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# Experimental Analysis of Four Dental Composites for Their Micro Hardness and Wear Rates

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***ABSTRACT:*** *The emphasis of the research is on the comparative study of wear rates of four commercially available dental composites. The composites under study were each of micro-filled (3M Z350), nano-filled (Filtek Z250) and nano-hybrid composite (Charisma Diamond) and fibre reinforced composite (GC Ever X). The paper shows the relation between micro hardness and wear rates, regression equations for each composite using RSM optimization technique, Comparison of Wear Rates based on their exact composition, explanation of Residual plots. During study, it was found that the fibre reinforced composite showed better wear resistance over others. The micro hardness is obtained using Vickers hardness test (HV).*

***KEYWORDS:*** *dental composites, wear rate, micro hardness.*

## I. INTRODUCTION

The dental filler or restorative materials have to face various kinds of forces and stresses like chemical, thermal and mechanical [1]. The functions concerned with functional, biological and aesthetic aspects are greatly influenced by the excessive wear of teeth and restorative materials [2]. In this scenario, the wear rate becomes an area of concern as far as the restorative materials are concerned.

The normal aging process is the major cause of tooth wear. Although, the entity of teeth is independent of the rate of tooth wear in most of the people [3]. This uncertain life-span of tooth leads to the use of dental restorative materials.

The wear resistance and aesthetics of dental restorative materials have raised the interest in greater applications of resin composites [4]. Still their poor wear resistance limits their applications. The stress induced due to the abrasive action and occlusal loads during mastication are the major aspects of these limitations [5-8].

This current study gives the comparison of two types of dental restorative materials, namely micro filled and fibre reinforced, on the basis of micro hardness and wear rates for different values of variables like no. of cycles, load and ball diameter. Each of these variables represents the normal working conditions of the restorative materials. The no. of cycles shows the durability of the composites. It is the function of the chewing and biting action by a human. The more are the no. of cycles, the more is the durability of the composite.

## II. MATERIALS AND TEST METHOD

For the wear tests, the specimens were prepared. The materials chosen for the present study was ESPE 3M Z350 (micro filled), Filtek Z250 (micro hybrid), Charisma Diamond (nano filled) and GC Ever X (fibre reinforced).

### *2.1 Sample preparation*

The samples were prepared in aluminium mould. The size of samples was 15 mm in diameter and 2 mm thick. 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. 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.

### *2.3 Hardness measurement*

The Vickers micro hardness test was conducted on samples. The micro hardness of the specimens was tested on the Micro hardness Tester, (Reichert Austria make, Sr.No.363798). The effective time of measurement of micro hardness was 10 sec. per specimen.

***2.4 Wear tests***

The wear test was carried on ball-on-disc machine. The wear tester was Two Body Wear Tester (Metaserv Grinder/Polisher with wear test set up). Before testing, the specimens were weighed on Precision Digital Balance machine (LWL Germany Make, Model: LB 210S, Least count of 0.0001gm). The balls embedded in acrylic were used for the tests. The values of rpm, load and ball diameter were chosen as per the experimental procedure for the research work [9].

## III. RESULTS AND ANALYSIS

Under the conditions of this particular 2-body wear test, different dental materials exhibit different wear mechanisms that will have a significant effect on their wear resistance. Two composite materials were tested on ball-on-disc machine for their respective wear rates. The comparative wear rates within the research work constraints are as follows-

**Table 1: 3M- Z350 micro filled composite**

| No. of Cycles | Load (gm) | Ball Dia. (mm) | Wear Rate (%) |
|---|---|---|---|
| 5000.00 | 1000.00 | 6 | 0.9747 |

**Table 2: GC Ever X fibre reinforced composite**

| No. of Cycles | Load (gm) | Ball Dia. (mm) | Wear Rate (%) |
|---|---|---|---|
| 5000 | 1000.00 | 6 | 0.04550 |

**Table 3: Filtek Z250 nano filled composite**

| No. of Cycles | Load (gm) | Ball Dia. (mm) | Wear Rate (%) |
|---|---|---|---|
| 5000.00 | 1000.00 | 6 | 0.5270 |

**Table 4: Charisma Diamond nano-hybrid composite**

| No. of Cycles | Load (gm) | Ball Dia. (mm) | Wear Rate (%) |
|---|---|---|---|
| 5000.00 | 1000.00 | 6 | 0.07340 |

The relation between micro hardness and wear rate of the composites under study is also seen in this particular study.

**Table 5: Relation between micro hardness and wear rate**

| Composite | Micro hardness (HV) | Wear Rate (%) |
|---|---|---|
| 3M- Z350 (micro filled) | 53.92 | 0.9747 |
| GC Ever X (fibre reinforced) | 54.86 | 0.04550 |
| Filtek Z250 (nano filled) | 54.053 | 0.5270 |
| Charisma Diamond (nano hybrid) | 54.296 | 0.07340 |

Regression Equation for all composites under study using Minitab -14 software is as follows

**Table 6: Regression Equations**

| Composite | Regression Equation | R-Sq value |
|---|---|---|
| 3M Z350 | Wear = 0.807 + 0.000031 No. of Cycles + 0.000078 Load + 0.00369 Ball Dia. | 95.0% |
| GC Ever X | Wear = 0.0339 + 0.000002 No. of Cycles + 0.000002 Load + 0.000131 Ball Dia. | 94.8% |
| Filtek Z250 | Wear = 0.514 + 0.000002 No. of Cycles + 0.000002 Load + 0.000388 Ball Dia. | 89.6% |
| Charisma Diamond | Wear = 0.0665 + 0.000001 No. of Cycles + 0.000002 Load + 0.000069 Ball Dia. | 96.5% |

The highest R-Sq value is for micro hybrid composite which shows the 96.5% of fitted data and 3.5% variation.

The wear rates of these composites were dependent on their compositions. Following is the comparison of Wear Rates based on their exact composition.

**Table 7: Comparison of Wear Rates of composites based on their exact composition**

| Composite | Exact Composition | Wear Rate (%) | Micro hardness (HV) |
|---|---|---|---|
| 3M Z350 | Inorganic filler loading- 72.5% by weight (55.6% by volume), average cluster particle size of 0.6 to 10 microns, non-agglomerated / non-aggregated 20µm silica filler, 4 to 11 nm zirconia filler | 0.974 | 53.92 |
| GC Ever X | Methacrylate monomers- 23% by wt, 35% by vol, Silica- 19% by wt, 13% by vol. Fluoro-Alumino-Silicate Glass- 38% by wt, 24% by vol. Pre polymerised filler- 20% by wt., 28% by vol | 0.045 | 54.86 |
| Filtek Z250 | Filler- 0.01 to 3.5-µm particles, Non-agglomerated/non-aggregated 20µm surface-modified silica particles, The filler loading is 82% by weight (68% by volume), The Resin System - PEGDMA | 0.527 | 54.053 |
| Charisma Diamond | Monomers- TCD-DI-HEA and UDMA, Fillers- 80–82 %-m (63,5–65,1%-vol) filler, Range of filler particle size: 5 nm–20µm, Barium Aluminium Fluoride glass, Highly discrete nanoparticles | 0.073 | 54.296 |

The wear rate is lowest and micro hardness is highest for the Fibre Reinforced composite (GC Ever X). The reason is that the silica surfaces are treated hydro-phobically with dimethyl constituents rather than with silanol to improve the bond between silica and matrix resin. This hydrophobic treatment improves the intimate contact between silica and the matrix because both ingredients will attract each other.

The wear rate is highest and micro hardness is lowest for the Micro filled composite (3M Z350). The reason is the varying size of filler particles.

The results obtained of Residual plots in Minitab-14 software show whether the experimentation was within permissible constraints or not.

**Table 8: Residual plot analysis**

| Composite | Normal probability plot | Residuals versus fits | R-Sq value | Remarks |
|---|---|---|---|---|
| 3M Z350 | Residuals are normally distributed | Residuals have constant variance | 95.0% | The parameters are evenly skewed. Constant variance shows absence of noise |
| GC Ever X | Residuals are normally distributed | Residuals have constant variance | 94.8% | The parameters are evenly skewed. Constant variance shows absence of noise |
| Filtek Z250 | Residuals are normally distributed | Residuals have constant variance | 89.6% | The parameters are evenly skewed. Constant variance shows absence of noise |
| Charisma Diamond | Residuals are normally distributed | Residuals have constant variance | 96.5% | The parameters are evenly skewed. Constant variance shows absence of noise |

Following is the comparison of experimental values with Minitab values

**Table 9: 3M Z350**

| Sr. No. | No. of Cycles | Load (gm) | Ball Dia. (mm) | Expt. Value | Minitab Value | Variation (%) |
|---|---|---|---|---|---|---|
| 1 | 5000 | 1000 | 6 | 0.64 | 0.9747 | 33.47 |
| 2 | 4000 | 750 | 8 | 0.077 | 0.9739 | 89.69 |
| 3 | 3000 | 500 | 10 | 0.046 | 0.9732 | 92.72 |

**Table 10: GC Ever X**

| Sr. No. | No. of Cycles | Load (gm) | Ball Dia. (mm) | Expt. Value | Minitab Value | Variation (%) |
|---|---|---|---|---|---|---|
| 1 | 5000 | 1000 | 6 | 0.035 | 0.04550 | 1.05 |
| 2 | 4000 | 750 | 8 | 0.080 | 0.0457 | 3.43 |
| 3 | 3000 | 500 | 10 | 0.050 | 0.04050 | 0.95 |

**Table 11: Filtek Z250**

| Sr. No. | No. of Cycles | Load (gm) | Ball Dia. (mm) | Expt. Value | Minitab Value | Variation (%) |
|---|---|---|---|---|---|---|
| 1 | 5000 | 1000 | 6 | 0.69 | 0.5270 | 16.3 |
| 2 | 4000 | 750 | 8 | 0.638 | 0.5265 | 11.15 |
| 3 | 3000 | 500 | 10 | 0.041 | 0.5241 | 48.31 |

**Table 12: Charisma Diamond**

| Sr. No. | No. of Cycles | Load (gm) | Ball Dia. (mm) | Expt. Value | Minitab Value | Variation (%) |
|---|---|---|---|---|---|---|
| 1 | 5000 | 1000 | 6 | 0.065 | 0.07340 | 0.84 |
| 2 | 4000 | 750 | 8 | 0.0783 | 0.07310 | 0.52 |
| 3 | 3000 | 500 | 10 | 0.051 | 0.07130 | 2.03 |

The variations in the readings may arise due to the factors which are not considered during experimentation like mechanical vibrations of testing machines.

### Application of study in dental science

a. The study would be helpful in determining the exact amount of load that a dental composite can sustain before failure.
b. The longevity and durability are known which can be used for the dentists in selection of composites.

### Influence of each parameter on wear rate

- Based upon the values of load taken for the study, it is desirable to consume softer food materials which require less biting force.
- The contact area of each type of tooth is different and this variation influences the wear rate of tooth. The harder food material is usually cracked by molar or canines. Thus the chances of failure of dental material are more on these areas.
- The repetitive and cyclic chewing actions may cause fatigue in the dental materials. Thus this type of loading is undesirable as the dental material is likely to fail with such types of food materials which require cyclic load.

### Discussion

In this research work, the no. of cycles shows the durability of the composites. The no. of cycles is the function of the chewing and biting action by a human. The more are the no. of cycles, the longer a composite work properly.

The varying load in the research work is the significance of the variable force a human tooth tolerates while chewing and biting. The chewing force is more for the harder food materials and less for the softer food materials. The composite must withstand both kinds of forces. Also the chewing force changes with person to person. It also changes with the age group. The other factors which affect the chewing force are physique of the person the chewing habits, the type of food he chews, environmental conditions where he lives etc.

The varying ball diameter is a significance of the varying area of the different teeth within a jaw. The molar teeth have larger cutting radius than the canines and incisors. This geometry of teeth will affect the amount of force that is going to be act on a tooth.

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