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INFLUENCE OF ZIRCONIA BASED DENTAL COMPOSITE ON ABRASIVE WEAR

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ABSTRACT
In this study, three experimental dental composites materials with zirconia as a major filler is used. It is intended to vary the percentage of the zirconia in the matrix along with other two fillers and study the wear behavior. It is intended to optimize the percentage of the fillers and obtain minimum wear for the experimental dental composite under study. Taguchi's method of optimization was used for limiting the number of experimentation and finding the most influencing factors.

Keywords: zirconia, experimental dental composites materials, wear rate, optimization.

INTRODUCTION
Wear resistance of denture teeth has been considered as one of the most important requirements for oral rehabilitation of patients with removable dentures, in order to maintain a stable occlusal support over time [1]. Wear of the occlusal surfaces may result in insufficient posterior tooth support, loss of chewing efficiency and non-functional activities. Although wear of acrylic resin teeth has also been related to the loss of vertical dimension of occlusion with complete dentures, the major factor affecting it is the reduction of residual ridges by absorption. Wear of the composite filling in the clinical conditions is a result of the opposing teeth contact, food consumption, teeth brushing and illnesses e.g. bruxism. The wear is a sum of phenomenon occurring in the operating conditions, thus abrasive wear and adhesive effect between two mating surfaces, as well as fatigue of the surface layer of the material and corrosive effects [2]. Especially important types of teeth wear are abrasion and attrition. The abrasive wear [3-5] occurs by means of the following three bodies, wearing friction surfaces of opposing teeth and foreign particles between them. In case of composite fillings the abrasive wear appears as abrasion of the soft polymer matrix exposing filler particles. The attrition is the effect of wear caused by the direct contact of the opposing teeth surfaces, thus the result of interaction of two bodies. During mating of two rough surfaces the micro-roughness contact occurs. If both body surfaces are hard and brittle at the same time, thus as a result of micro roughness contact they deform and fracture after exceeding a critical stress value. In case when the surface of one body has a higher hardness than the opposing surface, it can cause a fast wear by micro cutting. Wear resistance of denture teeth has been considered as one of the most important requirements for oral rehabilitation of edentulous patients with removable dentures, in order to maintain a stable occlusal support over time [4]. Wear of the occlusal surfaces may result in insufficient posterior tooth support, loss of chewing efficiency and non-functional activities. Although wear of acrylic resin teeth has also been related to the loss of vertical dimension of occlusion with complete dentures, the major factor affecting it is the reduction of residual ridges by absorption.

In conservative dentistry ceramic-polymer composites are most commonly used. It applies not only to the front teeth, but also to the side teeth - molars and premolars. The ceramic-polymer composites have suitable physical - mechanical properties to oral cavity conditions [6]. These maintain aesthetic appearance similar to the appearance of the natural tooth tissues for a long operating time. Due to clinical reasons they should also ensure long life of the fillings

MATERIALS AND TEST METHOD
Dental composites consist of a matrix (organic phase-resin) and filler (inorganic phase). The mechanical and tribological properties of dental composites are determined by many parameters such as: size, shape, content and distribution of filler particles in resin matrix [7]. Commonly used fillers are silica fillers, glass and quartz. In this study zirconia, glass and silica is used as filler and Bis Gma and Tegdma are used as matrix. The volume fraction of the three fillers namely: 1) Silica 2) Glass 3) Zirconia is varied. The fillers used are hybrid with two sets to improve the loading of the resin. The average size of set 1 is 10-100 nm and that of set 2 is 2 -15 micro meters. Hybrid composites contain a broad range of particle sizes. A wide range of particle sizes can lead to high filler loading with resultant high strength. While they may contain a small fraction of filler particles in the nanomer particle size range, they also contain a range of substantially larger filler particles which influences the optical properties of these composites and detracts from polish retention. The dispersion of the fillers in the matrix is uniform, and this is improved when the composite is cured with uv radiation at the time of cavity filling. Fully stabilised zirconia is used with dopant levels of 8mol% yttria, 16mol% magnesia or 16mol% calcia. It has a cubic solid solution and has no phase transformation from room temperature up to 2500 degrees C a small fraction of filler particles in the nanomer particle size range, they also contain a range of substantially larger filler particles which influences the optical properties of these composites and

detracts from polish retention. The dispersion of the fillers in the matrix is uniform, and this is improved when the composite is cured with uv radiation at the time of cavity filling. Fully stabilised zirconia is used with dopant levels of 8mol% yttria, 16mol% magnesia or 16mol% calcia. It has a cubic solid solution and has no phase transformation from room temperature up to 2500 degrees C [3]. It is believed that the use of filler particles in nano-sized enhance physical and mechanical properties of ceramic-polymer composites. The quantity of filler in the matrix depends on the type of the composite. Hybrid composites have the highest ratio of inorganic to organic phase, for which the content of the filler ranges from 60 up to 70 percent of the composite volume (% volume) or from 70 up to 85 percent of the composite mass (% weight). The wear resistance of dental composites depends on filler particle size and the percentage of fillers On the other hand some investigators found no direct correlation between filler content and wears resistance In addition, it has been shown that the degree of polymerization can affect the mechanical properties of composite resins. Wear resistance is essential because of the tremendous occlusal stresses that occur during normal mastication. Wear is a common phenomenon in dental composites due to abrasive, adhesive and fatigue processes. Abrasive wear occurs when surfaces pass each other and the harder material cuts the softer material. Adhesive wear is the result of the friction generated by two moving surfaces causing local cold welding between particles on both surfaces which results in fracture of these small pieces. Fatigue wear occurs as a result of propagation of microcracks through the material; leading to the separation of surface particles [8] described two mechanisms of abrasion and attrition for wear of composite resins. It is known that abrasive wear is the most common type of wear In oral cavity wear is a complicated phenomenon and the wearing testing devices have been developed to simulate this phenomenon.

A) Sample preparation: The samples were prepared in plastic mould. The size of samples was 4 mm in diameter and 27 mm length. The flow able composites were inserted in the cavity. The quantity taken actually for the sample preparation was somewhat more than the cavity in order to ensure that the cavity was filled completely every time. The surfaces were covered with the glass slides to ensure the flatness of the specimen. Care any was taken to ensure that there will not be any air bubble in the specimens.

B) Curing: The specimens were cured using LED light torch for the time suggested by the manufacturer. The torch was held about 2 to 3 cm away from the specimen. The hardened specimens were then placed under water at room temperature for a week. After a week, they were taken out, dried with soft cotton cloth and placed in dry environment at room temperature.

C) Wear tests: The wear test was carried on pin -on-disc machine shown in Figure-1. The wear tester was Two Body Wear Tester. Before testing, the specimens were weighed on Precision Digital Balance machine (LWL Germany Make, Model: LB 210S, Least count of 0.0001gm). The values of load, speed and sliding distance were chosen as per the experimental procedure for the research work.

Figure-1. Experimental set up of Pin on Disc machine.

According to SHIQI HE, *et at* [4], wear is usually expressed as the amount of material removed from a surface such as weight loss or volume loss per unit sliding distance. Thus,

$$\text{Wear rate} = \frac{Weightloss}{SlidingDistance}$$

Optimization of Wear Rate:

In order to optimize the wear rate, experiments were carried out on Pin on disc machine as per the L_9 orthogonal array and the methodology is presented below. Theoretically, the amount of wear rate is calculated and the results are reported [9].

ANOVA analysis is carried out to determine the influence of main factors and to determine the percentage contribution of each factor. Based on regression equation predicted values are calculated and which are compared with experimental values of wear rate.

Table-1. The parameters used for abrasive wear:

S. No	Parameter	Unit	
1	**load**	**N**	**600**
2	speed	Rpm	1000
3	Sliding Distance	M	50

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Table-2. Percentage of filler volume at each level.

Process	Levels		
Parameters	**Level 1**	**Level 2**	**Level 3**
Glass %	23.7	25.7	31
Zirconia %	21	27.5	29
Silica %	13.5	16	20

Regression Analysis

Regression analysis gives the functional relationship between input parameters and output response.

A mathematical model was developed with the volumetric percentage of the three fillers in the composite namely glass (Barium Aluminium Floride), zirconia and silica and its effect on the compressive strength. The correlation between factors {glass (barium aluminium floride), zirconia ,Silica}and abrasive wear was obtained by multiple linear regressions. To derive the models, the optimization software package “Minitab” was used.

By using multi variable optimization the regression equation obtained is as follows”

$$WR= 7523- 700G+300S+276Z+ 12.67GZ -2.66ZS +11.2G^2-2.3Z^2$$

For the minimization of quality characteristic variation due to uncontrollable parameter the responce variation is studied using signal to noise ratio (S/N Ratio) as enumerated in Taguchi’s method. In the dental composites smaller the abrasive wear will be better so the abrasive wear was considered as the quality characteristic and the concept of "the smaller-the-better" was used.

S/N = -10 Log_{10} [mean of sum of squares of abrasive wear]

RESULT AND DISCUSSIONS

In the present research work, the number of cycles shows the durability of the composites. The number of cycles is the function of the mastication action by a human. The more number of cycles, the more will be the longitivity of the experimental dental composite. The varying load in the research work is the significance of the variable dynamic forces a human tooth can sustain while mastication. The chewing force is more for the harder food materials like meat, bones, chikki etc and less for the softer food materials like vegetables. The experimental dental composite must withstand both kinds of forces. Also the chewing force vary from person to person. It also changes with the age group. The other factors which affect the mastication force are chewing habits, the type of food, environmental conditions where he lives etc. The study would be helpful in determining the exact amount of load that a dental composite can sustain before failure. The longevity and durability are known which can be used by the dentists in selection of composites. With the knowledge about the food habits of the patients it is possible to approximate the dynamic forces acting on the zirconia based dental composite and predict the wear. By optimizing the composition of the dental composite and with the most influeincing filler being zirconia, the abrasive wear can be predicted and suitable dental composite prescribed for a patient. It is observed that the influence of zirconia as a filler material on experimental dental composite is very significant in our study, effect of zirconia on abrasive wear being 62.45 %. Statistical results (at a 95% confidence level) show that the glass, zirconia and silica affect the abrasive wear by 18.25 %, 62.45 % and 19.3 % of the experimental dental composites, respectively.

Taguchi has strongly recommended a confirmation test for verifying the results (Ross PJ, 1996; Taguchi G, 1990). The experiments are conducted with the optimum conditions and the abrasive wear is found out. This abrasive wear is compared with that calculated value using the relation enumerated above. The analysis of the confirmation experiment for abrasive wear has shown that Taguchi parameter design can successfully verify the optimum filler volume percentages (A1B1C2), which are Glass=23.7% (A1), Zirconia = 21 % (B1) and Silica =16% (C2).

CONCLUSIONS

Effect of Zirconia on the abrasive wear of experimental dental composite is least than silica and glass. Nano particles further increase the effectiveness of the experimental dental composite. The optimum percentages obtained can be used for further evaluation of the other mechanical properties of the experimental dental composite. The other properties which can be evaluated are flexural strength, fracture toughness and micro hardness.

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