirossman in 1984 improved the all-ceramic systems by developing the controlled crystallization of a glass (Dicor). Further development was the introduction of a machinable glass-ceramic version (Dicor MCC). ln the early 1990s a pressable glass-ceramic (IPS Empress) containing approximately 34 volume% leucite was introduced that provided a strength and marginal adaptation similar to those of Dicor glass-ceramic but required no specialized crystallization treatment. A more fracture-resistant, pressable glass-ceramic (IPS Empress2) containing approximately 70 vol% of lithia disilicate crystals was introduced in the late 1990s with superior fracture toughness compared to IPS Empress glass ceramic

Significant progress has been made toward the goal of developing less abrasive veneering ceramics. In 1992 Duceram LFC (low fusing, ceramic) was marketed as an ultra low-fusing ceramic with three unique features (decreased glass transition temperature, viscosity, and firing temperature and increased thermal expansion coefficient) allowed its use as a veneer for certain low-expansion metals, other ultralow-fusing ceramics (sintering temperatures below 850" C), now commonly referred to as low-fusing ceramics, have been introduced as veneering glasses

The new generations of ceramics that have been developed include Cercon, Lava, In-Ceram Zirconia, IPS Empress2, and Procera AIICeram, Cerec1, Cerec2 and Cerec3 systems.

Mecholsky JJ Jr (1950) [25] according to his view the principle of linear elastic fracture mechanism (LEFM) were developed in 1950's by George Irwin. Location with respect to the loading geometry had a stress intensity associated with it.

He also demonstrated controlled evaluation of the toughness of a material. Toughness is defined as the resistance of a material.

Barghi N, Alexander L, Draugh RA (1976)[9] had a view that a smooth porcelain surface can be obtained by glazing after grinding. A low fusing glaze gave slightly smooth surface than a natural glaze.

Sulik and Pleavich (1981)[35] in their opinion they found no difference clinically or by means of scanning electron microscopy, between the polished and naturally glazed surfaces of vacuum fired porcelain, when they polished fully matured porcelain by using a hard rubber wheel, wet pumice and wet in oxide sequentially. Some voids were present on the glazed surface.

Smith and Wilson (1981) [34] used a series of soflex disc, to achieve a surface finish on trimmed porcelain surfaces, which indicated that the surface finish attained with a soflex discs was comparable to that produced by abrasives commonly used for trimming porcelain surfaces.

Hobo S (1982)[20] in his study the amount of vertical height distortion of porcelain cusps and fossae during glazing was investigated. It was inferred that the vertical distortion which was less after the second glaze than the first.

Klausner, Cartwright and Clarbeneau (1982) [22] in their study evaluated whether coarser abrasives give rise to rougher porcelain surfaces. It was observed that diamond produces the roughest surface and that porcelain-finishing stone also produces considerable roughness. They found the Shofu finishing kit was capable of producing as smooth surface as glazed porcelain.

Willey MG, Windeler AS, Barghi N Duke SE (1982)[43] had a view that polishing porcelain can produce a smooth surface similar to that resulting from a natural glaze. It has been reported that glazing porcelain causes changes in occlusal vertical dimension. An inch steel ball was cradled between the three cusps and the occlusal vertical dimension was measured Ten crowns received natural glazing and the remaining 10 were polished with shofu polishing kit. Their study showed the mean loss for polished crowns was significantly higher than that recorded for the glazed crowns.

Mackert JR Jr, Williams AL (1986)[26] in their study showed that Dental porcelains rely on high-thermal expansion mineral leucite to elevate their bulk thermal expansion to levels compatible with dental PFM alloys. The microcracks that form around these leucite particles when cooled during porcelain manufacture are a potential source of change in bulk porcelain thermal expansion during fabrication of porcelain fused-to-metal crowns and bridges. The purpose of this study was to determine whether multiple firings of dentistry. Specimens of six commercial porcelains were fabricated and subjected top 1,2,4,8 and 16. The microcrack densities were determined by quantitative stereology, whereby intersections of micro cracks were counted with a test grid. Their study indicated, that even for porcelains that exhibit a measurable change in microcrack density as a function of multiple firings, the magnitude of the increase or decrease in microcrack density after several firings was sufficiently small to cause onlyu negligible shifts in porcelain bulk thermal expansion.

Quinn JB, Sundar V, Lloyd IK (1986)[30] worked to measure fracture toughness for several groups of dental ceramics and determine how this properly was affected by chemistry and micro structure. Quinn JB, Sundar V, Lloyd IK obtained the values of fracturing toughness of several groups of dental ceramics using Single Edge Precracked Beam (SEPB) and Single Edge V-Notch Beam (SEVNB) methods. Their study showed upper toughness limits for micaceous glass – ceramics and feldspathic porcelain were significantly raised compared to the base glasses. The highest toughness was associated with high percent crystallinity, large grains and high aspect ratios.

Zalkind (1986)[46] in their study they found that glazing porcelain surface was reduced by an abrasive instrument would not reduce the resulting roughness. To produce a smooth surface it was needed to sandblast the abraded surface with aluminum oxide before retiring to produce a natural glaze.

Haywood, Heymann of Kusy (1988)[19] did a comparative study, when a series of finishing grit diamonds, 30 fluted carbide bars and diamond polishing paste was used to polish porcelain intraorally, it was found that surfaces produced were as smooth as glazed porcelain.

Goldstein (1989)[18] in his opinion Goldstein found that cups and points made by Shofu were the best instruments available for the final finishing of porcelain.

White SN (1989) [42] studied the mechanical fatigue of a feldspathic dental porcelain. They formed an opinion that Ceramics are known to undergo chemical static fatigue in the presence of moisture at ambient temperatures. This study, using an indentation technique demonstrated the existence of mechanically induced cyclic fatigue in a feldspathic dental porcelain under ambient conditions. The growth rates (dc/dN) were consistent with the Paris Law, which was a power law function of the applied stress intensity ranged (delta K) governing mechanical fatigue phenomena.

Wagner WC, O'Brien WJ, Mora GP (1989)[45] conducted a fracture initiation in a glaze-strengthened magnesia ceramic substance crowns. The fracture surfaces were located at the center of hackles that are oriented parallel to the direction of the crack advance. The distance from the fracture initiation point to the surface of the test bars was measured. The results of the study indicated a direct relationship between the flexure strength and the depth of the fracture initiation point. This was consistent with the theory that the residual compressive stresses at the glaze body interface inhibit the spread of flaws and are responsible for the increase in strength observed.

Rosenstiel SF, Porter SS (1989)[32] in their study they measured apparent fracture toughness (Kc) and elastic modules-to-hardness ratio (E/H) if dental restorations made with five all ceramic crown systems.

An indentation technique was used whereby Kc was calculated from the length of radial cracks formed on the release of a Vickers Diamond. After the crowns were hired and glazed they were embedded, polished, gold-coated and intended under oil. Statistically significant differences were found between DICOR and Cerestore materials for Kc and between DICOR, Renaissance and Cerestore materials for E / H.

Anusavice KJ, Lee RB. (1989)[6] found out that Static fatigue of dental ceramics resulted from the interaction of residual tensile stress and an aqueous environment. This phenomenon is a potential cause of delayed crack formation and propagation in unglazed porcelain. The objectives of their study were to characterize the influence of porosity on the crack propagation resistance of two feldspathic porcelains and to determine whether lower stress corrosion susceptibility or higher fracture toughness account for the superior thermal shock resistance of one of these ceramics. Under firing of both ceramic caused a slight increase in fracture toughness and a relatively small change in pore volume fracture untill the ceramics where at under tuned at 30 degree C or more. The crack propagation data indicated that the higher thermal shock resistance of one of the ceramics may be due to its greater resistance to stress corrosion at the initial stage of crack propagation.

Rosential SF, Baiker MA, Johnson WM, (1989) in their study they apparently compared fracture toughness (Kc) and stainability of a mental ceramic system with either a glazed or polished surface finish. The indentation technique was used for Kc determinations and colorimetry measurements of specimens immersed in a coffee solution for staining. Their study indicated, higher fracture toughness values for the polished specimens. No differences were detected in the staining characteristics.

Wagner WC, O'Brien WJ, Mora GP (1989)[45] conducted a study for fracture initiation in a glaze-strengthened magnesia ceramic substance crowns. The fracture surfaces were located at the center of hackles that are oriented parallel to the direction of the crack advance. The distance from the fracture initiation point to the surface of the test bars was measured.

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Rainmondo, Richardson and Wiedner (1990)[33] compared the surface finish of unglazed porcelain produced by six different polishing techniques, with that produced by glazing. The Shofu kit was the only kit, among those tested, that did not come with polishing paste. it produced a surface that was least acceptable visually, however, its results rated better when examined under the scanning electron microscope.

Taira M, Nomura Y, Wakasa K, Yamaki M, Matsui A (1990)[40] agreed that one important mechanical property of dental ceramics is fracture toughness Klc, which represents the serviceability in the oral cavity, such as the resistance to marginal fracture. Klc, Values of several dental ceramics, natural tooth enamel and industrial ceramics were examined by use of the indentation micros fracture (IM) method. It was observed that appropriate load levels should be selected on each specimen to induce radial / median cracks. They conducted that the Klc values of most dental ceramics examined were slightly higher than that of soda lime glass, but less than one third that of zirconia. It was confirmed that the IM method is simple and cost effective for evaluation of Klc of dental ceramics.

Patterson, Mc Lundic, Strirups, Taylor (1991)[28] examined the surface smoothness produced by a commercial porcelain refinishing kit, incorporating diamond paste (Chameleon Diamond Paste), by using scanning electron microscopy and profilometry. They found the paste was capable of achieving a good porcelain surface smoothness on surface previously adjusted by fine (red band FG) diamond burs. However, this polishing system was incapable of achieving a surface smoothness comparable to that produced by glazing.

Scherrer SS, Denry L, Wiskott HW (1991)[38] performed indentation methods to compare fracture toughness values as well as a newly established fracture mechanics test. The following methods for KIC determination were applied.

1. Indentation Fracture (F)
2. Indentation Strength (S)
3. The single-edge-V-notched-beam test (SEVNB).

The materials tested were a low fusing dental glass and a feldspar-based porcelain. Their study indicated that the IS technique demonstrated a load dependency for IPS porcelain which was not observed when using the IF method. This study has shown all three methods are agreeable within 10%. However none of the procedures proved absolutely straightforward. Decision on which method to use should be based on a sound understanding of the conceptual limitations and technical difficulties inherent to each technique.

Fischer H, Marx R (1991)[13] carried out a study to evaluate fracture toughness of dental ceramics comparison of bending and indentation method. Aimed to compare two fracture toughness methods, the bending method and the indentation method. Fracture toughness values were determined on seven dental ceramic materials, on single-edged-V-notched beams (blending method as out standard method). The results were determined before and after annealing of the samples. Their study indicated that the individual pre-factors various between 0.0122 and 0.0253 for the specimens before annealing and between 0.0150 and 0.0267 for the annealed specimens. According to the view indentation method is not an adequate tool to exactly determine the fracture toughness of an unknown ceramic material. This method can only be used for a rough Klc estimation.

Seghi RR, Denry IL, Rosenstial SF (1991)[37] compared the relative hardness and fracture toughness of fluormica-, leucite-, alumina- and zirconia-, reinforced glasses by the application of indentation technique. Their studies showed that Alumina-reinforced materials resulted in the highest fracture toughness values, whereas the flourmica-a, and leucite-reinforced material showed more moderate but statistically significant greater values compared with those of control materials. By this study, it was inferred that selection of appropriate restorative materials depends on clinical application and requires consideration of several physical properties including fracture toughness.

Flanders CA, Quina JB, Wilson Oc Jr, Lloyd lk (1992)[11] conducted a program to identify promising environments that could efficiently minimize machining induced damage of dental materials. Single point abrasion (SPA) scratch testing was used on five materials to determine the scratch hardness and amount of edge chipping as functions of chemical environment, including air, water, saline and glycerol solutions. They had a view that showed that there was a consistent trend across materials that the water and saline yielded the lowest values of scratch hardness, air the next lowest and glycerol the highest hardness values. Their study signified that it might not be possible to utilize a particular single environment to substantially improve the damage response of dental material to matching operations.

Seghi RR, Denry I, Brajevic (1992)[36] found out that dental ceramics generally fail because of the growth of microscopic surface flaws that form during processing or finishing. The icon exchange process has been shown to be effective in improving the flexural strength of most dental porcelains through the development of a compressive surface layers.

According to their investigation it indicated that ion-exchange reinforcement can significantly improve the resistance of the ceramic surface.

Fairhurst CW, Lockwood PE, Ringle RD,[14] **Thompson WO(1992)**[14] were of the opinion that the self-glazing technique provides an esthetic and hygienic surface for crowns and fixed partial dentures. Four groups of 50 porcelain disk specimens each were subjected to polishing and firing procedures.

Group 1 – Was fired glazed – no hold & polished

Group 2 – was fired, polished and glazed – no hold

Group 3 – was fired, polished, glazed / min – hold

Group 4 – was fired, polished and not glazed.

The piston on three-ball-method was used for testing biaxial flexure strengths. Significantly lower differences in biaxial flexure strengths were noted when group two values were compared with values from group two values were compared with values from group one, three and four. The specimens that were fixed polished to a 1 micros surface finish and not glazed (group 4) were significantly higher in flexure strength than groups one and three. The hypothesis that glazing of porcelain surfaces improves the biaxial flexure strength of test specimens was rejected.

Fairhurst et al (1992)[15] indicated that porcelains with highly polished (1-μm abrasive paste) have comparable strength to that of specimens that were polished and glazed. This observation was of clinical importance. This procedure viewed that when occlusion was adjusted by grinding the surface of the porcelain, it would weaken the porcelain markedly, when glaze was removed and surface was left a rough condition.

Hulterstrom and Bergman (1993) [29] in their study it was evaluated that two of the best polishing systems were Sof-Lex disks and Shofu Porcelain Laminate Polishing kit followed by diamond paste.

Luthy H, Dong JK, Wohlwend A, Scharer P (1993)[23] conducted this study to determine whether surface staining and glazing / veneer technique affected the flexure strength of IPS – Empress glass ceramic, which was a newly developed press type of all ceramic crown system. Eight groups of test bars were pressed. In group (1) and (2) one surface was stained and glazed. Group (3) was heat treated only. In group (4) to (7) one surface was of veneered with porcelain and then subsequently glazed. Group (8) was just heat-treated. Their study showed that greater strength was found in group (1) which was stained and glazed.

Jagger and Harrison (1994)[21] performed abrasive wear tests on unglazed, glazed and polished porcelain stud specimens using human enamel as the opposing plate specimens. The wear tests were carried out on a wear machine that was specifically designed to stimulate the masticatory cycle. They concluded that the amount of enamel wear produced by both glazed and unglazed porcelain was similar, however that produced by polished porcelain was substantially less.

Giordano RA 2nd, Pelletier L, Campbell S. Pober R (1995) [16] they had the opinion that In-ceram materials with improved properties. Their study determined the flexural strength on In-ceram system components and compared the core material with conventional feldspathic ceramics and with Dicor all-ceramic restorative material. Their study indicated that the flexural strength of polished Dicor ceramic was greater than self-glazed feldspathic porcelain and cast Dicor.

Griggs JA, Thompson JY, Anusavice KJ (1996) [17] also agreed that the functional surfaces of porcelain restorations are often ground to adjust occlusion. This removes the surface glaze and introduces flaws. The objective of this study were to determine whether re-firing after grinding increases the strength of dental-porcelain and to determine whether the effectiveness of this treatment was depended on the initial flaw size, 6 groups each containing, 12 disks specimens were prepared.

The specimens were fired under vacuum, ground to a thickness of 1 mm with 240-grit SiC abrasive and polished through 600 grit. Following indentations, half of the specimens were re-fired. The flexural strength of each specimen was determined by means of a piston-on-three-ball biaxial fixture. The results of their study indicated that re-firing of porcelain with large surface flaws does not significantly increase the flexural strength.

Ueda H, Shinya A, Tohyama Y, Yokozuka S (1996)[41] conducted a study to evaluate that materials resistance to brittleness fracture was quantitatively evaluated in the commercial porcelain, from which values of fracture toughness (KIc) obtained in the crack on a mode I, determined upon insertion of Vickers indenter. The results of the study showed that (1) means of maximum and minimum values of Vickers hardness degree of 9 kids of commercial porcelain at 5k of load for 15s were 1348 (SD 98.1) for OPT and 660 (SD74.6) for CE8, respectively. (2) The value of half of the diagonal of indentation (a) ranged from 42 (SD 1.5) to 58 (SD 3.3) microns and that of half of the crack length (c) ranged from 101 (SD 4.0) TO 175 (SD 17.2) microns.

Williamson RT, Kovarik RE, Mitchell RJ (1996)[44] conducted a study to determine how surface treatments of moisture affect the flexure strength was measured for porcelain beams whose surfaces were coarse ground, overglazed or polished. Half of the specimens were stored in distilled water, the other half was stored in dry environment. They had a view that the hign-leucite feldspathic porcelain was found to be sensitive to roughness and surface stresses, similar to leucite free and low-leucite feldspathic porcelain.

Baharav H, Laufer BZ, Mizrachi A, Cardash HS, (1996)[8] have endorsed the view that dental porcelain has superior esthetics but may be subject to fracture during mastication. Conducted a study to compare the fracture toughness (Kc) and vickers hardness number of an alumina reinforced porcelain at different thickness of glaze. Their study also included the duration of glazing at different duration of time at 0, 30, 60, 90 and 120 seconds on feldspathic porcelain. Fracture toughness and vickers micro hardness were determined with micro indentation techniques. The results of the study indicated residual compressive stress on the porcelain surface after cooling enhance resistance of porcelain to crack initiation, as quantified by its fracture toughness (Kc). The effect on different cooling rates on Kc and hardness of a glazed porcelain reinforced with approximately 2% aluminium oxide was examined in 45 porcelain disks which were divided into 3 groups. After final glaze firing, one group was cooled rapidly, second was cooled at medium rate and third was cooled slowly. In their view it indicated that the faster cooling rate of glazed alumina reinforced porcelain resulted in greater fracture toughness but had no effect on hardness.

Fuzzi M, Zacehero Z, Vallania G (1996)[12] conducted a study to evaluate the surface roughness of vita VMK porcelain by even glazing and also by various method of grinding / polishing treatments. Scanning electron microscopy analysis showed that all treatment left the surface partially porous and cracked and the glazed surface yielded the best results. Although no significant differences were detected for the different treatments the use of 30 microns diamond instrument produced rough surface.

Al-Hiyasat AS, Saunders WP, Sharkey SW, Smith GM, Gilmous WH (1997)[2] conducted the abrasive effect of various porcelain surfaces on human enamel. Sixty pairs of tooth-porcelain specimens were tested under a standard load and rate in distilled water and with and without intermittent exposure to a carbonated beverage. The amount of wear of enamel and porcelain was determined after 5,000, 15,000 and 25,000 cycles. The conclusion of this study was that overall exposure to a carbonated beverage significantly increased the amount of enamel wear produced by all porcelain surfaces (P<001). The finish of the porcelain surface did not influence its wear.

Al-Wahadni A, Martin DM (1998)[4] in their study they have examined the visual & microscopic appearance and roughness of glazed, unglazed and polished porcelain surfaces using Scanning Electron microscope and surface profilometry. In their view that the glazed porcelain provided a smooth & dense surface even though polishing produced and equally smooth surface with equally compatible esthetic. Further their study also has shown that unglazed porcelain is more abrasive than glazed.

Magne P, OLWS, Pintado MR, DeLong R (1999)[27] compared the wear of enamel against 3 types of ceramics with high esthetic potential: Feldspathic porcelain, Aluminous porcelain and low fusing glass. Laboratory finishing and chair side polishing with a Dialite kit were stimulated to compare respective efforts on wear. As the study was in-vitro tooth material specimens were placed in an artificial mouth using closed loop servo hydraulics constant masticatory parameters were maintained for 300,000 cycles at a rate of 4 hz. The occulusal surface of each pair was mapped and digitally recorded before and after each masticatory test.

According to their view most significant difference was noted in volume loss, not in depth of wear. For all 3 ceramic systems, qualitative SEM evaluation revealed an abrasive type of wear. Wear characteristics of chair-side polished specimens were similar to those of laboratory finished specimens.

They concluded that the Ducermam-LFC was not most abrasive, ceramic, due to defects brittleness and possible insufficient toughness and creation ceramic was the least abrasive and most resistant to wear. Laboratory and chair-side finishing procedures generated similar results.

Scherrer SS, Kelly JR, Quinn GD, Xuk (1999)[39] evaluated the use of fractography in franchise toughness methods within a feldspathic dental porcelain, in which Klc was measured fractographically as well as numerically using two controlled flaw beam bending techniques. The following methods for Klc determination were applied to a dental porcelain, in which Klc determination were applied to a dental porcelain containing a leucite volume fraction of 15 – 20%. (1) Surface crack in Flexure (SCF) (2) Indentation strength (IS) at indentation loads of 9.8 and 19.6 N. The environment were (1) ambient air (2) Flowing Dry nitrogen. They noticed no significant differences were found between numeric and fractographic Klc values for the IS technique in ambient air, although Klc values were sensitive to indentation load.

Scherrer SS, Denry IL, Wiskott HW[38] performed indentation methods to compare fracture toughness values as well as a newly established fracture mechanics test.

The following methods of KIC determination were applied. (1) Indentation Fracture (IF), (2) Indentation Strength (IS), (3) The single-edge-V-notched-beam test (SEVNB). The material tested were a low fusing dental glass and a feldspar based porcelain. Their study indicated that the IS technique demonstrated a load dependency for IPS porcelain which was not observed when using the IF method. This study has shown all three methods are agreeable within 10%.

Baharav H, Laufer BZ, Dilo R, Cardesh HS (1999)[7] in their opinion porcelain is the most esthetic restorative material available, it is subjected to fracture during function. Glazing reduces the size of flaws in the surface of the porcelain and increases the resistance to crack propagation but the optimum thickness of this glazed layer has not been determined. The study compared the fracture toughness (Kc) and Vickers Hardness Number (VHN) of an alumina-reinforced porcelain at different thickness of glaze. Discs of feldspathic porcelain reinforced with 2% aluminium oxide were prepared and glazed for 0,30,60,90 and 120 seconds. Fracture toughness and Vickers micro hardness were determined with a Micro indentation technique. It was concluded that minimal and maximal thickness of glaze layers on alumina-reinforced porcelain resulted and surface that was harder and more resistant to fracture than moderate glaze thickness.

A.M. Al-Wahadnil, D.M. Martin 2 (1999) [3] designed a machine to stimulate the physical parameters of masticatory function which was used to investigate the amount of wear produced on Perspex plates opposing discs of porcelain which were glazed, unglazed or finished to varying stages of a polishing sequence recommended with a proprietary finishing kit. Assessments of wear of the Perspex based upon depth measurements of the wear track recoded on surfometric tracing. Their study showed that the best finish and least abrasive surface was produced by glazing of porcelain. It was recommended that any adjusted porcelain restoration should be re-glazed or subjected to a finishing sequence which should be by a final stage of polishing with a diamond paste.

Chu FC, Frankel N, Smales RJ (2000)[10] they investigated 3 methods for reducing surface roughness and improving the strength of porcelain restorations. Ninety laminated In-Ceram/Vitadur Alpha porcelain disks were fabricated and randomly divided into 3 groups. Group one, consisted of 30 original disks, Group 2 consisted of 30 polished disks. Group 3 were 30 polished disks were re-glazed. Average roughness values (Ra) of the veneers were measured by a profilometer. They conducted that reglazing polished porcelain surfaces significantly improved the surface texture and flexural strength of the materials tested.

Alkhiary YM, Morgano SM, Glordano RA (2003)[5] evaluated by means of indentation technique, the effects of acid hydrolysis and mechanical polishing on the surface residual stresses of low-fusing ceramic materials. A total of 64 ceramic bars were formed to produce 4 groups of 16 bars each of 4 ceramic materials the four surface treatment were hydrolysis, glaze / polish, (autoglaze) and polish / glaze. Vickers indenter was used. Scanning Electron Microscope (SEM) was used to study surface texture before and after hydrolysis and polishing. In their opinion SEM showed obvious surface flaws as a result of hydrolysis. However statistical analysis of the resulting crack lengths revealed no significant differences between values for the control groups and hydroysis groups for enamel and Dentin. Within the limitations of this study, it was concluded that hydrolysis does not improve surface residual stresses of Duraceram – CFC and Finesse Ceramic Material. Mechanical polishing improved surface residual stresses of all materials tested, except Duraceram LFC Dentin Porcelain.

M.C. Bottino, LF Valandro, KZ Kantorski, R. Scotti, M.A. Bottino, (2003)[24] conducted to a study to investigate the roughness of a ceramic submitted to 5 different surface treatments, as they were of the view that dental porcelain occasionally requires adjustments in circumstances. All the thirty specimens of vitadus Alpha porcelain were glazed and randomly divided into six groups. In which Group1 – glazed (control): Group 2- diamond bur roughening; Group 3- G2 +polishing with KGS silicon rubber points; Group 4- G3 + felt wheel / diamond polishing paste; Group 5 – G3+diamond felt wheel; Group 6- diamond bur ultra fine. The qualitative analysis was made using a scanning electron microscope.

CONCLUSION

The following conclusions could be drawn from this study

1. The glazed porcelain had maximum resistance to penetration by the indenter, giving it the highest micro-hardness.
2. Its high hardness makes it less susceptible to tensile fracture thus giving it the highest fracture toughness.
3. Polished porcelain also effectively resisted penetration by the indenter, giving it the next highest micro-hardness value.

4. Its fracture toughness was also high, and comparable with that of glazed.
5. The autoglazed porcelain was less resistant to penetration by the indenter when compared to glazed and polished. Hence it had lesser micro-hardness value.
6. Its fracture toughness was also lesser than that of glazed and polished.
7. The unpolished had least resistance to penetration by the indenter, giving it the least micro-hardness.
8. Its fracture toughness was also the least.

SUMMARY

Hardness and fracture toughness are very critical mechanical properties of any material selected for fixed partial denture in prosthodontics. The clinical success depends upon these properties. A study was done to evaluate the difference in these properties between the ceramic specimens that was varying in the surface finishing procedures.

Forty standardized metal specimens were prepared and ceramic was applied to it. Ten of these were left unpolished. Another ten specimens were conventionally polished with Shofo porcelain finishing and polishing kit with diamond polishing paste also. Ten specimens were autoglazed and another ten were glazed with applied glazed material.

All these forty specimen were subjected to hardness testing by indentation method and the VHN was found. This test was done with

pyramid shaped diamond point under loads of both 0.2 kg and 1 kg applied for 20 seconds.

The values thus obtained were computed to obtain the hardness and fracture toughness of porcelain with various surfaces finishing procedure. Add on glazed porcelain was found to be hardest and had highest fracture toughness. Next was the polished specimen and then autoglazed, unpolished had the least values of hardness and fracture toughness too.

BIBLIOGRAPHY

1. **Albakry M, Guazzoto M, Swain MV. –** Fracture toughness and hardness evaluation of three pressable all – Ceramic dental Materials *J Dent 200; 31 (3): 181-8.*
2. **Al – Hiyasat AS, Saunders WP, Sharkey SW, Smith GM, Gilmous WH.** The abrasive effect on glazed, unglazed and polished porcelain on the wear of human enamel and the influence of carbarated soft drinks on the rate of wear. *Int J prosthodont. 1997; 10(3) : 269-82.*
3. **A.M.Al – Wahadnil, D.M. Martin 2.** An in vitro investigation into the wear effects of glazed, unglazed and dental porcelain on an opposing Material. *Journal of Oral Rehabilitation 1999; 26(6) : 538.*
4. **Al-Wahadni A, Martin DM.** Glazing and finishing dental porcelain: a literature view; *J can dent Assoc: 1998 64 (8):580-3.*
5. **Alkhiary YM, Morgano SM, Giordano RA.** Effects of acid hydrolysis and Mechanical polishing on surface residual stresses

of low fusing dental ceramics. *J Prosthet Dent 2003; 90(2):133-42.*

6. **Anusavice KJ, Lee RB.** Effects of firing temperature and water exposure on crack propagation in unglazed porcelain. *J Dent Res 1989; 68 (6) : 1075-81.*

7. **Baharav H, Laufer BZ, Pilo R, Cardash HS.** Effects of glaze thickness on the fracture toughness and hardness of alumina reinforced porcelain. *J Prosthet Dent 1999; 81(5):515-9.*

8. **Baharav H, Laufer B.Z. Mizrachi A, Cardash HS.** The effects of different cooling rates on fracture toughness and microhardness of a glazed alumina reinforced porcelain : *J Prosthet Dent 1996; 79(1): 19-22.*

9. **Barghi N, Alexander L, Draugh RA,** When to glaze – an electron microscopy study *1976: 35(6): 648-53.*

10. **chu Fc, Frankel N, Smales RJ,** Surface roughness and flexural strength of self – glazed, polished and reglazed In – Ceram, Vitadur Alpha porcelain laminates. *Int J. Prosthodiont 2000; 13(1) : 66-71.*

11. **Flanders CA, Quian JB, Wilson OcJr, Lloyd IK.** Scratch hardness and chipping of dental ceramics under different environments, JPD 1992; 15(2):23-25.

12. **Fuzz. M. Zacchero Z, Vallania. G.** Scanning electron microscopy and profilometer evaluation of glazed & polished dental porcelain *Int. J. Prosthodant: 1996; 9 (5): 425-8.*

13. **Fischer H, Marx R.** Fracture toughness of dental ceramics: Comparison of bending and indentation method, Int. J. Pros. 1991; 10(2): 15-17.

14. **Fairhurst CW, Lockwood PE, Ringle RD, Thompson WO.** The effect of glaze on porcelain strength. *Journal of Dental Material. 1992; 8(3): 203 – 7.*

15. **Fairhurst et al. Philips :** Science of dental materials; *11th edition*
21: 672.

16. **Giordano RA 2nd, Pelletier L, Campbell S, Pober R.** Flexural strength of an infused ceramic, glass ceramic and feldspathic porcelain; *J Prosthet Dent : 1995; 73(5) : 411-8.*

17. **Griggs JA, Thompson JY, Anysavice KJ.** The effects of flaw size and autoglaze treatment on porcelain strength. *J. Dent Res. 1996; 75 (6): 144-7.*

18. **Goldstein.** Finishing of composites & Laminates; dental Clinics of North America*, 1989; 33-305-18.*

19. **Haywood, Heymann, Kusy.** Polysing Porcelain veneers: an SEM & specular reflectance analysis. *Dent Mater 1988; 4:116-21.*

20. **Hobo S.** Distortion of Occlusal Porcelain during glazing; *J Prosthet Dent 1982; 47(2): 154-6*

21. **Jagger DG, Harrison A.** An Invitor Investigation into the wear effects of unglazed, glazed and polished porcelain on human enamel. *J Prosthet Dent 1994; 72(3): 320-3.*

22. **Klausner, Cartwright, Clarbeneau.** Polished Versus auto glazed dental porcelain surfaces. *J Prosthet Dent. 1982; 47:157-62.*

23. **Luthy H. Dong JK, Wohlwed A, Scharer P.** Effects of veneering and glazing on the strength of heat pressed ceramics. *Schweiz Monatsschr Zahnmed 1993; 103 (10): 1257-60.*

24. **M.C. Biottino, LF Valandro, K.Z. Kantrorske.** Evaluation of the effects of finishing and polishing systems on ceramic surface roughness, June 2003 Svenska Massan.

25. **Mecholsky JJ Jr.** Fracture Mechanics Principles – *1950*. A literature view from the book of advanced bioceramics; Jammes F. Shackleford. Vol.1

26. **Mackert JR Jr. William AL.** Microcracles in dental porcelain and their behaviours during multiple firing – *1986.* Journal of Oral Rehabilitation; 46:152-4.

27. **Magne P. OHWS, Pintado MR, Delong R.** Wear of enamel and veneering ceramics offer laboratory and chairside finishing procedures. *J. Prosthet ent 1999; 82(6): 669-79.*

28. **Patterson, MC Lundic, Stiroups, Taylor.** Polishing of porcelain by using a refinishing kit, in Corporating diamond paste. *J. Prosthet Dent. 1991; 65: 383-8.*

29. **Philips ,** Book of Dental Materials 11^{th} edition.

30. **Quinn JB, Sundar V, Lloyd Lk,** influence of Microstructure and chemistry on fracture toughness of dental ceramics Int. J. Pros. 1986; 11(4):82-85.

31. **Rosential SF, Baiker MA, Johnston WM.** Comparison of glazed and polished dental porcelain. *Int. J. Prosthodont. 1989; 2(6): 524-9.*

32. **Rosential SF, Porter SS.** Apparent fracture toughness of all – ceramic crown system. *J. Prosthet Dent 1989; 62(5): 529-32.*

33. **Raimondo, Richardson, Wiedner.** Polished Versus authoglazed dental porcelain. *J. Prosthet Dent 1990; 64:553-7.*

34. **Smith, Wilson.** Surface finish of trimmed porcelain. *J. Dent 5. 1981; 15(1) : 222-4.*

35. **Sulik and Plekavich.** Surface finish of dental porcelain. *J.Prosthet Dent. 1981; 46:217-21.*

36. **Seghi RR, Denryl, Brajevic F.** Ion exchange on hardness and fracture toughness of dental ceramics. *Int. J. Prosthodont. 1992; 5(4): 309-14.*

37. **Seghi RR, Denryl, Rosential SF.** Relative fracture touchness and hardness of new dental ceramics. Int. S. Pros. 1991; 5(2): 120-5.

38. **Scherrer SS. Denryl L, Wiskott HW.** Comparison of three fracture toughness testing techniques using a dental glass and dental ceramic J. Pros. Dent 1991; 5(4):98-100.

39. **Scherrer SS, Kelly JR, Quinn GD, XU, K.** Fracture toughness (KIC) of dental porcelain determined by fractographic analysis 1991 J. Dent. Res; 62(5); 120-25.

40. **Tiara M, Nomura Y, Wakasak, Yamaki M, Matsui A.** Fracture toughness of Dental Ceramics. J. Oral Rehabilitation, 1990; 17(6): 551–63.

41. **Ueda H, Shinya a, Tohyama Y, Yokozuka S.** Toughness of porcelain using indentation method, Int. J. Pros. 1996; 10(7): 196-8.

42. **white SN.** Mechanical fatigue of a feldspathic dental porcelain – *1989.*

43. **Willey MG, Windeler AS, Barghi N, Duke SE.** The vertical dimensional change resulting from polishing or glazing porcelain – *1982.*

44. **Williamson RT, Kovarik RE Mitchell RJ.** Effects of grinding, polishing and overglazing on the flexure strength of a high – leucite feldspathic porcelain. *Int. J. Prosthodont 1996; 9(1):30-7.*

45. **Wagner Wc, O' Brien WJ, Mora GP.** Fracture surface analysis of a glaze – strengthened magnesia core material-*1989.*

46. **Zalkind.** Porcelain surface texture after reduction and natural glazing. J. Prosthet Dent 1986; 55:30-3.