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ORIGINAL ARTICLE

A Comparative Evaluation of Wear of Enamel Caused by Ceramics with Different Fusion Temperatures

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Abstract Dental ceramics are the most used esthetic fixed Prosthodontic restorative material today. However, dentists remain suspicious about their potential abrasivity. Lower-fusing ceramic materials developed, are claimed to be wear friendly. This study was conducted to compare the wear of enamel of extracted teeth against one conventionally used ceramic VMK-95 (fusing temperature 930 °C) and two new lower-fusing ceramics-Omega 900 and Finesse with fusing temperatures 900 and 760 °C respectively, used for metal–ceramic restorations. Metal disks were prepared from ceramic alloy and divided into three groups of 10 disks each on which VMK-95, Omega 900 and Finesse ceramics were applied respectively. Ceramic disks and tooth specimen were mounted on custom-made wear simulator and subjected to predefined masticatory test. Each tooth specimen was profiled by laser triangulation sensor before and after masticatory test. Difference in height was calculated. The results showed that mean loss of height of tooth was least against Finesse (0.3431 + 0.0177 mm) followed by Omega 900 (0.4076 + 0.0135 mm) and VMK-95 (0.6177 + 0.014 mm). Statistical analysis revealed statistically significant difference between VMK-95 & Omega 900 and VMK-95 & Finesse. The difference in loss of height of tooth against Finesse & Omega 900 is statistically insignificant ($P < 0.001$). The results of this study indicate that lower-fusing dental ceramics cause less wear of opposing enamel.

Keywords Wear · Fusion temperature · Wear simulator · Profilometry · Laser triangulation sensor

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Introduction

The wear of dental hard tissue is a natural and unavoidable process. Wear is a progressive phenomenon in oral cavity characterized by loss of the original anatomical form. This process may result from physiological or pathological conditions. Excessive wear results in unacceptable damage to the occluding surfaces and alteration of the functional path of masticatory movement. It may also destroy anterior tooth structure that is essential to acceptable anterior guidance function or esthetics, resulting in increased horizontal stresses on the masticatory system and associated temporomandibular joint disorders [1, 2].

The wear of tooth structure caused by opposing restorative material is often a critical concern when selecting a restorative material for any given clinical restorative treatment. Ideally, a restorative material that replaces enamel should have wear characteristics similar to enamel. According to Seghi et al. [3] such a material should wear at the same rate as enamel and should not cause more wear of the enamel it opposes than enamel itself would. The proper selection of restorative materials is important to preserve function, esthetics and occlusal harmony.

Gold alloys are considered the most ideal restorative material because they are the most similar to enamel in function and wear characteristics. They are wear resistant and cause minimal wear of opposing enamel. However, their esthetic limitations cause them to be overlooked in favor of more natural appearing alternatives i.e. the dental ceramics.

Dental ceramic technology is one of the fastest growing areas of dental materials research and development. They have been used for many years, and in many forms as the esthetic alternative to gold alloy [4–6]. However, dentists remain suspicious about its potential abrasivity. The severity of this problem is stated by Wiley as "Group function in porcelain can elicit group destruction" [7]. This shortcoming has made dental ceramics a subject of criticism. Dental research in ceramics addressed response regarding wear problem. This concern has directly influenced the development of ceramic materials and laboratory processing systems. Ceramics are developed with lower fusing temperatures which are claimed to cause less wear of opposing natural dentitions than conventional porcelains [2, 4, 8].

The potential advantages of lower-fusing ceramics are the reduction in sintering times, decrease in sag deformation of FPD frameworks, less thermal degradation of ceramic firing ovens, and less wear of opposing enamel surfaces [2, 4, 9, 10].

The hypothesis that lower-fusing ceramics cause less wear of opposing enamel is explored by various researchers with mixed results [11–15]. This in vitro study was conducted to evaluate and compare the wear of enamel of extracted teeth against ceramics with different fusing temperatures; VMK-95 (fusing temperature 930 °C), Omega 900 (fusing temperature 900 °C) and Finesse (fusing temperature 760 °C).

Materials and Method

Ceramics used in this study were veneering ceramics used in porcelain fused to metal restorations. They were

1. VMK-95 Metallkeramik (Vita Zahnfabrik, Germany) with fusing temperature 930 °C.
2. Vita Omega 900 Metallkeramik (Vita Zahnfabrik, Germany) with fusing temperature 900 °C.
3. Finesse (Ceramco, USA) with fusing temperature 760 °C.

Preparation of Enamel and Ceramic Specimens

Tooth Specimens used were prepared from thirty maxillary first premolars with normal anatomy, extracted for Orthodontic purpose; by sectioning them mesiodistally and isolating the buccal cusps (Fig. 1). These teeth were stored in deionized water. Teeth were mounted on prefabricated acrylic mounting pieces with the help of auto polymerizing acrylic resin and randomly divided into three groups with ten specimens in each, for masticatory test against VMK-95, Omega 900 & Finesse veneering ceramics respectively.

For preparing ceramic specimens (Fig. 2); thirty metal disks of 1.4 cm diameter and one baseplate wax thickness were prepared from ceramic alloy, by conventional procedure of sprueing, investing, casting, divesting and finishing as per manufacturer's recommendations. Disks were divided into three groups of 10 disks each for applying VMK-95, Omega 900 and Finesse ceramics respectively. Metal disks were subjected to oxidation firing. Subsequently wash opaque, opaque and dentine layers were applied and fired according to firing chart as recommended by manufacturer [16–18]. The surfaces of ceramic disks so formed were ground flat and finished using sintered diamond points to achieve 1 mm uniform thickness of ceramic layer. The thickness of each specimen was measured with a Vernier Calipers at five different points to give a uniform thickness of 1 mm of ceramic layer. All samples of VMK-95, Omega 900 were glazed with Akz25 glaze and all samples of Finesse were glazed with Finesse glaze. Glazed samples were mounted on prefabricated acrylic mounting pieces (Fig. 2b).

Masticatory Test

Masticatory movements and forces were simulated in a custom made wear simulator (Figs. 3, 4). Wear Simulator consisted of an iron base and frame on which all parts were secured. The machine was driven by an 180 W, 0.25 HP electric motor with the speed of 1,425 rpm. The motor powered a reduction gearbox that moved a series of interchangeable cams and dimmer stat which reduced the speed to 30 rpm. An eccentric wheel was attached to this, which converted the circular motion to linear reciprocating motion. One rotation of machine was equivalent to two strokes i.e. the speed was 60 strokes/min. The reciprocating shaft was confined in an iron box, which contained a housing to mount the lower members. The shaft contained the housing for the upper member. The box had a drain cock to remove water. Reciprocating shaft can move a distance of 8 mm. It was designed to support weights for applying loads to the specimen. A presettable electric counter with digital display was attached to the resultant drive of the gearbox to note the number of strokes.

The ceramic disks were positioned as the lower member of the system. Tooth specimen represented the upper member of the system (Fig. 5). Each experimental pair (ceramic disks and tooth specimen) were subjected to 10,500 defined masticatory cycles (reciprocating strokes) at the rate of 1 stroke/s. The masticatory parameters included an occlusal force of 4 kg, stroke length of 8 mm and specimens were placed submerged in deionized water at 37 °C temperature. All thirty experimental pairs were subjected to same masticatory cycles (Fig. 6).

Fig. 1 Preparation of tooth specimens & mounting

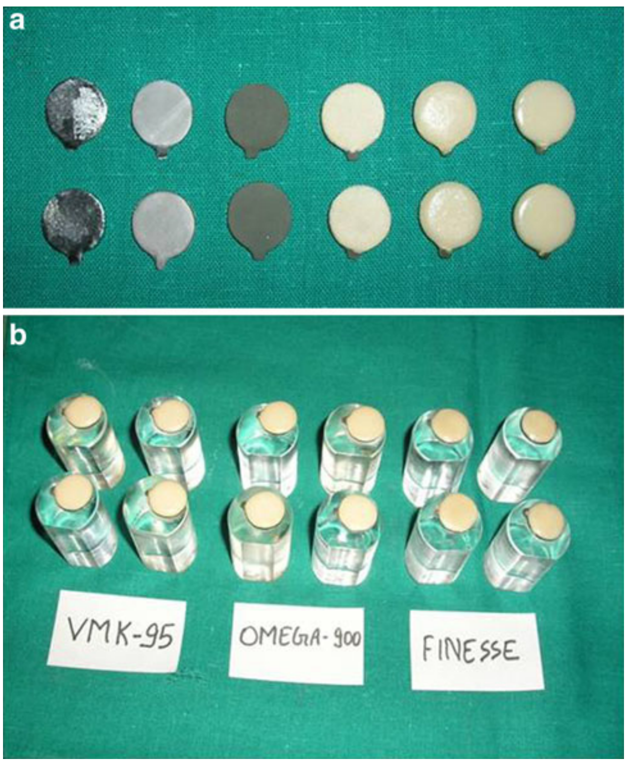

Fig. 2 **a** Preparation of ceramic specimens, **b** ceramic specimens mounted on acrylic blocks

Measurement of Wear by Profiling

Each tooth specimen was profiled before and after the masticatory test to find the difference in height. Profiling Device used in the study consisted of two systems—Laser Triangulation Sensor and Translation Platform [19–21] (Fig. 7). It was designed such that the surface being profiled moves, and not the system which profiles as seen in conventional profilometers.

Laser Triangulation Sensor falls into the general category of non-contact height or range measurement devices. A triangulation sensor may provide the same information as a contact probe, but without touching the object to be measured. The sensor works by projecting a beam of light onto the object of interest and calculating the distance from a reference point by determining where the reflected light falls on a detector. Changes in the target height result in a corresponding change on the detector.

Translation platform is a computer-controlled sliding table capable of moving in two directions (*X*-axis and *Y*-axis). It moves the target at desired intervals when the profile is generated. The complete data i.e. the *X* and *Y* positions along with their corresponding depth is then communicated to the computer where a three dimensional graph is plotted with depth constituting the third axis (*Z*-axis).

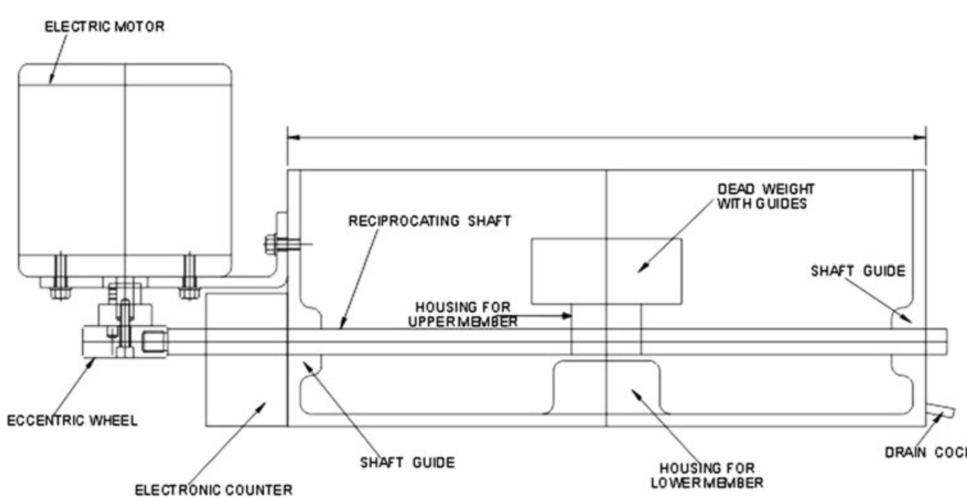

Fig. 3 Line diagram of wear simulator

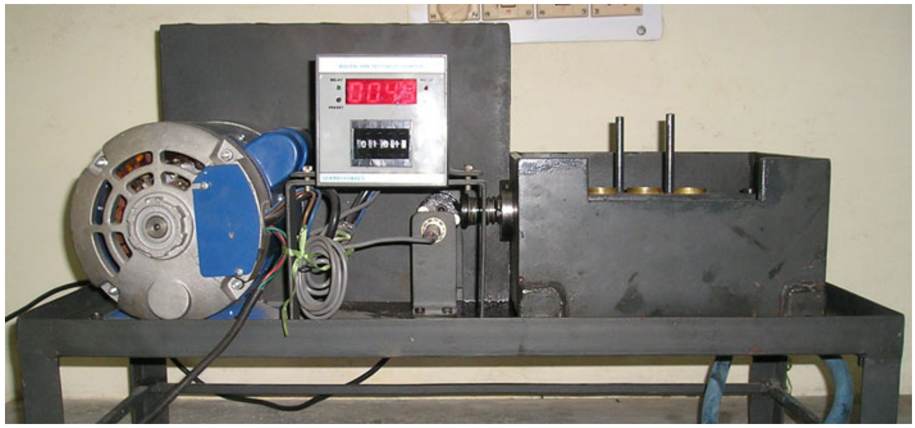

Fig. 4 Wear simulator

Fig. 5 Test specimens mounted on wear simulator-tooth specimen as upper member and ceramic specimen as lower member

Fig. 6 Masticatory test in progress

All thirty tooth specimens were profiled before and after masticatory test (Fig. 8).

Calculation

The three dimensional digital image produced on graph for a tooth specimen before and after masticatory test were compared. The peaks of both graphs are analysed and difference in height was calculated. Loss of height after masticatory test was calculated for all thirty specimens. Statistical analysis of the available data was carried out by calculating mean, standard deviation (SD) and standard error (SE). Student's '*t*' Test was employed to correlate and compare the data in two different sets of samples to find out the significance of difference in their means at 0.1 % level of significance ($P < 0.001$) for loss of height of tooth specimens after masticatory test against VMK-95, Omega 900 & Finesse veneering ceramics.

Results

The mean value of loss of height of tooth after masticatory test against Vita VMK-95 ceramic was 0.6177 mm with SE ± 0.014; Omega 900 ceramic was 0.4076 mm with SE ± 0.0135; Finesse ceramic was 0.3431 mm with SE ±0.0177. (Table 1).

The value of 't' in *t* test of difference of means for loss of height of tooth against Vita VMK-95 & Omega 900 was 11.34, significant at 0.1 % level of significance ($P < 0.001$); Vita VMK-95 & Finesse was 12.80, significant at 0.1 % level of significance ($P < 0.001$); Finesse & Omega 900 was 3.05, insignificant at 0.1 % level of significance ($P < 0.001$).

Discussion

Wear may be defined as the loss of matter characterized by the loss of anatomical form. There are various reasons as to why wear occurs in the oral cavity, such as functional

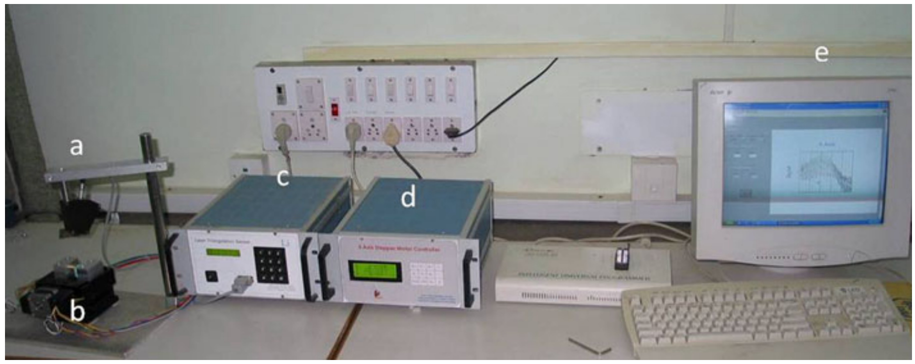

Fig. 7 Profiling device **a** laser triangulation sensor, **b** translation platform, **c** electronic processor for laser triangulation sensor, **d** motor controller for translation platform, and **e** computer showing 3D image of tooth specimen

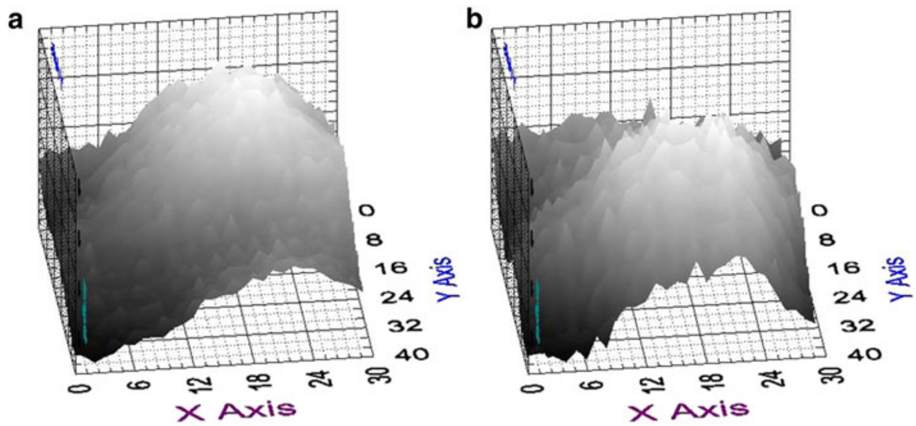

Fig. 8 Three dimensional image of tooth specimen **a** before, and **b** after masticatory test

Table 1 Showing loss of height of tooth specimens after masticatory test against VMK-95, Omega 900 and Finesse

Specimen no.	Loss of height (mm) against VMK-95	Loss of height (mm) against Omega 900	Loss of height (mm) against Finesse
1	0.622	0.426	0.329
2	0.595	0.382	0.316
3	0.675	0.448	0.263
4	0.585	0.437	0.354
5	0.628	0.433	0.376
6	0.699	0.382	0.369
7	0.571	0.352	0.419
8	0.629	0.434	0.271
9	0.587	0.411	0.322
10	0.586	0.371	0.412
Mean Value (±SE)	0.6177 ± 0.014	0.4076 ± 0.0135	0.3431 ± 0.0177

contact with abrasive foods, socio-professional habits, tooth-brushing or abnormal contacts depending on functional disorders. The wear of enamel and of restorative material is often a critical concern when selecting a restorative material for any given clinical restorative treatment.

There has been an increase in the use of ceramic restorative material in dentistry because patients want dental restorations that simulate the appearance of their natural teeth. Although ceramic restorations provide acceptable esthetics but the clinical loss of enamel opposing conventional dental ceramics has been a matter of serious concern [22]. Both in vitro and in vivo studies, regardless of the simplicity or complexity of machinery or measurement method have consistently demonstrated the destructive behavior of ceramics on enamel [8, 15, 22–24]. Professional and public demands have prompted the development of new esthetic restorative materials. Several lower-fusing ceramics were subsequently introduced with claims of being less abrasive to opposing natural dentitions than conventional porcelains [2, 4, 8].

Lower-fusing ceramic materials developed, are claimed to be wear friendly because of their lower hardness, lower concentration of crystal phase and smaller crystal sizes.

The hypothesis that lower-fusing ceramics cause less wear of opposing enamel is explored by various researchers with mixed results. Mezler et al. [11] and Imai et al. [12] found that lower-fusing porcelains can result in significantly less wear than conventional porcelain. Clellant et al. [13] and Al-Hiyasat et al. [15] were unable to find statistically significant difference between a lower-fusing porcelain and conventional porcelain. Magne et al. [14] found that a lower-fusing porcelain resulted in significantly greater enamel wear than a conventional porcelain.

Further, in vivo measurement and comparison of wear is difficult due to relative variation in forces of mastication, eating habits, parafunctional habits, etc. from person to person. Thus, this study was taken up to investigate in vitro wear of human enamel against ceramics with different fusing temperatures; using a custom made wear machine.

A wear machine was developed in an attempt to simulate the wear process that occurs in the mouth. The masticatory parameters included an occlusal force of 4 kg, stroke length of 8 mm at the rate of 1 stroke/s and total number of 10,500 strokes. The load, stroke length and the speed chosen in the study lied in the normal range of masticatory load and speed [8, 22, 24–27].

Wear assessment has been made in various studies by measuring loss of height, loss of weight, wear track depth, loss of volume etc. In the present study wear of enamel is measured as loss of height. Loss of height is clinically relevant with regard to the vertical dimension of occlusion. Loss of height was measured by three-dimensional laser profilometry.

Loss of height of tooth was least against Finesse followed by Omega 900 & VMK-95 in increasing order respectively. There is statistically significant difference between the loss of height of tooth after masticatory test against VMK-95 & Omega 900; and VMK-95 & Finesse. The difference in loss of height of tooth against Finesse & Omega 900 is statistically insignificant.

The results of this in vitro study indicate that lower-fusing dental ceramics cause less wear of opposing enamel than conventional low-fusing dental ceramics. This result is consistent with the study of Metzler et al. [11] and Imai et al. [12] who found lower-fusing Finesse porcelain to be less abrasive to enamel than conventional low-fusing Ceramco II. They also found that Finesse was not statistically less abrasive than Omega 900. In our study there is statistically insignificant difference in loss of height of enamel against Omega 900 and Finesse. This result is consistent with findings of Magne et al. [14]. Another study in support of our result revealed that surface roughness of Finesse & Omega 900 were lower than the other ceramics tested in the study and Finesse had the lowest value of hardness among them [28].

The difference in abrasive behavior of lower-fusing ceramics may lie with the difference in composition and microstructure. They have decreased leucite content, lower concentration of crystal phase, smaller crystal size, and homogenous dense structure. The finer grain size of the lower-fusing porcelains, coupled with a decrease in crystalline phases, makes these porcelains more amenable to chairside polishing. These factors make lower-fusing ceramics kinder to enamel [2, 4, 9–11].

The limitation of this study is that it does not correlate completely with clinical wear. The weakness of this correlation lies in that, clinically a wide range of forces have been measured and there is uncertainty of in vivo contact time. In addition, the amount and duration of load on the teeth during functional and parafunctional are varied. Within the in vitro limitations of this study the testing method was repeatable.

Conclusion

The results of this study indicate that dental ceramics with lower fusion temperatures cause less wear of opposing enamel. Further studies are indicated to investigate properties of lower-fusing ceramics, effects of lower-fusion temperature on bond strengths, metal distortion, solubility, strength, and esthetics.

The development of wear machines is an attempt to simulate the clinical masticatory cycle and oral environment, but complete simulation by a machine is difficult to achieve. Thus, this fact should always be considered in both interpretation of results and any conclusions drawn from in vitro studies. Nevertheless, these in vitro studies may help to understand the wear mechanism of restorative materials and help to rank restorative materials and enable comparisons with new materials in a shorter testing time.

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