IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 16, Issue 6 Ver. IV (June. 2017), PP 61-64
www.iosrjournals.org

Dental Porcelain (Reinforced) with Increased Deformation Resistance

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Abstract: *60 samples of porcelain disc dimensions 12 mm diameter×0.8 mmthickness were prepared. Specimens were divided into four groups, each group containing 15 discs. Group 1subjected to immediate cooling after firing, Group 2 subjected to intermediate speed cooling and group 3 ultra-slow cooling. All 3 groups are alumina-reinforced and group 4 is conventional porcelain. Indentations on each disc were made with a Vickers indenter with a microhardness tester loaded with 1000g for 20 seconds. Statistical analysis revealed significant differences in fracture toughness values of first three groups from 4th group. From the study it can be inferred that reinforcement with alumina not only improves esthetics but this metallic modification definitely improves deformation resistance by interacting with cracks and thus preventing their propagation.*
Keywords: *Crack propagation,deformation resistance, dental porcelain,reinforcing.*

I. Introduction

Dental art and science have long been in the search to enhance the esthetics of the mankind. During the 18th century, the candidate materials for replacing teeth were human teeth, carved animal teeth, ivory, and mineral or porcelain teeth. In 1723, Piere Fauchard was credited with recognizing the potential of porcelain to imitate the color of teeth and gingival tissues.Porcelain is esthetically very much appreciable but it is very prone to fracture.Metal-ceramic restorations to a certain extend overcame the problem,but metal has got its own problems. The metal-free restorations precluded the potential problems associated with metal-ceramic restorations such as metal allergy, alloy corrosion and discolouration of some ceramics from silver containing alloys. Then came the metal-free ceramics.This was very good in esthetic aspect and effeicient in overcoming metal-associated defects.But a major draw back associated with ceramics is its brittle nature.As an attempt to improve the material,various modifiers were added.All-ceramics evolved so far include porcelain reinforced with aluminium oxide, castable glass ceramics, shrink free core ceramic, injection moulded core ceramic, high strength glass infiltrated alumina core ceramic, CAD-CAM (computer aided design, computer aided machining) ceramic etc.All these modified ceramics are better in one or other property of conventional one.
Hardness is resistance to plastic deformation, usually by indentation. It also refer to resistance to scratching, abrasion. The greater the hardness of a material, the greater is its resistance to deform. Fracture toughness (Kc) quantifies the ability of a material to resist crack propagation. It is calculated by measurement of radial cracks created in the material by a loaded microindenter. In the present study,it is tried to prove that reinforced porcelain is better than conventional porcelain in properties like deformation resistance (Vickers Hardness,VHN) and propagation resistance (Fracture toughness,Kc).

II. Review of literature

Bacterial biofilm formation depends on the surface quality of dental ceramics. Adherence of microbial species to dental ceramics and the subsequent formation of biofilms on their rough surfaces act as favourable factors to plaquerelated systemic diseases[] .Literatures are there that physical tempering can reduce the sizes of surface cracks associated with both positive and negative differences in contraction coefficients of the ceramic layers[]. Sandblasting also improves surface of porcelain and it is well tolerated by In-ceram but not advisable for feldspathic[].It was made clear that performance of porcelain restorations could be greatly improved by better understanding of the thermal conditioning procedures[]. Flexure strength increases by ion exchange is proportional to the thickness of the exchanged layer[]. The studies are there showing that the coefficient of thermal expansion of the porcelain could be controlled by stabilizing high (cubic) leucite to low leucite phase transformation by adding Cs2O. Addition of cesium oxide had got an effect on hardness and toughness[].Studies have reported that overglazing, grinding and polishing all significantly increase the flexural strength. Polishing of all the ceramic materials significantly increases flexural strength[]. The reported average flexural strengths of AllCeram, In Ceram, and Empress ceramics were 687 MPa, 352 MPa, and 134 MPa respectively[].From all these studies ,it is clear that surface finish of the porcelain is very important in achieving esthetic and mechanical qualities. Residual compressive stresses on the porcelain surface after cooling enhance resistance of porcelain to crack initiation, as quantified by its fracture toughness (Kc).There are reports that the aluminous porcelain is significantly better in toughness than feldspathic porcelain. These differences in Kc may be due to differences in the nature of crack-microstructure interaction.It has been reported that higher thermal shock resistance of the ceramics –as measured by a water –quench technique-may be due to its greater resistance to stress corrosion at the initial stage of crack propagation.Alumina-reinforcement resulted in the highest fracture toughness values. In the present studt alumina reinforced porcelain is compared with conventional porcelain.

III. Materials and methods

Materials

Metal mould for the test specimen,12mm diameter and 0.8mm thickness,Wax pattern,petroleum jellyIP,Disc abrasives,LAMINA VEST,Alumina reinforced porcelain powder, conventioanal porcelain & Gauge. Equipments Ceramic furnace, Sand blaster-BEGO & Microhardness indenter-CLEMEX. 60 samples of porcelain disc dimensions 12mm diameter×0.8mmthickness were prepared.Specimens were divided into four groups, each group containing 15 discs. Group 4 is conventional porcelain.Group 1subjected to immediate cooling after firing, Group 2 subjected to intermediate speed cooling and group 3 ultra-slow cooling.

Method

After cooling at different rates, indentations were made on each disc.Vickers indenter with load one kilogram, for twenty seconds was used.Just after indentation,crack diameter measured.
Three readings were made for each indentation, and the average of the readings were used to derive the fracture toughness(K_c).

$$K_c = \frac{1}{\pi^{3/2}\tan.\psi}\,[P/D^{3/2}]$$

K_c fracture toughness, ψ angle of indenter cone (136/2=68), P contact load (peak) and D radius of crack. The average measurement of six indentations was used for the calculation of K_c.

IV. Results

One Way ANOVA were performed as parametric test to compare different variables. Fig 1 & Fig 2 and TABLES 1 & 2.

Table1: Fracture toughness of different groups

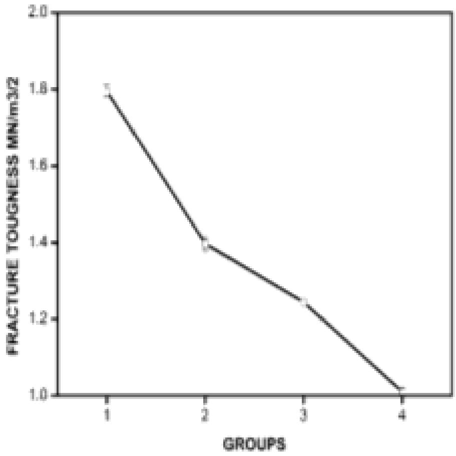
Group	Fracture Tougness (Mean ± Sd) Mn/M$^{3/2}$	P Value
1	1.7953±.06221	<0.001*
2	1.3973±.07086	
3	1.2440±.03225	
4	1.0100±.04392	

*One way ANOVA analysis

Table 2: Group Wise Differences in Fracture Toughness

Group Pair	Difference In Fracture Toughness (Mean ± Se) Mn/M$^{3/2}$	95% Confidence Interval Of The Difference	P Value
1-2	.39800*±.01988	.4524 - .3436	<0.001*
1-3	.55133*±.01988	.6057- .4970	<0.001*
1-4	.78533*±.01988	.8397 - .7310	<0.001*
2-3	.15333*±.01988	.2077 - .0990	<0.001*
2-4	.38733*±.01988	.4417 - .3330	<0.001*
3-4	.23400*±.01988	.2884 - .1796	<0.001*

* post Hoc- Analysis (Bonferroni Test)



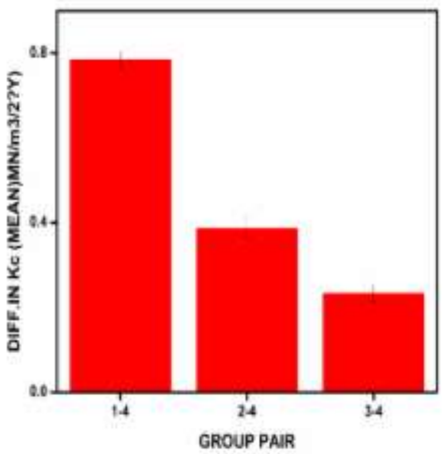


Fig. 1 Fracture toughness (Kc).
Fig. 2 Comparing Kc of 1st,2nd and 3rd groups with Kc of 4th group.

Statistical analysis shows Groups 1,2 and 3 are having higher values compared to Group 4. Inference of data analysis is that Fracture toughness depends on the ability of a material to prevent or interact with the crack formation and propagation.

V. Discussion

Use of ceramics dates back to the stone age, more than ten thousand years ago. Ceramic is a material made from a non-metallic mineral (as clay) by firing at a high temperature.Porcelain is a ceramic material formed of infusible elements joined by lower fusing materials and composed essentially of kaolin, quartz and feldspar. Greek word "keramos" means"burnt stuff". Pierre Fauchard in 18th century attempted to use porcelain in dentistry []. Aluminous porcelain containing 40-50% Alumina crystals was developed by McLean and Hughes in 1965 as an inner core of to block the propagation of cracks[]. Fracture toughness has got prime importance in determining the various aspects of mechanical behaviour of a brittle material []. Various studies compared the strength of various all-ceramic materials and found out that alumina and zirconia reinforced core materials were significantly stronger than all other ceramic systems[]. Various methods are there to improve fracture resistance of ceramics.Crack deflection appears to be the principal strengthening mechanism and alumina was found to be the most effective reinforcing agent[,6,]. Alumina was proven as the most effective toughening phase.The improved aesthetics of all-ceramic restorations is due to the ability of porcelain to transmit light. Alumina-reinforced ceramic systems also improve the light reflection characteristics of crowns when compared to conventional metal - ceramic restorations[17].Kc is not sensitive to the size and density of surface flaws, which are inturn controlled by the manner in which test specimens are prepared. This was supported by the studies conducted by Rosenstiel and Porter[].

In the present study, fracture toughness was determined by the indentation fracture technique. This method is particularly suitable for expensive materials like dental ceramics as only small quantity (a few grams) of sample is required for this method[1,]. The basis of this technique is the series of cracks appear to emanate, when viewed from the above, from each of the corners of the indentation. The size of the crack is an inverse function of fracture toughness[]. Basic difference between the crack propagation in feldspathic and alumina reinforced porcelain was that indentation cracks deflected away from the leucite crystals in feldspathic porcelain whereas cracks interact directly with the alumina dispersed phase in the latter[2].

VI. Conclusion

All the three groups of reinforced porcelain showed better deformation resistance and better resistance to crack propagation than 4th group (Conventional porcelain). Deformation resistance, which is a very desirable quality for a brittle material is very much improved with reinforcement.

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