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EFFECT OF PORCELAIN TEETH ON NATURAL TEETH

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ABSTRACT
Tooth wear is a process that is usually a result of tooth to tooth and/or tooth and restoration contact. The process of wear essentially becomes accelerated by the introduction of restorations inside the oral cavity, especially in case of opposing ceramic restorations. The newest materials have vastly contributed toward the interest in esthetic dental restorations and have been extensively studied in laboratories. However, despite the recent technological advancements, there has not been a valid *in vivo* method of evaluation involving clinical wear caused due to ceramics upon restored teeth and natural dentition. The aim of this paper is to review the latest advancements in all-ceramic materials, and their effect on the wear of opposing dentition.

KEYWORDS: All-ceramic materials, all-ceramic restorations, surface roughness, tooth wear.

INTRODUCTION
Wear of tooth structure is a natural unavoidable process which occurs when tooth and tooth, or tooth and restoration are in contact and slide against each other. However, this natural process may be accelerated by the introduction of restorations whose properties of wear differ from those of the tooth structure that they slide against. It has been shown that enamel may be subject to accelerated wear when opposed by ceramic.[1]

Therefore and despite the truth that a constant wear of the entire dentition is possible independent of dental restorations,[2] it is desirable that wear behavior of restorative materials is similar to natural enamel, because excessive wear could lead to clinical problems such as damage of teeth occluding surfaces, loss of vertical dimension of occlusion, poor masticatory function associated with temporomandibular joint remodeling, dentine hypersinsivity or death of the tooth and at least may lead to esthetic impairment.[3,4,5]

In the oral cavity, many factors contribute to the wear of enamel and dentin, such as the nature of the occlusal contacts with antagonist teeth (attrition), chewing of food items, tooth brushing with toothpaste, inhalation of dust (abrasion), acidic attack due to the consumption of certain fruits and beverages, inhalation of industrial acids or vomiting and regurgitation of gastric juice as in the case of bulimia and anorexia nervosa (corrosion).[6]

In order to observe and assess wear, it is necessary to understand tooth wear mechanisms and how it can be measured and evaluated, both clinically and in the laboratory. The terms abrasion, attrition and even corrosion were often used to identify the same thing which is the tooth wear caused mostly by alimentation and utilities use. Contrary, nowadays there is an agreement that the terms, abrasion, attrition and corrosion describe different mechanisms.

Attrition: tooth-to-tooth contact causes this form of wear, this occurs without the presence of food or foreign substances during deglutition and clenching; it is typically characterized by the facets on a tooth and the opposing tooth. It becomes more serious during bruxism.[7]

Abrasion: is the wear caused by friction between a tooth and an exogenous agent. The ‘masticatory abrasion', usually occurs by friction from the food and abrasion, which is a result of bad oral habits such as nail biting or hard objects such as pens, pencils or pipes, opening hair pins with teeth. Occupational abrasion may occur among hairdressers because of opening hair pins with their teeth, tailors through cutting thread with their teeth, shoemakers who hold nails between their teeth and musicians who play wind instruments.

Tooth-cleaning, habits such as extreme tooth brushing, improper use of dental floss and toothpicks are the most common cause of abrasion. Even normal tooth-cleaning practices produce some abrasion of dentine over a lifetime. In Western populations, the major abrasive agent is toothpaste, which affects dentine much more than enamel.[8] Tooth brushing without paste has no effect on enamel and clinically negligible effects on dentine.[9]

Corrosion: Is the loss of tooth surfaces caused by chemical dissolution without the involvement of plaque. Depending on the source of the acids causing the dissolution, there are two types of corrosion, intrinsic and extrinsic corrosion.[10,11] The tooth corrosion caused by intrinsic sources such as bulimia and gastro esophageal reflux disease, shows enamel surfaces which appears to be translucent and thin; moreover bowel-shaped defects on the posterior occlusal surfaces and an enamel lost on the anterior palatal surfaces can be recognized. It has been reported that consuming drinks and food with a pH value of less than 5.5 can cause corrosion and demineralize teeth. Corrosive damage to anterior teeth may affect workers in industries where they are continuously exposed to acid droplets and fumes. Softened enamel exposed to saliva for an adequate time can regain mineral and thus re-acquire mechanical strength. On the other hand, it has been stated that fluoridated toothpaste had a protective effect on enamel corrosion progression.

THE RECENT ADVANCEMENTS IN CERAMICS

All-ceramic materials have superior esthetic qualities, and their appearance is very similar to natural dentition. Their brittleness is a major drawback as they tend to fracture in conditions where there are high tensile stresses. Advancements have been made to re-enforce these materials with crystalline materials. The complete classification ceramics used in dentistry are outlined in. A brief description of these materials is described below.

SINTERED CERAMICS

Sintering is a process in which heat at very high temperatures is used to cause consolidation of the ceramic particles. Sintering causes a decrease in surface porosity and the bulk of ceramic during production, and the amount of porosities is directly influenced by the sintering time and temperature. Porosities on the surface cause an increase in surface roughness of a ceramics and could lead to increase wear of opposing dentition.

Porcelain can also be reinforced using alumina and magnesia, it can be re-enforced into dental ceramics by a mechanism termed as "dispersion strengthening. Zirconia can be re-enforced into conventional feldspathic porcelain to achieve highest levels of strength. This mechanism of incorporating zirconia is termed as "transformation toughening. Zirconia stabilized with yttria has high fracture toughness, strength, and thermal shock resistance. It has decreased translucency and low fusion temperature. Majority of zirconia re-enforced ceramics are radio-opaque, and copings are required to be veneered for better esthetic outcomes.

GLASS CERAMICS

Restorations using glass ceramic materials are produced in a noncrystalline state which is converted into a crystalline phase by the process termed as devitrification. Fabrication of restorations using glass ceramics involves the use of wax patterns made using the phosphate-bonded investment material. The burn-out process is done, and a centrifugal machine is used to cast the molten ceramic into the pattern at 1380°C. After the sprue is removed, glass is invested yet again and heated at 1075°C for a period of 6 h which leads to crystallization of glass to form "tetra-silicic fluoromica crystals." The procedure of crystal growth and nucleation is termed as ceramming. These crystals lead to increase in strength, abrasion resistance, fracture toughness, and chemical durability of the material.

PRESSABLE CERAMICS

These ceramics involve the process of production at elevated temperatures in which sintering of the ceramic body occurs. The technique of fabrication prevents the formation of porosities and secondary crystallization which results in a restoration with superior mechanical properties.

Until recently, Ivoclar Vivadent developed two more ceramics named as IPS e.max-Press and IPS e.max. IPS e.max-Press is processed in the laboratory with pressing equipment which provides very high accuracy of the restoration fit. The microstructure of this material can be distinguished as needle-like disilicate crystals which are embedded into a glass matrix. The flexure strength of IPS e.max-Press is more as compared to IPS Empress.

Machined ceramics

The development of computer-aided design and computer-aided machining method for the fabrication of inlays, onlays, crowns, and bridges has lead us to the development of next generation of machinable ceramic material. The crowns fabricated using these systems can be delivered to the patient in a single appointment since these are made chair-side. There several drawbacks which include the expense of the equipment used, and also the process requires a high level of expertise. If a zirconia coping is to be used, the color difference between the core of zirconia and adjacent tooth must be matched using a specific layering technique for the veneering ceramic, and appropriate shade selection technique should be practiced.

Measuring methods (wear quantification)

One of the most popular measuring methods of tooth wear is the direct measuring using clinical tooth wear indices with this method, special equipment is not required, but the assessment is subjective and it takes a long time to get significant results. In addition, most tooth wear indices use unclear and complicated diagnostic criteria. Other limitations of these indices are no clear classification and quantification of tooth wear, besides the limited ability to determine the critical value of acceptable wear. Also, there are a lot of tooth wear index which make it difficult to achieve standardized and reliable tooth wear quantification and that leads to difficulties by comparing the results of various studies.

Indirect techniques for evaluation of tooth wear suggest measuring the loss of tooth surface using cast replicas. For more accurate quantification, image analysis, scanning electron microscopy, computer graphics, three dimensional (3D) scanner and profilometry were developed. Disadvantages can be inaccurate replicas and repositioning problems, due to the fact that reproducing of tooth surfaces with impressions before scanning always adds a source of error.

Various clinical studies applied these 3D measuring techniques, which allow 3D scanning of the entire tooth surface without affecting the tooth surfaces. These techniques are highly accurate, quantitative, applicable to both the clinic and the laboratory, and provides storable 3D databases that enable comparison to other 3D databases.

3D images can be obtained using contact profilers, non-contact white light, micro/cone computerized tomography (CT) scanners, laser scanners and computer-aided design/computer-aided manufacturing (CAD/CAM) systems such as Cerec and Cercon systems. However, 3D canning requires a specialized hardware and software and has the disadvantage of time-consuming, high cost and the limited availability to clinical investigators.[24,43] Measurement accuracy of the cone-beam CT scanners approximates few hundred microns, and thus they have limited ability to determine tooth wear on the occlusal surfaces.

Direct intraoral 3D scanning of teeth, e.g., intraoral digital camera of Cerec, is accurate and requires less number of steps when compared to the indirect scanning of models, but the need for spraying teeth with white powder might decrease the accuracy of measurement.

Clinical studies which evaluate dental wear are very time-consuming, expensive and have the disadvantage that a lot of factors such as chewing forces cannot be controlled. Thus, laboratory mastication simulation has been used by a lot of investigators to study single parameters of the wear processes. But even the *in vitro* wear simulations show considerable variability and do not simulate the clinical condition, because the loads, speeds and abrasives used are often more severe than the masticatory standards.

CERAMIC CROWNS OPPOSING TOOTH STRUCTURE

As mentioned before, wear of teeth differs according to the different restorative materials used as antagonist. Ceramic reconstructions have become increasingly popular as a result of rising patient demands for more aesthetics. But the main disadvantage of ceramics is their high abrasiveness to opposing enamel. Various types of ceramic crowns can be used as fixed dental prosthesis; some entirely made of the same ceramic material through out and others consist of high-strength ceramic substructure veneered with porcelain; in addition metal-ceramic crowns veneered with porcelain are still used. Recently, the high-strength zirconia ceramic (yttrium-oxide tetragonal zirconia polycrystal) was introduced for dental application; it has a high bending strength and fracture toughness. The clinical use of this ceramic is increasing because of its chemical and dimensional stability, its higher fracture toughness, hardness and frictional resistance in comparison to conventional dental porc whereas other all-ceramic restorations show a percentage of framework fracture.

Using CAD/CAM techniques, it has become possible to produce full-zirconia restorations with occlusal design that do not need to be veneered (Zirluna; ACF GmbH, Amberg, Germany; Zirkonzahn Prettau; Zirkonzahn GmbH, Bruneck, Italy; BruxiZir; Glidewell Laboratories, Newport Beach, CA, USA); and must have the advantage that no chipping of the veneering porcelain will occur because of the absence of this veneering layer. Mono-block restorations could be also fabricated from glass ceramics; however, they are less stable in comparison to zirconia-based restorations and their indication range is clearly limited to single crowns and small fixed dental prostheses.

FACTORS AFFECTING ENAMEL WEAR WHEN OPPOSED BY CERAMIC

At this point of research, some of the features of ceramic which affect enamel wear were evaluated:

Hardness of ceramics was always associated with the greater abrasiveness against teeth, but some studies showed that the hardness of ceramics will not substantially lead to wear of the opposing teeth. On the other hand, the degree of wear is more affected by the surface structure and the roughness of the restoration or environmental factors. Various *in vitro* investigations on the effect of ceramic hardness on the dental wear have supported this fact by their finding that soft ceramics caused more abrasion against enamel (enamel abrasion) in comparison with harder ceramics.

Similarly, more wear was expected from zirconia, because zirconia has strong surface hardness, but certain investigations reported that less wear of antagonistic teeth was measured with zirconia than with the feldspathic dental porcelain. Rosentritt has no wear traces for enamel against zirconia using a chewing simulation. It was also reported that the wear rate of zirconia is bad in water and even under dry sliding conditions, that suggests that the hardness of ceramics alone is not a reliable predictor of the wear of opposing teeth.

Resistance to friction: Many factors may affect the frictional resistance of the both teeth and ceramic restorations when coming together in contact, e.g., morphology, properties and structure of tooth and restoration, as well as mastication movements. With increased coefficient of friction, more wear of the tooth structure would be expected. It has been shown that high loads, rough surfaces and high sliding speed caused an increase in the coefficient of friction which leads to greater wear. Therefore, meticulously polished ceramic surfaces would lead to an decrease in the rates of wear of the opposing tooth surfaces.

Porosity: Undesirable characteristic of ceramic like decreased strength, reduced aesthetics and increased plaque accumulation can be impart by porosity. Furthermore, during the wear process, a subsurface porosity of ceramic may be exposed, then the sharp edge of the defect will cause increased wear in the opposing teeth; therefore, porosity of dental porcelain needs to be minimized.

Some parameters are associated with increased porosity of dental ceramics such as particle size, higher sintering temperature and longer sintering time. More porosity was showed in low-fusing porcelains with a fine grain size than in conventional feldspathic porcelain. It was also reported that aluminous porcelain has a higher viscosity than conventional feldspathic porcelain, which requires a higher firing temperature to increase the wetting of crystals and the glassy matrix[73] and because of that, a higher porosity of aluminus porcelain is expected. Although a reduction of porosity is expected by longer sintering time, Piddock and Cheung reported an increase in porosity with increasing sintering time, because of the limited ability of air to escape during rapid firing. During the building of porcelain layers in order to simulate the teeth tissues, the influence of mechanical vibration on the reduction of porosity is limited.

Full-zirconia restorations without veneering are free from the problems associated with porosity, because they have no veneer layer and their microstructure shows no open porosity.

EFFECT OF ROUGHNESS OF CERAMIC SURFACES

The surface treatment of all ceramic crowns may be responsible for the changing in the rate of enamel wear. Glazing of ceramic restorations produces a smooth, aesthetic and hygienic surface and is considered as a step which reduces the amount of wear of opposing teeth and restorations, but this layer of glaze can be removed shortly after being in function or by a required occlusal adjustment that may lead to more abrasive wear of the opposing teeth because of the insufficiently polished exposed surface of the crown.

Jagger suggested in his study that the amounts of wear of enamel caused by glazed and unglazed porcelain are similar. Some investigators found that the glazed ceramic surfaces are smoother than the polished ones. However, other authors found no significant differences between glazed and polished ceramic surfaces. Contradictorily, some investigations confirmed the finding that the smoothness of polished ceramic surfaces is similar or better than the glazed surfaces. This conclusion was supported through various *in vitro* studies, which found that the glazed surfaces caused more teeth wear compared to polished surfaces. Functional finishing of ceramic surfaces during the wear process was documented by Monasky, who reported in his *in vitro* study that the initially high rate of wear decreased over time, suggesting that the effect of surface roughness on wear may be self-limiting. depending on wear or chewing simulation device and these results are contradictory.

DISCUSSION

This review was performed to evaluate available information in the dental literature on tooth wear against ceramic crowns in posterior region both *in vitro* and *in vivo*. The first idea was to see whether there were any clinical prospective studies supporting the findings of *in vitro* studies that showed how wear friendly the ceramic materials are. Surprisingly, we observed that there are no *in vitro* studies measured tooth wear against ceramic crowns in posterior region. Further intensive search yielded no *in vitro* investigation focusing on the evaluation of the effect of anatomical occlusal surfaces on tooth wear process. Available *in vitro* investigations mostly measured tooth wear against flat-shaped ceramic specimens[33,36,46,65] and that made a comparison of *in vitro* results with those of *in vivo* trials impossible. Therefore and based on the available literature, we decided to present an overview of the current thinking on the relationship of clinical tooth wear and the ceramic crowns in posterior region.

Only five *in vivo* studies dealt with establishing a causal relationship between insertion of ceramic crowns and increased tooth wear in posterior region. Detailed full-text analysis of these five studies revealed that in three of them (Silva 2011, Esquivel-Upshaw 2012, Esquivel-Upshaw 2013), the authors made the same investigation and evaluated the same patient population. Due to that, we had to consider the results of these three studies as results of one investigation and to compare it with the other two studies of Etman 2008, Suputtamongkol 2008.

To measure the amount of worn dental tissues after cementing the crowns, impressions were made of each of the maxillary and mandibular arches at 1 week (baseline) and after 6 months,[22,88,89,90] 1 year,[22,25,88,89,90] 2 years[22,88,89,90] and 3 years.[88,89,90] Resulting gypsum casts were produced by a dental technician with type IV gypsum (GC Fujirock, Leuven, Belgium) and scanned using the same 3D laser scanner (es1 Scanner; Etkon, Gräfelfing, Germany).[25,88,89,90] In one study,[22] the quantitative measurement of wear was performed by digitizing the impressions of the restored teeth and their antagonist using a non-contacting laser profilometer (Keyence LC-2400 series laser displacement meter). The use of different methods in obtaining wear data may account for such a broad range (Table 3) between the results of this study[22] and the results of the other studies.[25,88,89,90]

Etman 2008 reported in his investigation that the metal-crowns produced the least tooth wear and the Procera AllCeram veneered with feldspathic porcelain (Ducera) was the most abrasive ceramic which caused more tooth wear than the metal-ceramic (Simidur alloy veneered with IPS Classic) and the other experimental glass-ceramic (IPS Empress/lost wax technique); it also suffered the greatest loss of test material. Contrary Silva 2011 results showed that the metal-ceramic crowns (Argendent alloy veneered with IPS.d.SIGN) caused the highest tooth wear volume compared to the other tested all-ceramic crowns (IPS Empress 2 veneered IPS Eris and the other all-ceramic system IPS e.max Press without veneering). The natural teeth opposing these crowns exhibited at year 3 wear as follows: (1.10±0.10) mm^3 for metal-ceramic crowns/IPS d.SIGN; (1.02±0.20) mm^3 for IPS Eris for E2 and (0.80±0.09) mm^3 for IPS e.max Press. We can recognize that crowns made using the system IPS. e.max Press were the most wear friendly after 3 years.

The use of two different measuring methods in these two studies (Etman 2008 and Silva 2011) may explain these two different statements. Moreover, the results by Etman 2008 were obtained after 2 years and by Saliva 2011 after 3 years. And at least we must mention that the veneering ceramics used were different and each investigator compared metal-ceramic crowns with different all-ceramic systems.

Volume of tooth wear measured by Suputtamongkol 2008[25] against lithiadiasilicate-based all ceramic crowns and after 1 year, was less than that measured by Silva 2011[88] against lithiadisilicate all-ceramic crowns after three years (Table 3). This comparison may lead to the conclusion that tooth wear increased with time.

This article addressed some of the material factors related to the wear of opposing enamel by ceramic. It can be concluded that hardness of ceramics should not be blamed for the accelerated loss of enamel as various studies have demonstrated that there is no strong correlation between the ceramic hardness and the wear rate of human enamel;[61,62] however, it was confirmed that wear process would be more affected by ceramic microstructure and ceramic roughness and therefore, surface treatment of ceramics played a significant role on wear of opposing tooth structure.[36,46,48] Etman 2008 confirmed that in his clinical trial, low-fusing porcelain used to veneer Procera AllCeram copings caused the highest tooth wear. Various *in vitro* investigations on the effect of ceramic hardness on the dental wear have supported this fact by their finding that soft ceramics caused more abrasion against enamel in comparison with harder.[36,48]

Roughened and pitted surfaces of the feldspathic porcelain were detected by clinical and by scanning electron microscope examination;[90] as a result, exposure of the crystalline structure happened and thus. will accelerate the rates of tooth wear in the future.

There was no significant relationship between bite force and tooth wear through the first year[25,89] and the second year;[90] however, there was a significant effect of bite force on wear at year 3 when enamel contralateral antagonist was analyzed alone.[90] That confirms the truth that a constant wear of the entire dentition is possible independent of dental restorations.[2]

As clinical recommendations demand perfectly polished surfaces of all ceramic restorations after any occlusal adjustments, the maintenance of a smooth ceramic surface during clinical use is the key for avoiding initiation or progression of microcracks and for minimizing abrasion of the opposing teeth. Nevertheless, it would be difficult to find an answer about the optimal ceramic treatment that is not responsible for accelerated enamel wear. That is because of the inconsistent results of various studies that were performed to identify the best techniques to achieve a smooth ceramic surface. It can be assumed that when enamel is opposed by unglazed and unpolished ceramic surface, the wear rate of enamel is higher than when opposed by glazed or polished one.[36,85]

It can be suggested that dentists should consider the type of ceramic restorative material used. Further, the ceramic restorations should be sufficiently polished after any chairside adjustment of occlusal surface so that it minimizes the undesired effect of roughened ceramic materials on wear of antagonistic tooth. Wear requires the sliding of one surface against the other; therefore, when a ceramic restoration is placed, sliding contact in centric and eccentric movements should be minimized.

The literature reveals that studies on this topic are subject to a substantial amount of bias, such as evaluation bias (use of non-blinded examiners) and confounding bias (no control of other aethiological factors). Up to now, it has been impossible to associate tooth wear with any specific causal agent, and the role of surface treatment of ceramic crowns that may be responsible for the changing in the rate of enamel wear seems as yet undetermined. Therefore, additional studies, properly designed to diminish bias, are warranted.

Based on the applied literature, it can be concluded that for ceramic material, their proper handling and control of the patient's intrinsic risk factors related to wear are all critically important to the reduction of enamel wear by dental ceramics.

CONCLUSION

Technological advancements in dental ceramics are a fast and growing area in dental research and development.

The esthetic appearance of ceramic restorations is attributable to surface texture of the restoration, which is determined by the surface finish. It is very important that clinicians are aware of recent advancements and that they should always consider the type of ceramic restorative materials used to maintain a stable occlusal relation. Further, the ceramic restorations should be adequately finished and polished after chair-side adjustment process of occlusal surfaces. Modifications of ceramic materials are recommended to produce more durable ceramic in terms of wear resistance and to minimize the undesired effects.

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