Effect of Thermocycling on the Flexural Strength of Porcelain Laminate Veneers

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CONTENTS

INTRODUCTION

Dental ceramics was introduced nearly one fifty years ago and it has stood the test of time with their superior properties like biocompatibility, surface hardness, light absorp tion, light scattering behavior and low electrical and thermal conductivity. In the course of evolution, attempts were made to strengthen the ceramics to overcome the inherent brittle nature. This has enhanced the possibility to use ceramics in thinner sections. Porcelain laminate veneers were thus developed and which is presently considered as a fine esthetic treatment option. The conservative, radical preparation executed in the making of crowns was eliminated to a greater extent by the laminate preparations which could change the shape and color of teeth. Ceramics are functioning in the wet environment of the oral cavity and they deteriorate by slowly generating cracks possibly due to the hydrolysis of silicate bonds. These flaws are further aggravated by the stresses induced by thermal variations that would happen within the oral cavity. Eventually, both the mechanical and chemical fatigue will lead to the failure especially in the case of ceramic laminate veneers. Clinical failure of PLV restorations was due to the development of flaws on the glazed surface of the restorations. Surface imperfections act as a potential source of crack propagation which may be either inherent in the porcelain or introduced during PLV manufacture, surface treatment or cementation. Post-operative cracking and failure of the restorations also occur as a consequence of thermal variations that these restorations are likely to encounter in service that has to be investigated. Further the resin cement used for luting the laminate veneer may impose surface changes on the veneer when subjected to thermocycling.

In the above context, we had designed an invitro study with the following objectives:

1. To examine the impact of thermo cycling on the development of surface flaws on the glazed surface of the restoration using scanning electron microscope.
2. To evaluate the biaxial flexural strength of the porcelain laminate veneers after subjecting to thermo cycling.
3. To evaluate the biaxial flexural strength of porcelain laminate veneers luted with composite resin after subjecting to thermocycling.
4. The influence of thermal varia tions of food and drinks on the survival probability of porcelain laminate veneers within 1 year of low level applied stress.

REVIEW OF LITERATURE

Crim GA et al1 compared the effectiveness of four thermocycling techniques, using two thermocycling systems. First system comprised of 4 baths with dwell times of 4 seconds in 600C bath, followed by 23 seconds at 370C, 4 seconds at 120C and 23 seconds at 370C. All baths were maintained within ±20C.Second system consisted of 2 baths maintained at 600C and 120C, ±20C with 30 second s dwell time in each bath. The specimens were subjected to 1500 cycles in both the systems. Fifty extracted premolars were prepared for a class-V restoration. The preparations were etched for 1 minute with 37% unbuffered phosphoric acid and were washed in running water for 1 minute. Then a composite filling was done. The restored teeth were placed in 370C water for 1 hour prior to cycling. Ten teeth containing restorations were randomly selected for testing by one of the following methods.

Method 1A - 4 bath cycle in dye (*basic fuschin*)

Method 1B - 4 bath cycle in water; dye immersion

Method 2A - 2 bath cycle in water; dye immersion

Method 2B - 2 bath cycle in water; (*45Ca*) isotope Immersion

Method 3 - constant temperature; dye immersion

This investigation revealed that there was no significant difference among the four thermocycling techniques. The use of a dye or an isotope was equally effective and penetrated the tooth/ restoration interface to a similar degree. The extent of tracer penetration appeared to be independent of the dwell time in water baths. All procedures involving thermal changes were more potent in demonstrating leakage than the non- cycled methods.

Morena R et al2 used the dynamic fatigue method to obtain sub-critical growth parameters. Fatigue in ceramics refers to growth of cracks aided by the combined influence of water and stress. The dynamic fatigue method which used a constant stressing rate was used to obtain sub -critical crack growth parameters for three dental ceramics. They are feldspathic porcelain, aluminous porcelain and a fine- grain polycrystalline core material. The constant stressing rate experiments were carried out at 37° C for all the three ceramics in distilled water, and for the feldspathic po rcelain in artificial saliva as well. The feldspathic porcelain showed the lowest crack growth exponent, while the fine- grain ceramic showed the highest. Lifetime prediction curves showed that the fatigue failure within five years is a good possibility for feldspathic specimens at stress es which can be anticipated to occur in the oral environment. Little likelihood of failure was perceived for the fine –grain ceramic. The aluminous porcelain was intermediate between two materials with respect to failure prob ability.

Anusavice KJ et al3 investigated the crack propagation resistance of two body porcelains as a function of incomplete sintering and determined their static fatigue by an indentation technique. Two commercial products of feldspathic porcelain designated as C and V were selected. 3 bars of each porcelain 2´5mmx5.5mm were prepared and were underfired as much as 840C below their recommended firing temperatures. After the specimens were polished with 0.05m alumina, cracks were induced with a Vickers microhardness indenter. If was found that semi-circular cracks produced with a load of 19.6N, grew when stored in distilled water at 370C. Underfired ceramics exhibited a slight increase in fracture toughness and small change in pore volume. This was due to enhanced thermal shock resistance of the porcelain due to their reduced susceptibility to stress corrosion at the initial stage of crack propagation. Even when the firing temperature was decreased, moisture had little effect on slow crack growth bec ause the pores were not continuous and they contained air not easily displaceable by water.

Anusavice KJ et al4 found that tempering of glass produces a state of compressive stress in surface regions that enhanced the resistance to crack initiation and cr ack growth. This study determined the influence of tempering on the sizes of surface cracks induced within the temper ed surfaces of opaque porcelain-body porcelain discs with contraction co-efficient differences (*alpha O–alpha B*) of +3.2, +0.7, 0.0, -0.9 and 1.5ppm/°C. The discs were fired to the maturation temperature of 982°C and then subjected to 3 cooling procedures as slow cooling in a furnace (*SC*), fast cooling in air (*FC*) and tempering (*T*) by blasting the body porcelain surface with compressed air fo r 90s. The body porcelain discs were used as the thermally compatible control specimens. Crack diameter induced by a micro hardness indenter with an applied load of 4.9N at 80 points along diametral lines within the surface of body porcelain. Mean values ranged from 75.9m to 103.3m. The results indicated that differences in crack dimensions were attributed to the cooling rate, contract mismatch or their combined effect. It was also found that crack sizes for tempered specimens were much low when compared with fast–cooled and slow-cooled specimens.

Kelly JR et al5 investigated fracture surfaces to understand failure mechanisms, source of the failure and to eliminate strength limiting flaws. They demonstrated that quantitative fracturography can be used to study failed aluminous and glass ceramic dental porcelains. Fracture surfaces of Dicor and Vitadur-N core porcelain modulus of rupture bars were studied to identify fracture mirror features which were useful in locating the source of fracture and calculating the stresses at fracture in clinically failed restorations. The morphology of fracture surfaces resulted from events related to the initiation and propagation of the crack front during failure. Modulus of rupture testing was performed in four point bending. Fracture surfaces were studied by scanning election microscope (*SEM*). The mean fracture stress of Vitadur-N porcelain was 94.7±12.4MPa and for Dicor the fracture stress was 55.4±10.6MPa. Fracture always initiated at the surface, usually at location involving porosity. Two sources of porosity are suggested for Dicor porcelain. They are casting porosity and porosity associated with an oriented crystal whisker reaction zone at the glass ceramming investment interface. Clinical Dicor porcelain crowns fail from the internal surface, often at an internal line angle.

Palmer DS et al6 in their study suggested that thermocycling as a common method of testing dental materials to establish the suitability for in vivo use. There is no standard temperature adopted for dental material thermocycling. This study investigated the highest and the lowest temperature that can reasonably be achieved at the tooth surface by ingesting very hot and cold substances. By using an intra oral digital thermometer probe, 13 human subjects were observed while they drank very hot and cold liquids. The temperature extremes produced were intraorally measured and adjusted for possible error. The results of this study suggest that a range of 00 to 670C may be appropriate for thermocycling dental materials.

White SN7 demonstrated the existence of mechanically induced fatigue in feldspathic dental porcelain under ambient conditions. 30 test specimens 5x1x20mm were fabricated using 1gm of feldspathic porcelain powder (*vita VMK 68, Zahn Fabrik*) and VITA modeling fluid. The specimens were ground flat on one side with 120- grit alumina, washed with water, glued to a peterographic glass slide and sectioned with a slow speed diamond saw into samples of uniform thickness of approximately 1mm, using a peterographic thin section attachment. The 30 specimens were randomly assigned into 3 groups, one of 10 for cyclic load testing, one of 10 for testing the effects of ambient humidity, and one of 10 for flexural testing. Crack growth under repeated loading was characterized using an indentation technique. Microhardness tested with a Vickers pyramidal diamond was used to apply forces of 29.4N for 15 seconds. Indentation and crack lengths were measured using the microhardness tester, with four measurements per indentation. Each of 10 specimens was indented 10 times at the same location at 90 seconds intervals, under ambient conditions, with measurements made immediately after each indentation and after poststorage for 5 days. The mean elastic modulus was determined using 3 point flexural testing on 10 specimens from load deflection data. Significant crack growth failed to occur when specimens were stored under ambient conditions in the absence of cyclic mechanical loading. The results showed that the feldspathic dental ceramic underwent mechanical fatigue when subjected to cyclic loading. Thus this effect of mechanical fatigue either alone or in combination with static chemical fatigue might have important implications to the longevity of these restorations.

Edge MJ et al8 investigated whether the surface morphology i.e. surface cracking was affected by a variety of polishing and self- glazing treatments. They also investigated the theory that polishing and glazing porcelain surfaces of restorations reduced the wear on the opposing occlusion because of reduced roughness. To test this theory, samples of dental porcelains were prepared and subjected to various polishing and self- glazing treatments commonly used in dentis try and viewed under SEM. Fine cracks were discovered in the surface of the samples that had been polished and self-glazed. These cracks were typically greater than 50mm in length and depths were less than 20mm.

To establish the treatments responsible for the formation of these cracks, a more controlled study was performed. Samples of VITA VMK incisal porcelain were prepared and subjected to six treatments.

Treatment no. 1 à as- fired condition

Treatment no. 2 à Self- glazed

Treatment 3 & 4 à Wet ground followed by 1 mm diamond polish.

Treatment 5 & 6 à Ground and polished using Shovel adjustment kit with 6 again self- glazed.

All the samples were observed using SEM. This study showed that polishing and then self- glazing the porcelain surfaces initiated formation of fine cracks to levels of 5100mm/mm2 . This cracking was not observed for specimens which were only polished or only self- glazed.

Giordano RA et al9 compared the strengthening effect of the Tuf-coat ion exchange system with that of surface treatments such as overglazing, polishing and finishing. Eighty bars of feldspathic material, 3x3x30mm were formed in an aluminium split mould, sintered and randomly assigned to eight different surface treatment groups to examine these effects. The 8 groups were subjected to self- glaze, heat treatment, Tuf- coat ion exchange, grinding and polishing, over- glaze, Tuf-coat ion exchange followed by self-glaze, Tuf-coat ion exchange followed by grinding and polishing, overglaze followed by Tuf- coat ion exchange respectively. The ion exchange material significantly increased the flexural strength of porcelain relative to the self-glazed group. The strength increase generated by ion exchange was not statistically different from that in over glazed porcelain. Self glazing procedures after Tuf-coat treatment eliminated the strengthening effect of ion exchange. An increase in strength of approximately 43% was recorded for ion-exchanged porcelain. This increase may not be identical for all fe ldspathic porcelain because it depends on the composition of the porcelain, the exact amount of ion exchange material and press heating cycle.

Myers ML et al10 investigated the stress corrosion fatigue characteristics of Optec- hsp porcelain. Disks (*1mm thick and 12mm in diameter*) were prepared according to the manufacturers recommendations. Dynamic fatigue was measured using a biaxial flexural strength test in a circulatory water bath. Samples were subjected to dynamic loading at multiple constant stressing rates like 100MPa/s, 10MPa/s, 1MPa/s, 0.1MPa/s and 0.01MPa/s. Inert strength was determined in a moisture- free environment at a stressing rate of 100MPa/s. The wet strength values demonstrated a decrease in strength as the stressing rate decreases. This is because at higher stressing rates there is less time for crack growth to occur. The higher stressing rates resulted in higher fracture strength for the Optec porcelain. The dry strength specimens were not exposed to moisture, so crack growth caused by stress corrosion could not take place. Failure of these specimens resulted from the intrinsic flaw distribution resulting in higher strength. From this study, it was found that Optec- hsp is less fatigue susceptible than feldspathic porcelain and comparable to aluminous porcelain.

Giordano RA et al11 characterized components of the Inceram ceramic system with respect to strength of the glass, alumina matrix and infused alumina by use of a four-point bend test. Flexural strengths of feldspathic porcelain and Dicor ceramic were also compared. Inceram ceramic is based on formation of an interpenetrating network of alumina and glass. Results of flexural strength tests of Inceram ceramic components were of greater interest when the final strength of the infused material was considered. Sintered alumina matrix had strength of only 18.39±5.00MPa, which showed that the initial sintering was not responsible for the strength of the core. Logically, glass was the next material responsible for strength, but the flexural strength was only 76.53±15.23MPa. But the overall strength was 236.15±21.94Mpa. There were several explanations for this drastic increase in strength. They were

Ø Due to a decrease in the total porosity by the infused glass.

Ø Strengthening mechanisms like crack deflection and crack bridging may also contribute.

Ø Compressive stresses around the alumina particles were also attributed to the strengthening effect. Flexural strength of Inceram ceramic core, Dicor ceramic and feldspathic porcelain were also co mpared for strengths. There were two critical findings. First, Dicor strength was highly dependent on the presence of the Ceram layer. Removal of this layer with diamond polishing paste increased flexural strength by approximately 50%, which occurred during the fabrication of Dicor ceramic. Second, with respect to all-ceramic restorative materials, Inceram ceramic was the strongest core material.

Giordano RA et al12 examined the effects of grinding and polishing on a feldspathic porcelain, an aluminous po rcelain and a ceramic used in the Cerec system. A total of 105 bars of the feldspathic ceramic were made, randomly divided into 7 groups, and sintered according to the manufacturer's recommendations. The groups consisted of as fired, self-glazed, overglaze d, ground, polished, ground/annealed and polished/ annealed. A total of 45 bars of aluminous ceramic and Vitabloc MKI were randomly divided into 3 groups: as fired, ground and polished. Overglazing, grinding and polishing all significantly increased the flexural strength of the tested materials by 15 to 30%. Overglazing with a material having a lower coefficient of thermal expansion than that of the underlying porcelain increased the flexural strength, but the strength improvement was below the effects obtained from grinding and polishing during clinical procedures. The increase in the flexural strength of aluminous porcelain is even larger than the effect seen with the feldspathic porcelain. This is attributed to the crystalline nature of the ceramic i.e. since the aluminous material have crystals i.e. 50% the crystals were plastically deformed during the finishing procedures which lead to the development of compressive stresses around the crystals. A higher stress then had to be applied to cause the material to fail, since stresses induced inhibited crack propagation.

White SN et al13 used blunt- indentation mechanics technique to investigate the response of a feldspathic dental porcelain to cyclic mechanical fatigue. The indentation stress- strain curve showed that the critical pressure necessary for crack initiation was 0.72GPa. This research also showed that subcritical pressures can also cause irreversible damage. A second series of experiment conducted by them evaluated the strength loss. These experime nts showed that the porcelain was susceptible to cyclic mechanical fatigue and the damage was cumulative. Also cyclic loading cumulatively decreased the strength of the specimen. This test favored evaluating the evolution of damage because contact pressure increases monotonically from early linear elastic behavior to fully elastic- plastic regions. It provided controlled flaws for evaluating strength properties, with special insight into the stability or growth of natural flaws, and allowed for the stud y of crack initiation and crack propagation.

Harvey CK et al14 investigated the failure mode involved during the traditional in vitro testing of glass-ceramic and determined whether the measured failure loads in those type of testing would be influenced by indenter radii and specimen thickness. Fracture surfaces and failure probability data from glass ceramic cuspid tested in a previous in- vitro study were examined to determine their mode of failure. 100 ceramic platelets –50 glass ceramic and 50 feldspathic porcelain were loaded to failure beneath spherical indenters (*radii 0.75 to 0.94mm*).

Glass ceramic cuspids failed from blunt contact damage at the point of loading. Such indentation damage was a unique response to localized contact stresses and was entirely a different failure mode from the cementation surface cracks which was reported for clinical specimens. Ceramic platelets exhibited failure from either the indentation surface (*hertzian cone cracking*) or from the supported surface (*mimicks bending failure*). It was found that the failure loads increased with the indenter radius for both failure modes. Failure from blunt contact damage occurred at markedly higher loads. Blunt indentation was identified as the failure source for the glass ceramic cus pid and a major failure mode for both feldspathic porcelain and glass ceramic platelets loaded beneath spherical indenters. The failure mode was not similar to that reported for clinically failed glass-ceramic crowns. The testing variable which influe nced the study were contact radius, ceramic thickness and surface finish of the ceramic specimen.

Cattell MJ et al16 evaluated the biaxial flexural strength and reliability of four dental ceramics including: Empress glass ceramic (*EM*), Cerinate porcelain (*CE*), Corum porcelain (*CO*) and Alpha porcelain (*AL*) were compared. 20 disc specimens were prepared per material and overglazed. The piston on three ball test was used to test the specimens in a Universal testing machine at a cross head speed of 0.15mm/min. It was found that mean strengths were 133.5±21.5 for EM; 109.1±11.3 for CE; 119.8±19.2 for CO; and 68.2±9.9 for AL. Weibull m- values included EM –6.60, CE–10.20, CO–5.27, AL–6.93. Cerinate thus had the highest m- value and therefore good dependability. Thus Empress was not stronger or more reliable than many of the frit materials.

Sobrinho LC et al17 investigated the influence of fatigue on the fracture strength of Inceram, Optimal pressable ceramics and IPS empress in both wet and dry environments. 26 crown shapes measuring 8.0mm in diameter and 8.5mm in height were fabricated for each ceramic system. For each ceramic system, 10 specimens were tested for fracture strength without fatiguing. A second group (*8 specimens*) was submitted to fatigue regime of 10,000 cycles with minimum and maximum load of 20 and 300N and then it is fracture tested under dry conditions. A third group (*8 specimens*) was fatigued and fractured in a wet environment using a mechanical testing machine (*Instron*). The strength of the three ceramic systems decreased significantly after fatiguing than non- fatiguing specimens either in a wet or dry environment. For the three systems fatigued in a dry environment and then fracture tested, Inceram and Optimal pressable ceramics was stronge r than IPS empress, but no difference was found in the three systems fatigued in a wet environment. Thus differences in fracture strengths of the different systems investigated may be due to the nature of the system and the environment in which the specimens were fatigued. Factors which were found to affect the strength of ceramics were ² Presence of stress corrosion cracking in high alumina systems. ² Moisture diffusion accelerated by the presence of interfaces.

Magne P et al18 investigated the developme nt of cracks in porcelain veneers using cyclic thermal fatigue. Maxillary incisors were restored with porcelain laminate veneers and subjected to thermocycling (*5 to 500C*) for 1000 cycles. Ceramic cracks were reported in 11 out of 27 specimens. Ceramic and luting composite thickness was measured after sectioning the teeth using SEM. Measurements were done at different locations like facial, incisal and proximal. Significant differences were observed in the ratio of the ceramic and luting composite thickness . The cracked sample exhibited a ratio at the facial location below 3.0, whereas noncracked specimens were above this value (*3.9±1.0*). It was found that the ceramic was thin in the facial aspect, which in turn was thinner than the incisal aspect. Thickness of composite was lesser in the cervical than in the incisal in the facial aspect.

This study showed that cyclic temperature changes can cause development of flaws in porcelain veneers. They concluded that controlled tooth reduction and the application of die spacers during laboratory procedures provided a sufficient and even thickness of ceramic combined with a minimal thickness of luting composite. This provided the restoration with a favorable configuration with regard to crack propensity (*i.e. ceramic and luting composite thickness ratio above 3*).Larger the cement thickness, the force exerted by the dimensionally changing cement decreased the strength of the ceramic. Shrinkage of the composite produced a static stress which in combination with cyclic thermal loads contributed to the failure of the feldspathic porcelain.

Chu FCS et al19 investigated three methods for reducing surface roughness and improving the strength of porcelain restorations. 90 laminated In ceram/ vitadur alpha self- glazed porcelain disks were fabricated and randomly divided into three groups. Group 1, consisted of 30 specimens of original disks. Remaining 60 disks were then polished by 6 operators. Group 2 consisted of 30 of these polished disks. Groups 3 had the remaining polished disks which were reglazed. Average roughness values (*Ra*) of the veneers were measured using a profilometer. It was found that the Ra values were 0.5±0.1mm, 0.7±0.3 mm and 0.4±0.1mm for Groups 1 to 3 respectively. Reglazed disks were also smoother than the original self- glazed disks ($P<0.01$). With the veneers placed in tension, the flexural strengths were 151±22MPa, 118±22MPa and 172±27MPa for groups 1 to 3 respectively. This study concluded that reglazing polished porcelain surfaces significantly improved the surface texture and flexural strength of the materials tested.

Fleming GJP et al20 investigated the implications of mixing variability on the slurry consistency used in the manufacture of dentine porcelain disc specimens for laboratory testing. 30 identical disc specimens were formed by condensing varying amounts of Vitadur-alpha dentine porcelain powder (*0.81g, 0.91g and 1.0g*) to a slurry consistency with a fixed volume of modeling fluid (*0.33ml*). The biaxial fracture strength of the disc specimens was then determined. It was found that the mean fracture strengths were 85.1, 87.3 and 81.9MPa for powder contents of 0.81, 0.91 and 1.0g respectively. Increasing or decreasing the powder content of the slurry from 0.91g resulted in an increase in porosity and a decrease in apparent solid density. The results suggested that an optimum consistency existed wherein consistent reproducible result was achieved. A comparison between materials can only be achieved if specimen preparation occurs cons istently between centers and thus the results had implications in laboratory testing of materials. As a consequence, it was proposed that the clinically induced variability in the dentine porcelain slurry consistencies can influence the longevity of dentine porcelain restorations. When there was a deviation from the optimal consistency, there was a increase in the apparent porosity and surface imperfections which decreased the life span of the porcelain veneer restorations.

Scherrer SS et al21 evalua ted the effect of prolonged exposure to water on the mechanical properties like fracture toughness and flexure strength of low fusing ceramics. Disks and bars were mirror polished and annealed prior to aging in i) Air, Control; ii) Water for 50°C. Fracture toughness was determined by indentation fracture (*IF*) and indentation strength (*IS*) using a 19.6 N Vickers indentation by a three point bending at 0.1mm/min. It was found that both IS and IF showed a significant improvement in the fracture toughness of LFC after 8 weeks in water as opposed to the 24 hr values both in water and air. The origin of the observed result was unclear. Several explanations were given i) due to change in the surface structure ii) intricacies of crack lengths measurements. However for the flexural strength, the weibull characteristic (*So*) and the 'm' parameter showed no significant difference with water storage. The increase in toughness of Duceram LFC after aging in water was an interesting observation for a restorative material exposed to the oral environment but its important was not overemphasized, as its fracture toughness still remained in the lower range of currently available ceramic materials.

Aristidis GA et al22 evaluated the clinical performance of porcelain laminate veneers for 5 years. 186 laminate veneers were placed in 61 patients aged 18 to 70 years, by a single operator following the same clinical procedure. At 5 years, 98.4% of the veneers were judged clinically acceptable. The retention rate was excellent, the fracture rate was low, and the maintenance of esthetics was superior. Also patient satisfaction was encouraging. The weak link in the porcelain veneer system is the composite luting agent. Only one of the restorations showed marginal defects at the restoration- luting composite interface because of loss of marginal seal and wash out of the luting agent. The study concluded that further research was required towards the improvement of marginal adaptation of porcelain veneers. It was concluded that the porcelain laminate veneers offered a reliable and effective procedure for the conservative and esthetic treatment of anterior teeth.

Bona AD et al23 investigated the failure probability of monolithic and laminated ceramic structure from a four-point flexure test. This study tested the hypothesis that weibull moduli of single and multilayer ceramics are controlled by the structural reliability of the core ceramic. Seven groups of 20 bar specimens were made from the following materials i.e. IPS empress, IPS empress 2, Evision, IPS empress 2 body, Evision core plus glaze layer, Evision core plus veneer plus glaze. Each specimen was subjected to four-point flexure loading at a cross- head speed of 0.5mm/min while immersed in distilled water at 370C, except for one group where Evision core was tested in a dry environment (*vaccumed with nitrogen*). Failure loads were recorded and the fracture surfaces were examined using SEM. It was found that there were no significant differences in flexural strength among Empress 2, Evision core, Evision core with glaze and Evision core veneered with glaze and between empress 1 and glass ceramic. But there were differences in the flexural strength when it was tested in different environments i.e. flexural strength was more when tested in a dry environment compared to a wet environment. Glazing had no significant effect on the flexural strength or the Weibull modulus, which is measure of flaw size distribution for a given volume of ceramic under stress. In this study it was found that there was no difference in the flexural strength between core ceramic and core ceramic that is veneered. Therefore, it was concluded that the structural reliability of veneered core ceramic is controlled primarily by that of the core ceramic.

Flanders LA et al24 investigated about the environments that could efficiently minimize machining induced damage of dental materials.Single point abrasion (*SPA*) scratch testing was used on five materials. They are feldspathic porcelain, MGC 1000, MGC 1120, Empress and Empress II. Scratch testing was done to determine the scratch hardness and amount of edge chipping in different chemical environments like air, water, saline and glycerol solutions. Instruments used were a conical diamond indenter and a conventional tungsten carbide machining tool. It was found that water and saline yielded lowest scratch hardness values, air the next lowest and tests performed in glycerol yielded the highest hardness values. It was found that the hardness values measured with a conical diamond indenter in glycerine environment was twice than that measured in water and saline solutions. Environmental effects on chipping were minimal but a directly proportional relationship exists between load and percentage chipping for the tungsten carbide tool within the 10-50N test range. Effects of surface hardness was found to be more dependent on tool interactions rather than material specific properties i.e. diamond indenter removed more particles than the tungsten carbide tool. As a result, it may not be possible to utilize a particular single environment to substantially remove the damage response of dental materials to machining operations as the chemical environment had effect only on machining characteristics.

Fleming GJP et al25 examined the impact of thermocycling on the development of surface flaws on the fit surface of porcelain laminate veneer restorations. Sets of Vitadur –alpha dentin porcelain discs (*15mm diameter, 0.9mm thickness*) were thermocycled at three different temperature regime ns i.e. between 40C and 370C; between 370C and 650C and between 40C and 650C, both on glazed and unglazed surfaces to simulate the conditions encountered in service. A control group was kept in water at 370C for a period of 3500 cycles as thermocycling was done for this amount of cycles. Mean fracture strengths, standard deviations and associated Weibull moduli (m) were determined using biaxial fracture (*ball on ring*). One way analysis of variance revealed no significant difference between means of porcelain specimens exposed to different thermocycling regimens.

However, a discontinuity existed at the lower strength values in the survival probability plots for porcelain specimen groups that were thermocycled. It was found that large flaws on the surface of the specimens may become extended due to the thermocycling regimens imposed. Further, the greater the tensile stresses imposed on the disc specimen surface by the thermocycling regimes, more likely the flaws are extended resulting in premature fracture. Consequently, the discontinuity in the survival probability distributions may be attributed to a different defect mechanism (*possibly by the extension of surface flaws*) superimposed on the distributions at these low values of strength.

Griggs JA et al2 6 verified the formation of a hydrolyzed surface layer on Duceram LFC porcelain and determined the effect of such a layer on mechanical material properties including flexural strength, fracture toughness, surface micro hardness and surface elastic modulus. Specimens were fabricated from dentin porcelain by a vibration blotting technique and were prepared to have either blunt or sharp surface flaws. Half of the specimens underwent accelerated aging. Specimens were fractured in three-point flexure to measure their strength and fracturographic analysis used to determine fracture toughness and residual surface stress. Surface hardness and elastic modulus were measured using a micro indentation method. Porcelain surface topography was examined using atomic force microscopy to determine the composition of the surface layer. It was found that the aging treatment modified the porcelain surface topography, but did not create a layer with increased hydroxyl ion content. Porcelain strength increased upon aging, and the increase was proportional to the initial flow severity. The apparent toughness of sharp flaw specimens increased to match that of the specimens containing blunt flaws upon aging. Surface hardness and elastic modulus decreased upon aging. Modified surface layer was described as a remodeled surface because the severity of surface flaws decreased through a selective dissolution mechanism. Thus, surface remodeling reduced the stress intensities of sharp flaws to match those of blunt flaws, which resulted in an increase in strength proportional to the initial flaws.

Geoffrey A Thompson28 examined the influence of relative layer heights and displacement rate on the weibull parameters i.e. weibull modulus (*m*) and weibull characteristic (s) of bilayered ceramic composite disks composed of In-ceram and Vitadur alpha porcelain. Totally ninety specimens were fabricated and divided into 3 groups based upon the relative layer height of Inceram alumina and Vitadur alpha porcelain which was in the ratio 1:2, 1:1 and 2:1. Each group thus had 30 specimens and were tested in an equibiaxial ring on ring testing apparatus at different displacement rates of 0.127, 1.27 and 12.7mm/min. For the constant displacement rate, weibull parameters were significantly affected for the different relative layer heights. Many specimens exhibited non-brittle mode of failure i.e. they exhibited a fall followed by a rise in load before they underwent failure at low displacement rates. This was due to the greater core thickness that exhibited effects of slow crack growth in laboratory equibiaxial tests. This study showed that the relative layer heights of laminate materials may have a significant effect on the reliability and longevity of those materials.

SUMMARY AND CONCLUSIONS

This study was conduced to assess the influence of thermocyling on the flexural strength of porcelain laminate veneers. 80 discs of 10mm diameter and 0.9mm thickness were made with Vitadur alpha dentin powder by using a metallic mold. They were glazed on one side. The specime ns were divided into two Groups A and B, each containing 40 discs. The specimens in Group A consisted of porcelain laminate veneer only. In the disc specimens of

Group B resin cement was luted on to their inner non- glazed surface to simulate clinical condition. The cement thickness was standardized to 0.2mm. The discs in Group A and B were randomly divided into four subgroups each. The subgroups were subjected to thermocycling under different temperatures. After thermocycling the specimens were examined under SEM for evaluating crack formation if any after thermocycling. Breaking load values were obtained for the specimens using universal testing machine (INSTRON), by loading the discs with a metallic fixture. Flexural strength was calculated for Groups A 85 and B using Timoshenko's equation and formula for bilayered discs respectively.

The data obtained were statistically analyzed using Student's independent 't' test, one -way ANOVA and Kaplan Meier's survival probability analysis to find

. Level of signific ance of mean values between control and subgroups of both A and B Groups.

Level of significance of mean values between Group A and B.

Level of significance of mean values between Group A and B for each sub group.

Survival probability of specimens in A and B respectively

The conclusions drawn from the study are

Laminate veneer specimens exhibited greater flexural strength than those which were luted with resin cements

. Laminate veneer specimens luted with resin cement when subjected to extremes of temperature (4□10C and 37□10C) and (4□10C and 65□10C) showed marked decrease in flexural strength. Laminate veneer specimens luted with resin cement after thermocycling at extremes of temperature showed crack propagation The clinical implications are Fit of laminate veneers cannot/ should not be compensated by thickness of luting agent. As the resin cement used for luting porcelain laminate veneer actually decreases the flexural strength and causes crack propagation in the laminate veneer. The crack propagation in t he laminate veneer was possibly due to Difference in the co-efficient of thermal expansion and elastic modulus between ceramic and resin cement Water seeping into the resin cement that decreased the elastic modulus of the resin further when subjected to thermocycling. During the laboratory phase of porcelain laminate veneer fabrication, the die spacer must be applied carefully to form a uniform layer. This is to avoid excessive thickness of luting cement that would reduce the ceramic and luting cement ratio.Tooth reduction must be sufficient to ensure uniform ceramic thickness in the final restoration that would provide favorable ceramic and luting cement ratio.

References

1. **Crim GA, Swartz ML, Phillips RW:** Comparison of four thermocycling techniques. J Prosthet Dent 1985; 53:50-52.

2. **Morena R, Beaudreau GM, Lockwood PE, Evans AL, Fairhurst CW:** Fatigue of dental ceramics in a simulated oral environment. J Dent Res.1986; 65: 993-997.

3. **Anusavice KJ, DeHoff PH, Hojjatie B, Gray A:**Influence of tempering and contraction mismatch on crack development in ceramic surfaces. J Dent Res 1989;68: 1182-1187

4. **Anusavice KJ, Lee RB:** Effect of firing temperature and water exposure on crack propagation in unglazed porcelain. J Dent Res 1989; 68: 1075-1081.

5. **Kelly JR, Campbell SD,Bowen HK:** Fracture-surface analysis of dental ceramics. J Prosthet Dent 1989; 62:536-541.
6 **Palmer DS, Barco MT,Billy EJ:** Temperature extremes produced orally by hot and cold liquids. J Prosthet Dent 1992; 67; 325-327
7 **White SN:** Mechanical fatigue of a feldspathic dental porcelain. Dent Materials 1993; 9: 260-264.
8 **Edge MJ, Wagner WC**: Surface cracking identified in polished and self-glazed dental porcelain. J Prosthod 1994; 3: 130-133. 90
9 **Giordano RA, Campbell S, Pober R:** Flexural strength of feldspathic porcelain treated with ion exchange, overglaze, and polishing. J Prosthet Dent 1994; 71:468-47.
10 **Myers ML, Ergle JW, Fairhurst CW, Ringle RD:** Fatigue characteristics of a high strength porcelain. Int J Prosthodont 1994; 7: 253-257.
11 **Giordano RA, Cima M, Pober R:** Effect of surface finish on the flexural strength of feldspathic and aluminous dental ceramics. . Int J Prosthodont 1995;8: 311-319
12 **Giordano RA, Pelletier L, Campbell S, Pober R:** Flexural strength of an infused ceramic, glass ceramic and feldspathic porcelain. J Prosthet Dent 1995; 73: 411-418.
13 **White SN, Zhan XY, Yu Z, Li ZC, Kipnis V:**Cyclic mechanical fatigue of a feldspathic dental porcelain. Int J Prosthodont 1995; 8: 413-420.
14 **Harvey CK, Kelly JR:** Contact damage as a failure mode during in vitro testing. J Prosthodont 1996; 5:95-100.
15 **Sherhri SAA, Mohammed H, Wilson CA:** Influence of lamination on the flexural strength of a castable glass ceramic. J Prosthet Dent 1996; 76:23-28.

16 **Catell MJ, Clarke RL, Lynch EJ:** The biaxial flexural strength and reliability of four dental ceramics. J Dent 1997; 25: 409-414

17 **Sobrinho LC ,Catell MJ, Glover RH, Knowles JC** Investigation of the dry and wet fatigue properties of three all-ceramic crown ystems. Int J Prosthodont 1998; 11: 255-262

18 **Magne P, Dr Med Dent, Kwon K, Belser UC, Hodges JS, Douglas WH:** Crack Propensity of porcelain laminate veneers: A simulated operatory evaluation. J Prosthet Dent 1999; 81: 327-334.

19 **Chu FCS, Frankel N, Roger, Smales J:** Surface roughness and flexural strength of self- glazed, polished, and reglazed In- Ceram/ Vitadur Alpha porcelain laminates. Int J Prosthodont 2000; 13:66-71.

20 **Fleming GJP, Shaini FJ, Marquis PM:** An assessment of the influence of mixing induced variability on the bi-axial flexural strength of dentine porcelain discs and the implications for laboratory testing of porcelain specimens. Dent Materials 2000; 16:114-119.

21 **Scherrer SS, Denry IL, Wiskott HWA, Belser UC:** Effect of water exposure on the fracture toughness and flexure strength of a dental glass. Dent Materials 2001; 17:367-371.

22 **Aristidis GA, Dimitra B:** Five- year clinical performances of porcelain laminate veneers. Quintessence International 2000; 2: 22-25.

23 **Bona AD, Anusavice KJ, Dehoff PH:** Weibull analysis and flexural strength of hot pressed core and veneered ceramic structures. Dent Materials 2003;19: 662-669

24 **Flanders LA, Quinn JB, Wilson OC, Lloyd IK:** Scratch hardness and chipping of dental ceramics under different environments. Dent Materials 2003; 19: 716-724.

25 **Addison O, Fleming GJP, Marquis PM:** The effect of thermocycling on the strength of porcelain laminate veneers. Dent Materials 2003; 19:291-297

26 **Griggs JA, Kishen A, Le KN:** Mechanism of strength increase for a hydrothermal porcelain. Dent Materials 2003;19: 625-631

27 **Isgro G, Pallav P, Zel JMVD, Feilzer AJ:** The influence of the veneering porcelain and different surface treatments on the biaxial flexural strength of a heat-pressed ceramic. J Prosthet Dent 2003; 90: 465-473.

28 **Thompson GA:** Determining the slow crack growth parameter and weibull two-parameter estimates of bilaminate disks by constant displacement-rate flexural testing. Dent Materials 2004; 20: 51-62.

29 **Brien WJO:** Dental Materials and these selection, ed 2, Quintessence Publishing Company, 1997.

30 **Anusavice KJ:** Philips' science of dental materials, ed 10, Bangalore, WB Saunders Company, 1998.