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ABSTRACT-

Human teeth is the hardest organ in body. It has a very unique anatomic and chemical structure. Tribology deals with lubrication, friction, and wear. To understand the wear behavior of human teeth, it is desirable to evaluate the properties of materials and structures and the structure of tooth as well. Human tooth wear occurs very slowly. Tooth wear is a complex multifactorial phenomenon involving chemical, physical, and mechanical processes. The oral environment plays an extremely important role in the tribological behavior of both human teeth and artificial teeth. Considering the complex interoral environment and biomechanics, the wear processes of artificial dental materials are very complicated . the wear processes commonly include abrasion, attrition, corrosion, fretting wear, and fatigue. These processes occur in various combinations and as a result the surface loss of materials in the mouth occur. Excessive wear may lead to premature failure and leading to the replacement of dental restorations and implants. Although we have made a remarkable progress in the field of dental wear but still it can be said that much work and evaluation remains to be achieved toward a systematic correlation between the tribological behavior and structure of human teeth, a bionic design for engineering wear system, and a clinical treatment against dental wear based upon the concept of tribological design. Inevitably, more and more research directions will eventually show us the path that will lead to better treatment prognosis. So these discussions hopefully would help to through some light and provide more knowledge on what already has been learned from human teeth.

Keywords –implant, restoration, saliva, tribology

BIOTRIBOLOGY

According to Sharov tooth is defined as a open ended vital, innervated, calcified box (dentin and enamel) filled with soft normal tissue (pulp chamber) and coated orally with a relatively non vital hard tissue that is not innervated (enamel).

The term "tribology" was first introduced by Jost Report in the year 1966. Tribology was defined as "the science and technology of interacting surfaces in relative motion and the practices related thereto."

In brief, tribology deals with lubrication, friction, and wear. This include a number of basic disciplines such as mechanics, material science, chemistry, and physics. Tribology focuses on the research involving the unique material of the tooth. Although it seems very simple, but the function and biomechanics of human teeth are relative complicated. From a materials scientist's and engineer's point of view, human teeth are very fascinating. Teeth is the hardest organ in body .the normal survival of teeth is for few decades. However, teeth experience wear, and there are a few mechanisms of how teeth wear under the influence of various local environmental factors. The tribological behaviour of human teeth to various external influences has inspired the scientists to look into the anatomical, chemical and materialistic properties and their influences on tribological behaviour. Ultimately, it will help the scientists to mimic these properties. This will in turn help us provide solutions to achieve ultra-low-wear systems. In addition, a better understanding of the wear mechanisms of teeth will lead the development and use of better materials and systems in restorative dentistry, prosthodontics and even in dental implants.

Human teeth is the hardest organ in body. It has a very unique anatomic and chemical structure. However in order to understand the wear behavior of human teeth, it is desirable to evaluate the properties of materials and structures. To evaluate the these properties multiple quantitative and qualitative methods to measure are there.

Scott was the first scientist to introduce us with an ordinal dental attrition scoring technique involving a quadrant system for human molars. [1]

A few years after Scott's scoring system, Eccles developed a classification system for erosion indicating the severity and site of a lesion on each tooth. [2]

Human tooth wear occurs very slowly. Months or years are required to measure the tooth wear. Teaford and Tylenda proposed that microscopic changes in wear patterns on human teeth detected in a matter of days could be used as indicators of rates of wear. [3]

Millward et al proposed a similar diagnostic criteria to evaluate tooth erosion. [4]

Mastication leads to physiological wear of tooth surface. The result of mastication is surface degradation leading to a progressive, very slow loss of the convexity of tooth cusps. This loss of convexity manifests as a flattening of both cusp tips on the premolars and molars and as well as incisal edges on the anterior teeth as seen in humans. [5,6,7]

Simulation of the oral environment in vitro was attempted many a times previously. However most in vitro studies have been carried out on different test rigs with differing contact geometries, loads, sliding speeds, lubricants, etc. This makes it difficult to compare wear results obtained by different machines. Additionally, an appropriate wear-testing device has not been found. As a result there is a great difficulty in relating in vitro results to in vivo tooth wear.

Human teeth are the involved in mastication in our day to day life . In general, oral biomechanical functions results in tribological behavioural pattern of our teeth [8, 9, 10]

Hence, tooth wear is a cumulative multifactorial process occurs till the entire span of our lives. This mostly is an irreversible process.

In vitro friction and wear tests were performed on different locations of human teeth. This is done in order to explore the effect of frictional forces on the tooth microstructure. The wear process was investigated in detail. Moreover, the effect of age on the tribological behavior of human teeth was also studied. Finally, pathological factors and toothbrushing was reviewed in detail. Based on the given test conditions, the main conclusions can be summarized as follows

1. Microhardness and tribological properties differ remarkably between layers in a permanent tooth. A higher microhardness, lower friction coefficient, and better wear resistance are observed in the enamel zone than in the dentin, which appears both on the occlusal section and on the axial section. Furthermore, friction and wear behaviors of an individual tooth depend strongly on microstructural orientations. A tooth shows better wear resistance along the occlusal section than along the axial section due to the orientation of the enamel rods and the dentinal tubule.

2. The wear of human tooth enamel changes gradually from two-body wear into three-body wear, with plastic delamination occurring on the enamel surface during the wear process. With the number of cycles increasing, the wear rate decreases, and, finally, the wear of enamel stays at a stable stage. Microscopic examinations indicate that enamel wear is controlled by the

mechanical removal of materials without obvious changes in the compositions and crystal structures of the enamel. The enamel rods are worn away after the interrod enamel.

3. The tribological behavior of a human tooth depends strongly upon its age. The friction and wear behaviors of young permanent teeth are similar to those of middle-aged permanent teeth, and the worn surfaces are characterized mainly by slight ploughs and delamination traces, which have a better wear resistance.

However, significant ploughs and massive delamination are dominant for the primary teeth and for permanent teeth of an old age, accompanied by a strong fluctuation in the evolution of the friction coefficient.

1. Tooth wear is generally associated with pathological factors. These include erosion bruxism, and xerostomia, which can result in excessive tooth wear. Normal tooth brushing appears to have no effect on enamel and very little on dentin. It is also noted that the wear of enamel and dentin can be dramatically increased if tooth brushing follows an erosive challenge.

Tooth wear is a complex multifactorial phenomenon involving chemical, physical, and mechanical processes. [11]

The oral environment plays an extremely important role in the tribological behavior of both human teeth and artificial teeth.

Saliva is the most important component of the chemistry of human mouth. All solid substrata as well as mucosa membranes exposed to the oral environment are covered by a layer of absorbed salivary proteins, the acquired pellicle. Formation of acquired pellicle starts within seconds on any solid surface exposed to the oral environment.[12]

The physiological role of saliva in the oral cavity is manifold. An important function of saliva is to form a boundary lubrication system . saliva also serve as a lubricant between hard (enamel) and soft (mucosal) tissues. [13]

This helps to decrease the wear of teeth and reduce the friction of oral mucosa and tongue surfaces to prevent those lesions, and make swallowing easier, which is of crucial importance to maintain functions such as mastication, deglutition, and the faculty of speech. In general, saliva has a pH of 7 (neutral); [14]

However, corrosive agents such as acids can also be introduced into the mouth.

Therefore, another role of saliva is thought to involve both the protection of tooth surfaces against acid attack because it is a buffer to acids produced in plaque and the provision of a matrix for remineralization.[15, 16]

Saliva supplies calcium and phosphate ions to remineralize enamel. Apart from the saliva, the tribological behavior of human teeth is also closely associated with food particles and occlusal load. Mass [17] carried out compression tests to investigate the microscopic wear features on the occlusal surfaces of teeth caused by food particles. The results showed that large particles produced fewer, larger wear features than the small particles. It was also seen that the total wear area increased with particle size. Interestingly, wear seemed to be independent of load. But Eisenburger and Addy found that load significantly influenced enamel wear by attrition both in acidic and neutral conditions.[18]

Although such studies have taken the effects of food particles and normal load on tooth wear into account, they focused simply on the wear loss, rather than investigating the wear mechanism in detail.

In vitro wear tests we performed on human teeth under various conditions. The different conditions include dry, artificial saliva, food slurry, and citric acid solution, in order to explore the effect of the oral environment on the teeth's tribological behavior. Furthermore, the erosion behavior of enamel in citric acid and the remineralization behavior of acid-eroded enamel in artificial saliva were also studied. Based on the given test conditions, the main conclusions can be summarized as follows:

1. Artificial saliva can play both a cooling and lubricant effect during the wear process.The risk of burning the tooth texture may be greatly reduced in the artificial saliva condition in comparison with the dry condition.

2. Due to the lubrication and the stress decentralization of food slurry on the contact surface, human teeth had a better wear resistance in a food slurry medium than in an artificial saliva medium. Therefore, both a low friction coefficient and a small wear depth were observed in a food slurry medium. In addition, increasing the load could result in more wear of teeth, and the effect of the normal load was more significant in an artificial saliva medium than in a food slurry medium.

3. A competitive mechanism existed between the mechanical action and the chemical action when enamel wear occurred in the citric acid solution. Under a low normal loading level, the surface softening of enamel caused by erosion dissolution played a significant role in its wear behavior, and the wear mechanism of enamel was dominant by adhesion delamination. Hence, enamel wear in the citric acid solution was significantly higher than in the artificial saliva. With the load increasing, brittle fracture by loading force was intensified, and enamel wear was gradually characterized by mechanical removal because of its inherent brittleness. The wear morphology and loss of enamel in the citric acid solution were similar to those in the artificial saliva.

4. At the early stage of erosion, the surface lesion of enamel was characterized mainly by partial demineralization and decreased microhardness without obvious substance loss. As the erosion time increased, a honeycomb-like structure appeared on the enamel surface as a result of severe dissolution of the enamel rods. Then substantial erosive substance loss happened. The loss increased almost linearly with the erosion time. Furthermore, the erosion properties of enamel were closely associated with its location. Erosive substance loss increased from the outer to the interior enamel. Additionally, enamel erosion had a significant influence on its friction and wear behaviors. Both the friction coefficient and wear loss of eroded enamel showed a strong dependence on erosion time.

Compared with the outer enamel, the influence of erosion on subsequent friction and wear behavior appeared more significant in the interior enamel.

5. Remineralization in artificial saliva could improve the antiwear properties of acid-eroded enamel. A layer of mineral deposits was formed on the acid-eroded enamel surface after in vitro remineralization. Compared with the original enamel surface, this layer had a similar chemical composition but a significantly different crystal orientation. The nanomechanical and microtribological properties of the acid-eroded enamel surface were significantly enhanced by remineralization.

However, the loss of hardness and Young's modulus of enamel surface by acid erosion could not be totally recovered after in vitro remineralization.

After remineralization the wear volume of acid-eroded enamel decreased .However it was still much higher than compared that of the original enamel.

Enamel is one of those unique natural substances having an excellent mechanical and tribological behavior. Till date enamel cannot be substituted effectively with artificial restorative materials. Enamel consists of aligned "prism-shaped" rods (4–8 μm in diameter) which are unique in nature and traverse approximately perpendicular from the dentin-enamel junction (DEJ) toward the tooth surface.[19]

Scratching tests were performed on the longitudinally sectioned enamel surface along the directions vertical and parallel to the enamel rods, respectively and recovery following scratching enamel was also investigated. Based on the given test conditions, the main conclusions can be summarized as follows:

1. The nanomechanical properties of the enamel rod were better than those of the interrod enamel. They were heterogeneous over its occlusal cross section.however considering a single enamel rod, the hardness and Young's modulus were higher in the central head area and tended to be lower in the edge area, especially in the tail area.

2. The scratch-induced damage was anisotropic on the longitudinal section of tooth enamel. enamel has the unique alignment of hydroxyapetite crystallites. However the buffer capacity of the interrod enamel provided a good wear resistance of tooth enamel when scratched along the direction parallel to the axis of the enamel rod.

3. The interrod enamel has a lower hardness. Thus revealed a relatively weaker wear resistance than the enamel rods although the buffer capacity of the interrod enamel played an important role during the masticating process of human teeth.

4. The enamel Hydroxyapetite crystals were found to be broken up into smaller ones by scratching. Such behavior may be helpful to release the stress concentration .This also prevent the generation of cracks in teeth during the masticating process. However it can effectively improve the wear resistance property of teeth.

5. After tooth samples were remineralized in artificial saliva, it was seen that the size of particles on the surface increased to 200 nm. It was also noted that the damaged tooth enamel surface could be repaired to some extent.

In restorative dentistry, the commonly applied materials are metals and alloys and ceramics and composites.

Considering the complex intraoral environment and biomechanics, the wear processes of artificial dental materials are very complicated . The wear processes commonly include abrasion, attrition, corrosion, fretting wear, and fatigue [20, 21]

These processes occur in various combinations and as a result the surface loss of materials in the mouth occur. Excessive wear may lead to premature failure and leading to the replacement of dental restorations and implants. The wear resistance of artificial dental materials is clinically important for clinical longevity, aesthetics, and resistance to dental plaquefor a better treatment prognosis. [22]

Therefore, a large number of studies have been carried out on their tribological properties. Recreating function and aesthetics are the two practical goals of restorative treatments, but the inadequate wear resistance of either the restoration or the implant may cause obvious defects in its anatomic shape due to excessive wear by friction during chewing. Changing the shape and functions of teeth, bone, and masticatory muscle, further affects the fitness of the stomatognathic system. Therefore, it is necessary to remember that the choice of material depends on a number of factors. These factors include corrosion behaviour, mechanical properties (including strength and wear resistance), cost, availability, biocompatibility, and aesthetic values.

Missing teeth is a common problem worldwide. The incidence of missing teeth is on the rise year after year. A dental implant is an artificial tooth root that is used in dentistry to support restorations and then replace missing teeth. The global dental implant and prosthetics market was valued at $6,781.7 million in 2011. This value is expected to rise rapidly in upcoming decades. Europe is leading the global dental implant market, with the largest share of 41.0 %, at an estimated $1,675.1 million in 2011.

We all know the fact that the damage produced by fretting and the healing and the osseointegration at the dental implant interface occur at the same time. Both processes involve bone formation, and both are influenced by the mechanical environment. It is very important for patients to optimize the structural design of dental implants. This will in turn help to reduce a risk of damage induced by fretting and prolong the service life of a dental implant system.

An ideal dental implant interface should be similar to the natural interface between the tooth and jawbone. This is bioactive and also mechanical damage is absent here . So we can say that much work remains to be done on the surface treatment of implant materials. The tribological design of the shape, size, and structure of the dental implant screw also to be considered and evaluated in order to make the implant a success for a long term period.

Different investigations are done not only on friction and wear of human teeth but also on the artificial dental implant-bone interface. Combining the different with a literature surveys, important suggestions can be made for the challenging future tasks involving both engineering and dental medicine streams.

The classification and definition of wear in dentistry are quite different from those in other tribology fields. Wear in dentistry is generally considered more or less from clinical causes or features of surface loss. However the wear in tribology is mainly from the detachment mechanisms due to particles. More and more research work on the wear of human teeth is being performed now a days. Thus considering the mechanical perspective, the confusion in concept may lead to some inconsistencies.

Mostly the dental wear studies are interdisciplinary in nature. So it is very important that scientists and researchers haave good cooperation and correlation and strengthen the cooperation between tribologists and the dental surgeons.

We all know that wear of human teeth is unavoidable due to the motion of mastication. However, until now, the level of wear has been mainly evaluated according to clinical observation. A system that spans from normal physiological wear to abnormal wear of human teeth has not been established till date. The mechanisms and palliative measures of abnormal wear should be directions of future research. Wear behavior of teeth strongly depends upon several factors. These factors include age, dietary habit, and pathological effect. The concept of tribological design and optimization forms the basis of individual restoration, particularly in the choice of dental restorative materials, should be also beconsidered while performing different clinical treatments.

In dentistry, the failure of dental implants due to loosening has been considered to be a result from medical reasons such as bone resorption. However the mechanical causes are usually have not yet been investigated . In fact, while chewing the occlusal surfaces of teeth are loaded repeatedly. Fretting occurs both at the fitting surfaces between implant materials and alveolar bone and also at interfaces of the screw joint. This can finally result in loosening failure. So it can definitely be said that, mechanical design, such as the choice of interference magnitude, the shape and size of the screw surface, the value of the pretightening force, and others, play an extremely helpful in reducing the damage to the dental implant surface caused by fretting wear. However, no matter how the fretting parameters are chosen, the dental implant–bone interface is still different from its natural tooth bone counterpart. The natural good cushioning effect in the periodontal ligament still remains absent from the natural tooth–bone interface. [23]

Perhaps the development of tissue engineering can provide us with a new concept; according to which the formation of a new periodontal ligament between the dental implant may help us to solve the issue of fretting damage at the interface.

Therefore, for dental surgeons, collaborative research with other scientists is mandatory to obtain a dental implant with a longer service life and better patient compliance.

Although we have made a remarkable progress in the field of dental wear but still it can be said that much work and evaluation remains to be achieved toward a systematic correlation between the tribological behavior and structure of human teeth, a bionic design for engineering wear system, and a clinical treatment against dental wear based upon the concept of tribological design. Inevitably, more and more research directions will eventually show us the path that will lead to better treatment prognosis. So these discussions hopefully would help to through some light and provide more knowledge on what already has been learned from human teeth.

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