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ABSTRACT-

The hardest organ in our body is the teeth. Tooth has a very unique anatomic and chemical structure. Tribology is the branch of science that discusses about lubrication, friction, and wear. To understand the wear behavior of human teeth, it is desirable to evaluate the properties of materials and the chemical structures of different materials and as well as the structure of tooth. Human tooth wear occurs very slowly. The process of Tooth wear is not only a complex process but also a multifactorial phenomenon which involves physical, chemical and mechanical processes. Our oral environment has an extremely important and determining role in the tribological behaviour of teeth. Considering the complex biomechanics and intraoral environment, the wear processes of artificial materials used in dentistry, are rather complicated. The different wear processes commonly occurring in our oral cavity include abrasion, attrition, fretting wear, corrosion and fatigue. These processes occur in various combinations and as a result the gradual surface decaying of materials in the oral cavity occur. Excessive wear may lead to early failure and as a result replacement of dental restorations and implants becomes inevitable. 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 done. This will help us to achieve a systematic correlation between the tribological behaviour and structure of human teeth, a bionic design, and a clinical treatment against dental wear which will be 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).

Jost Report in the year 1966 first introduced the term “tribology”. Tribology is defined as “the science and technology of interacting surfaces in relative motion and the practices related thereto.”

In short, tribology is the science of interacting surfaces in relative motion that deals with friction, lubrication and wear. This include a number of basic disciplines such as mechanics, material science, chemistry, and physics. Biotribology is essentially the study of friction, lubrication, and wear in biological systems. Tribology in dentistry 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 our body .the normal survival of teeth is for few decades. However, teeth experience wear, and there are multiple 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 a sufficiently reduced 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 organ with highest compressive strength. It has a very distinctive anatomic and chemical structure. However in order to understand the wear behaviour 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 a format which involves a quadrant system for human molars. [1]

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

Human tooth wear occurs at a very slow pace. 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 which 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, deliberate loss of the convex architecture of human 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. However in addition to this, an appropriate wear-testing device has not been found. As a result there is a great toil 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 contributes in tribological behavioural pattern of human teeth [8, 9, 10]

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

Frictional force, aging, and even tooth brushing affects the tribological behaviour of human teeth. Human teeth tribolocal behaviour can be summarized as follows

1. Micro hardness and tribological behaviour vary notably between layers in a permanent tooth. In the enamel zone the micro hardness is raised, friction coefficient is lowered than the dentin zone. A better wear resistance is also observed in the enamel zone than in the dentin. This finding is observed both on the occlusal section and on the axial section. Furthermore, friction and wear behaviours of an individual tooth depend strongly on microstructural orientations. The orientation of enamel rods and dentinal tubule contributes to the better wear resistance along the occlusal section than along the axial section

2. Plastic delamination occurring on the enamel surface during the wear process. This results in conversion of wear of human tooth enamel from two-body wear into three-body wear. As the number of cycles increases the wear rate reduces. Ultimately, the wear of enamel sticks to a stable stage. Microscopic examinations reveal 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 behaviour of a human tooth depends strongly upon time span it is present in the oral cavity. The friction and wear behaviour of young permanent teeth are comparable 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 byzantine event that depends on multiple factors and event. These include different chemical, physical, and mechanical processes occurring in the oral cavity. [11]

The oral environment plays a highly significant role in the tribological behaviour of both human teeth and artificial restorative materials used in dentistry.

Saliva is the most important factor that contributes to the integrity of oral environment. 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. The development of acquired pellicle begins within seconds on any solid surface that is exposed to the intraoral habitat.[12]

The functional importance of saliva in the human oral cavity is multifarious. An important function of saliva is to act as a lubricant between hard (enamel) and soft (mucosal) tissues. [13]

This helps to decrease the wear of human teeth and reduce the frictional forces within the oral mucosa and tongue surfaces. This helps us in swallowing. Saliva also plays a crucial role in maintaining other important functions such as mastication, deglutition, and speech. In general, saliva has a pH of 7 (neutral); [14]

Saliva acts as an important buffer in the intra oral environment. Another role of saliva is thought to involve both the protection of tooth surfaces against acid attack and help to maintain the integrity.[15, 16]

Saliva provides calcium and phosphate ions to enamel thus helping in enamel remineralisation. Apart from the saliva, the tribological behaviour of human teeth is also influenced by occlusal load by food particles. Mass [17] performed compression tests to determine the microscopic wear features on the occlusal surfaces of teeth due to different food particles. Mass found that large particles produced fewer, larger wear features than the relative smaller small particles. It was also seen that with the increasing particle size the total wear area also increased. Interestingly, wear seemed to be not influenced by load.

Eisenburger and Addy carried out similar experiments and they found that load significantly determined enamel wear by attrition irrespective of the chemical nature of the environment.[18]

Although such studies concentrated more on the wear loss instead of the mechanism that have taken place during wear phenomenon.

In vitro wear tests were performed on human teeth varying the environmental factors and conditions. The different conditions include citric acid solution, food slurry, and artificial saliva. The effect of the oral environment on the teeth's tribological behaviour was revealed by these conducted tests. In citric acid solution enamel expressed it's natural wear behaviour. Exposure of acid-eroded enamel in artificial saliva lead to mineralisation. Both of these phenomenon were also studied. Based on the given test conditions, the it can be concluded that:

1. Artificial saliva has both a cooling as well as lubricant effect during the wear process. Usage of artificial saliva helps to reduce the risk of burning the tooth texture in dry conditions.

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. When enamel wear occurred in the citric acid solution both mechanical and chemical action occurred. Under a low normal loading level, the surface softening of enamel caused by erosion dissolution played a significant role in its wear behaviour, and the wear mechanism of enamel was dominant by adhesion delamination. Hence, enamel wear in the artificial saliva is significantly lower than in citric acid solution higher than in the. 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 loss of enamel and the wear morphology and in the artificial saliva solution were similar to those in the citric acid solution.

4. At the early stage of erosion, the surface lesion of enamel was characterized mainly by partial demineralization and decreased micro hardness 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 behaviours. 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 behaviour appeared more significant in the interior enamel.

5. Remineralisation 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 remineralisation. Compared with the original enamel surface, this layer had a similar chemical composition but a significantly different crystal orientation. The Nano mechanical and microtribological properties of the acid-eroded enamel surface were significantly enhanced by remineralisation.

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

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

Enamel is a distinctive natural substance which has an outstanding mechanical and tribological properties. No artificial restorative material has been discovered till date which can substitute enamel. Enamel consists of aligned "prism-shaped" rods (4–8 µm in diameter) which are unique in nature and traverse approximately at right angles 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 Nano mechanical 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 hydroxyapatite 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 Hydroxyapatite 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]

Inadequate conception about the tribological property of restorative material will lead to obvious wear of teeth during mastication and this will eventually affect the stability of stomatognathic system. Therefore the biomechanics of dental materials, biocompatibility, corrosion resistance should also be evaluated along with cost and aesthetics.

Missing teeth is a familiar problem affecting peoples of all the countries throughout the world. The incidence of missing teeth is increasing yearly. 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. In implantology the dental implant interface should be alike to the natural interface between the tooth and jawbone. This is bioactive and also mechanical damage is absent here. So we can say that we must pay attention to the surface treatment of implant materials. The design 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 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 have good cooperation and correlation and strengthen the cooperation between tribologists and the dental surgeons.

.In dentistry, the failure of dental implants not only due to failed Osseointegration, or bone resorption. However 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 inevitably lead to loosening failure. So it can definitely be said that, biomechanics play an extremely helpful in reducing the damage to the dental implant surface caused by fretting wear. However the tooth bone counterpart can never be comparable to, the dental implant–bone interface. [23]

However the advancement of tissue engineering can provide us with a new intellection; 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 behaviour 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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