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In-vitro wear measurements of dental composite influenced by chewable tobacco environment

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KEYWORDS

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Wear
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Dental composite
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ABSTRACT

The present study aims at analyzing the effect of chewable tobacco on the in-vitro wear measurements of two dental composite materials. In this test, the pins were made up of dental composites: micro-filled Z250 and nano-filled Z350 translucent shade and immersed in tobacco solution. In-vitro measurements were conducted on a pin-on-disk tribometer in the presence of artificial saliva at three different loading conditions with a constant disc speed. Three specimens of each composite material were produced, and six readings were recorded by using both sides of pin specimens to observe the tribological behaviour. The microstructures of the pin surfaces were inspected by using scanning electron microscopy (SEM). At initial stages i.e. just a few days after immersion, there was less change in the wear measurement for both the materials. Significant changes were observed after one month. Specimens prepared with nano-filled Z350 material showed smooth wear features whereas micro-filled Z250 progressively articulated wear details were observed with a chewable tobacco environment. The wear measurements of tested dental material specimens were influenced by tobacco immersion. The nano-filled Z350 translucent material exhibits less wear as compared to micro-filled Z250 material.

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1.0 INTRODUCTION

The study of friction, wear, and lubrication through contact mode in living organisms is known as bio-tribology. In a human body, the tribological motion takes place especially within-side the joints and in the mouth (Mystkowska and Dąbrowski, 2010). Materials that can be designed to assist or update human organs for scientific functions are biomaterials. However, earlier than the use of them as a replacement, investigation of durability and stability of these materials or components is necessary and essential (Ayatollahi et al 2015; Vithya., et al 2018; Ramalhon, 2013; Palaniappan et, et al 2013; Sajewicz 2009). Dental caries is one of the serious diseases occurring in the world. Dental parts are subjected to wear and therefore need replacement using suitable dental restorative materials. Resin composites are widely used as the best choice for dental restorations due to their aesthetics and better filling capability. Composites are also capable of controlling the issues caused due to the presence of amalgam and help in protecting the natural tooth tissues by a better chemical bonding to dentin and enamel. The dental composites should be characterized with high intermolecular binding, resistance to wear caused by friction and the ability to avoid microbial leakage and cracks; also they must be bio-tolerant with natural appearance (Wojda et al., 2015; Meena et al., 2018). Mechanical properties and wear of these materials were influenced by the filler content, size and type. Additionally, dental wear is also affected by consumption of sustenance and beverage, utilization of extra cleanliness measures (such as toothpaste and toothbrush) and malocclusion (Vaishnavi et al., 2018).

The habitual chewing of tobacco, paan masala and paan is one of the prime causes of dental wear among a significant number of people (Jiang et al., 2019). Tobacco products categorized into two groups: chewing tobacco or smokeless tobacco (e.g. Tobacco plug, snuff and dentifrices) and smoking tobacco (e.g. Cigarettes, bidi and cigar) (Gupta and Ray, 2013). Long term tobacco addiction at first causes redness of teeth due to chemical reaction of poly-phenols leading to brown-black colour at the end (Bastiaan and Reade, 1976). Similarly, considerable wear occurs at occlusal and incisal surfaces. This type of wear is caused by the granularity of residual particles in tobacco. Another reason for this type of wear is the presence of 20% sugar content in processed tobacco (Going et al 1980; Vellappally et al 2007).

In the last two decades, new dental materials are made available for restorations by manufacturers. Recently, composite materials have a huge demand due to their stable performance and aesthetic properties (Cangul and Adiguzel 2017). Dental composites have improved mechanical properties because of advancement in filler technology. Recently composites have improved bonding system which ultimately increases the lifetime of the composite restorations drastically. Parameters that influence the mechanical properties of composite materials are particle size and the percentage of filler content. But the main concern of dental restorations is that they are subjected to wear. Dental wear is mostly influenced by mouth cleanliness, the presence of saliva and the use of extra cleanliness measures such as toothbrushes, toothpaste and malocclusion. After the invention of the composite material by Bowen, consistent efforts have been made to improve its performance (Bowen, 1963). The aim was to optimize the filler particle size and its content with an increasing factor of aesthetic look (Wojda et al., 2015; Rastelli et al., 2012). Filler particles are used to lower the polymerization shrinkage on the setting and also to increase the wear resistance. Suryawanshi et al., (2020) evaluate the effect of chewing tobacco on tribological behaviour of two nano-composite dental material. The present work is based on in-vitro experiments carried out for measuring the frictional and wear properties of two different composite materials: (i) nano-filled Z350 translucent and (ii) micro-filled Z250 material.

Dental resin composites are mostly used to restore the missing tooth tissue worn by the grinding process, cavities and non-carious cervical lesions (NCCLs). Generally dental resin composite material contains filler particles such as borosilicate glass, colloidal glass etc and polymer matrix e.g. bisphenol A glycidyl methacrylate (BisGMA), triethylene glycol dimethacrylate (TEGDMA), urethane dimethacrylate (UDMA) etc. (Mystkowska and Dąbrowski, 2010; Ayatollahi et al., 2015, Vithya et al., 2018). The important roles of filler particles are to enhance the dental composite's wear resistance and to minimize the polymerization shrinkage.

1.1 Types of Wear

In dentistry, the wear of natural teeth and artificial restorative material can be classified by the three terms namely attrition, abrasion and erosion. Recently a new terminology has been introduced by the researcher to classify the wear i.e abfraction (Zhou and Zheng 2008; Lee et al., 2012).

The friction caused by relative motion between tooth-to-tooth or restoration-to-restoration or restoration-to-tooth induces wear known as attrition. This type of wear is because of two-body interactions. It is associated with ageing but can be stimulated due to extrinsic reasons like malocclusion and bruxism (Zhou and Zheng 2008; Lee et al., 2012). Abrasion wear is a result of three-body wear interactions. It is mainly because of friction between the tooth or restoration with external particles such as toothpaste, food particles and toothpick. Commonly three-body wear in the cervical region is a result of improper tooth-brushing habits (Zhou and Zheng 2008; Lee et al., 2012). Surface degradation of natural tooth or restoration due to electrochemical activity is known as erosion. Erosion has different implications in engineering tribology and dentistry. The American Society for Testing and Materials Committee states that erosion is the progressive loss of material from a solid surface due to mechanical interaction between that surface and a fluid, a multi-component fluid, impinging liquid or solid particles. However, in the dental study, the surface loss caused by the non-bacterial acidic solution is known as erosion. Also, effective loss because of chemical or electrochemical reactions is appropriately quoted as corrosion (Zhou and Zheng 2008; Lee et al., 2012). Recently, the loss of hard tooth portion in the cervical area due to crack formation is termed as an abfraction. Some studies also suggest that the wedge-shaped tooth tissues are developed due to compressive and tensile stresses during the mastication and malocclusion process (Zhou and Zheng 2008; Lee et al., 2012).

The major problem which may occur while using the artificial dental composite restorations for stress-bearing applications is nothing but extensive wear. This may gradually cause early failure and restoration of the dental composite material. The most important factor affecting the chemistry of the real oral environment is saliva. Its important function is to minimize tooth wear by forming a boundary lubrication system so that it acts as a lubricant between soft (mucosal) tissues and hard (enamel).

2.0 MATERIALS AND METHODS

2.1 Materials and Specimens

In this work, nano-filled Z350 translucent material and micro-filled Z250 material have been chosen for the wear test. Cylindrical (10 mm x 30 mm) dental material specimens were made using an elastomer mould. Layers of the dental composite material of thickness 1 to 3 mm were inserted into the mould. Each layer is condensed and then polymerized by using a LED curing light in the mould. The curing time was different for the two composite materials. After removal from the mould, the pin was exposed to light laterally. Pin specimens were smoothened using 600 grit sandpapers (Suryawanshi and Behera, 2020; Sajewicz and Wojda, 2017; Karthick et al., 2014; Nuraliza et al., 2016). The specimens were then immersed in distilled water for seven days. Table 1 summarizes the important details regarding the selected material (Information courtesy-Material manufacturer).

Table 1: Main composition of the resin composite materials (Information courtesy - Material manufacturer).

Sr. No	**Resin-based Composite**	**Classification**	**Resin**	**Filler**	**Filler particle size**	**Total filler content**	
						wt %	**vol %**
1	Z250	Micro-fill (Universal restorative)	BIS-GMA UDMA BIS-EMA	Zirconia / Silica	Zirconia/Silica 0.01 to 3.5 µm.(Average size of 0.6µm	84.5	60
2	Z350 Translucent Shade	Nano-fill (Universal restorative)	BIS-GMA UDMA PEGDMA BIS-EMA	Zirconia & Silica	Silica- 20 nm, Zirconia- 4 to 11 nm	72.5	55.6

BIS-GMA: bisphenol A glycidal methacrylate
UDMA: urethane dimethacrylate
BIS-EMA: bisphenol apolyethethylene glycol dieherdimethacrylate
PEGDMA: Polyethylene glycol dimethacrylate

Figure 1: Specimens dipped in tobacco solution.

Two solutions were prepared by mixing an equal proportion of tobacco (BR-leaf red-brown grade) and the artificial saliva at room temperature. Then, the two dental composite material specimens namely Z250 (3M Dental Products, St Paul, MN, USA) and Z350 (3M Dental Products, St Paul, MN, USA) of Translucent shade were dipped entirely in tobacco solution as shown in figure 1. Before dipping the dental material specimens into the tobacco solution, the pH of the solution was evaluated using a pH meter at room temperature (Sajewicz, 2009). The dental material specimens were immersed in chewable tobacco for 24 hours a day. All the tobacco solutions were refreshed after some time so that the pH of the solution is maintained. The tribological behaviour was evaluated after 2 days, 3.5 days, 6 days, 15 days and 1 month which were equivalent to actual contact of dental material and tobacco solution for one week, two weeks, one month, two months and five months respectively. Before dipping the specimen in tobacco solution, tests were carried out to determine baseline readings in the presence of artificial saliva only.

3.0 RESULTS AND DISCUSSION

3.1 Effects of Applied Normal Load on the Wear Depth

Figure 2 and figure 3 illustrate the variation in wear behaviour of the restorative materials Z350 translucent and Z250 concerning time under three different loading conditions of 10N, 15N, 20N. Baseline readings for three loading conditions indicate the wear depth for the specimens which were immersed only in the saliva without tobacco. From the baseline readings, it is observed that the wear depth increased with an increase in load for both the specimens (Kumar et al, 2018). Three more readings plotted in figure 2 and figure 3 are for the specimens which were immersed in the tobacco solution for 1 month. Like baseline readings, the wear depth of tobacco-immersed specimens increases with an increase in load for both the specimens. Also magnitude of wear depth is found to be significantly more in the tobacco-immersed specimens as compared to the un-immersed specimens. It was observed that the Z350 translucent composite displayed better wear resistance over the Z250 composite when immersed in chewable tobacco solution under a given loading condition.

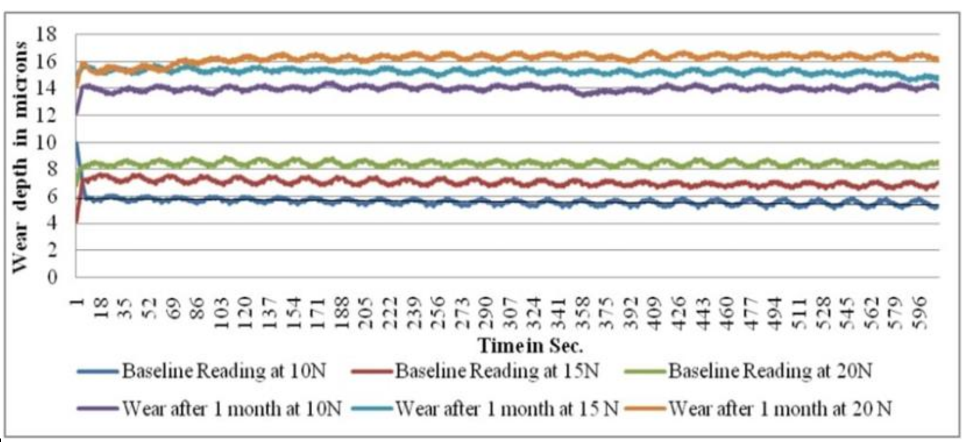

Figure 2: Wear measurements over time for Z250 material.

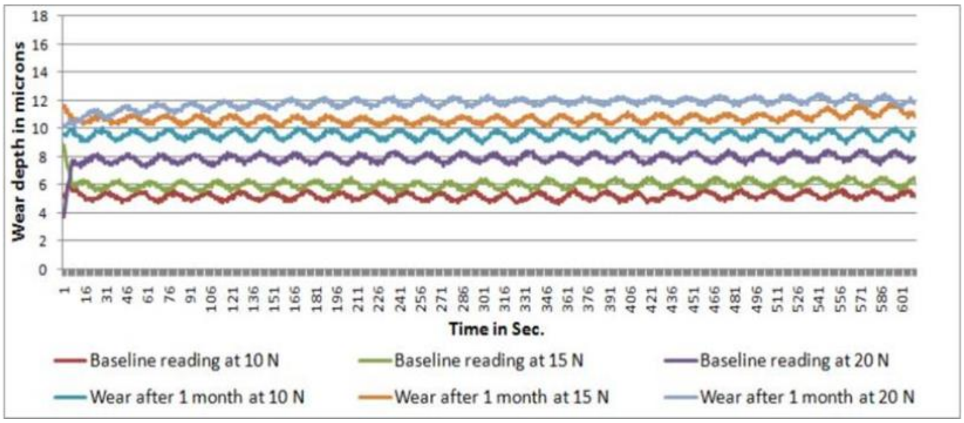

Figure 3: Wear measurements over time for Z350 Translucent material.

Figure 4 and figure 5 indicates the effective wear depth plot at different immersion interval for both the composites. It can be seen that exponential growth describes best the curve trend for both figure 4 & 5. The wear behaviour at the baseline reading and the wear behaviour after 2 days of immersion were not distinguishable for both the materials. The wear depth of cylindrical pins from the baseline reading up to 15 days immersion was more as compared to the readings observed after 15 days of immersion to one-month immersion. The most distinguishable average wear change from the baseline was observed after one-month immersion for Z250 composites at a particular loading condition. Thus, the average wear of both the composite materials increased when dipped in tobacco solution for a particular period. After the one-month immersion interval, the average wear of Z250 composite increased by 93%, 117% and 148% for given loading conditions of 20N, 15N and 10N respectively. Whereas, the averages wear of Z350 translucent composite increased by 50%, 77% and 83% for the given loading conditions of 20N, 15N and 10N respectively.

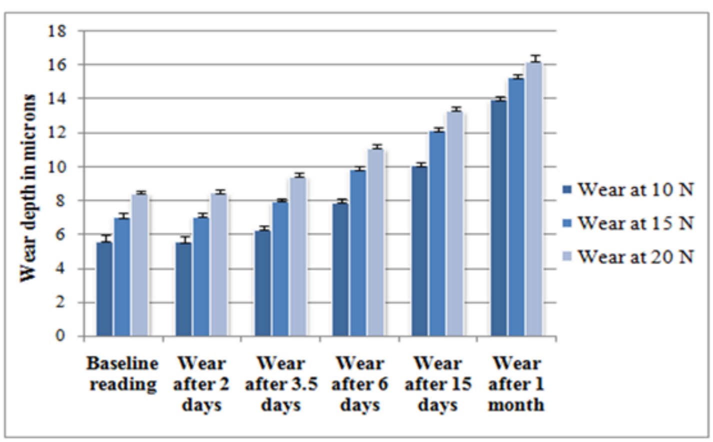

Figure 4: Effect of tobacco on wear depth (Z250 material).

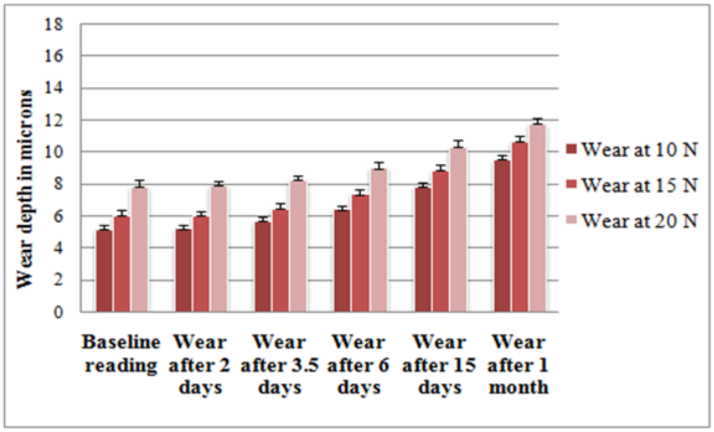

Figure 5: Effect of tobacco on wear depth (Z350 Translucent material).

3.2 Effects of Applied Normal Load On the Coefficient Of Friction

The effect of different loading conditions on the coefficient of friction needs to be studied because the dental composites have to perform well after the application of different loads in a real oral environment. Figure 6 shows the change in the coefficient of friction in the case of both the materials after one-month immersion in the tobacco solution for the given applied loading condition. It was found that the micro-filled Z250 composite has a higher value of coefficient of friction than the nano-filled Z350 translucent composites. For both the composites, as the applied load increases from 10N to 20N the coefficient of friction decreases.

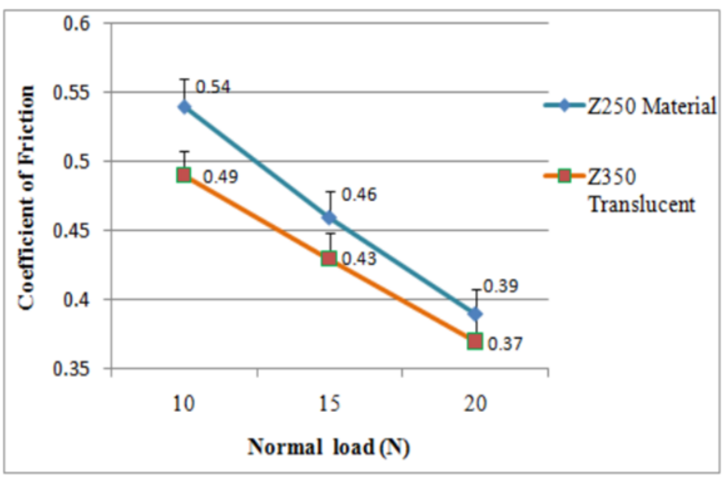

Figure 6: Variation of coefficient of friction with respect to applied load.

3.3 SEM Analysis of Worn Surfaces

The scanning electron microscopy (SEM) was used to examine and study the morphology of warn-out surfaces. Figure 7 shows the corresponding SEM images of Z350 translucent and Z250 material, before loading and after testing of specimens. The warn-out specimen surfaces were coated with gold and then analyzed by using a scanning electron microscope at 18 kV operating voltage. These surfaces exhibited noticeable roughness with deep indentations and small holes because of frictional and adhesive fatigues. In the case of Z350 translucent material, filler particles were dispersed over the entire surface. Void, pores and delamination can also be easily observed, but no groove on the surface can be observed (Fig. 7B). Also, it shows the surface damage of the material known as grains-peeling off in the case of Z350 translucent material, which occurs on a large scale in the case of Z250 material. SEM images in fig. 7D show the formation of the deep furrows with large particles been removed, resulting in an uneven surface in the case of Z250 material. Wear debris and wear track has been formed on a Z250 material specimen. The chemical process of poly-phenol oxidation results in a reddish hue on the specimens when they are immersed in chewable tobacco solution for the stipulated time which eventually changes to a brown-black shade.

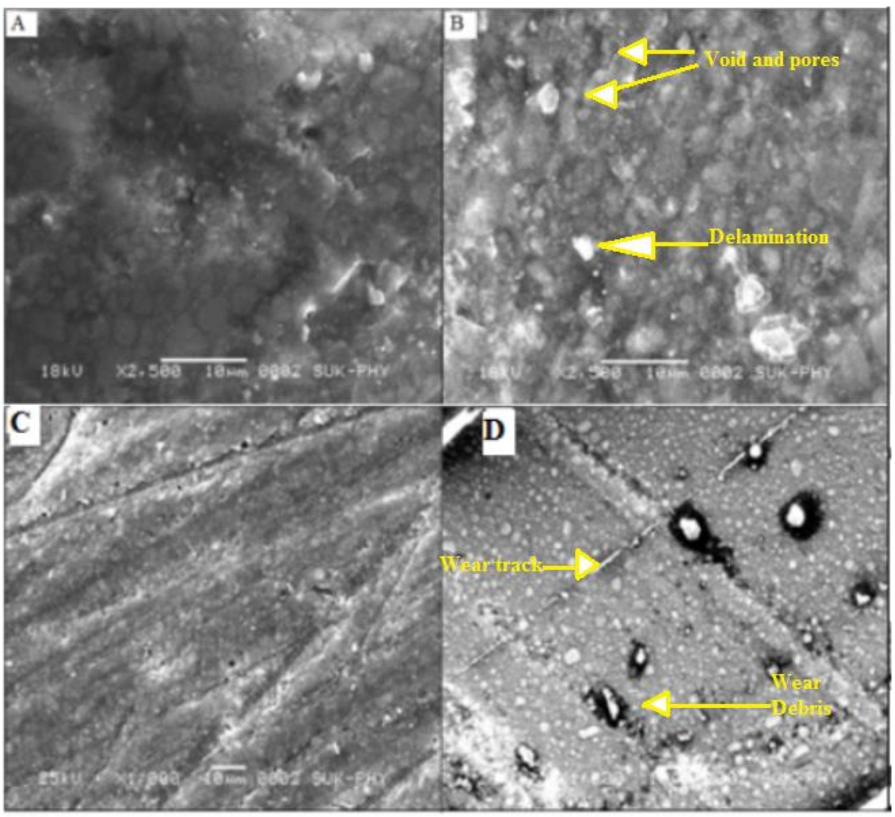

Figure 7: SEM images of, (a) before testing of Z350 translucent material, (b) after testing of Z350 translucent material, (c) before testing of Z250 material and (d) after testing of Z250 material.

4.0 DISCUSSION

Human teeth are known for their good tribological behaviour even under unfavourable oral conditions. Hence the artificial material used for restoration should exhibit similar properties to reduce the effect of dental wear and increase the mechanical strength of the restorative material. The two dental materials presented in this work Z250 and Z350 translucent shade material used for both anterior and posterior restorative purpose. Due to bruxism, the wear-resistant properties of the posterior restorative material under high loading conditions are of prime importance. During the mastication process, teeth undergo two-body (attrition) and three-body (abrasion) wear in the real oral condition, but two-body wear caused by bruxism majorly affects patients with critical wear. Hence in this work, the prime focus is to investigate the two-body (attrition) wear mechanism (Arsecularatne et al., 2016; Hu et al., 2002).

From the baseline reading of both materials (Figure 4 and 5), it is clear that the micro-filled Z250 composite exhibits more wear than the nano-filled Z350 translucent composite when in contact with the artificial saliva. Also, in the presence of tobacco solution, both the composites show a similar trend. Under normal conditions, nano-filled composites exhibit significantly lower wear compared to micro-filled composites which were concluded from the three-body abrasive test by Mitra et al. (2003). Also, the nano-filled composites show a lower wear rate than the hybrid composites as reported by Cao et al. (2013) under normal conditions. Mayworm et al. (2008) observed that after storing the specimens in saliva for nearly two months, the nano-composites show larger abrasive wear as compared to hybrid composites. This is due to the larger inter-particle space in nano-composites leading to increased wear rate. But in the present case, immersion of specimen in saliva may not be influenced much by the inter-particle space in nano-composites for which the wear is still lower than the micro-filled composites.

The contact pressure when the pin interfaces with the disk increase with an increase in the applied normal load eventually increasing the temperature of the interface. This change in temperature results in plastic deformation of the composite at the contact surface, which tends to increase the coefficient of friction and frictional force (Ahmed et al., 2012). Thus it can be stated that the larger the filler particle size greater is the coefficient of friction (Figure 6) (Hahnel et al., 2011).

The smokeless tobacco addiction results in tooth decay, as well as the colour of dental restorative material, which also fades away. Generally, there is a higher risk of tooth cavities due to the glucose level in processed chewable tobacco (Mubeen et al., 2013). The granularity of friction causing chewable tobacco particles may trigger the dental wear process, which may require the use of dental restorative composites in advanced stages. Long term chewable tobacco habits may cause disorientation of tooth tissues which results in root exposure (Mani et al., 2009). As per survey and analysis carried out across India, it was reported that most rural people prefer chewable tobacco (Nagarajappa et al., 2012). For stimulating oral moisture, peer pressure and addiction to nicotine are some of the reasons for the usage of chewable tobacco. The chewable tobacco has nicotine content ranging from 0.42% to 2.73% with a pH value scaling from 5.84 to 8.1. Even though the average pH value is close to basic, problems like disorientation of tooth tissue, tooth carries, and dental restoration wear significantly occur because of chemical carcinogens, preservatives and the abundant amount of sugar present in processed tobacco. The several factors that affect the life of dental restorations include firstly the type of material used, secondly the clinical skills of the dentist and thirdly oral hygiene along with patient care (Thompson, 2016). Also, there is a higher possibility of bacterial infection as a result of nicotine addiction.

The wear characteristics of the dental composite are highly affected by filler content, filler size and its distribution. It was expected that dental composites characterized by higher filler content and smaller filler particle size would exhibit lesser wear but in the case of Z250 and Z350 Translucent material, if the filler particle size is not the same (Z250: micro-filled, Z350: nano-filled) the wear increases even though the filler volume has been increased (Manhart et al., 2000; Venhoven et al., 1996). The posterior dental restorations should be enough strong and resistive to wear so that they can sustain the masticatory actions. Optimization of filler content and reduction in mean filler may fulfil the same (Condon et al., 1997).

Therefore, for durable dental application, the nano-composite Z350 translucent material would be preferable over the micro composite Z250 material (Yildirim Bicer et al., 2015). This happens due to the variation in filler content and the physical properties of matrix content.

5.0 CONCLUSIONS

In this study, two different dental composite materials, nano-filled Z350 translucent and micro-filled Z250 material shade have been selected for studying the effect of smokeless tobacco on their tribological properties. From the analysis of experimental results performed following points have been concluded.

1. For both the composite specimens the wear depth magnitude increased when the experiment was conducted for the specimen immersed in tobacco solution.
2. In the presence of artificial saliva with or without tobacco immersion, the micro-filled Z250 composite exhibits more wear than the nano-filled Z350 translucent composite when subjected to different loads.
3. With increasing applied load, the coefficient of friction decreases in the case of both the composites. However, the micro-filled Z250 composite exhibits a higher coefficient of friction than the nano-filled Z350 translucent composites.
4. After one month of complete immersion in tobacco solution, the wear depth of micro-filled Z250 pin material was increased by 148%, 117% and 93% from baseline reading at loading conditions of 10N, 15N and 20N respectively. Similarly, the wear depth of nano-filled Z350 pin material was increased by 83%, 77% and 50% respectively from the baseline reading at loading conditions of 10N, 15N and 20N respectively. This states that, for such applications, dental nano-composite is more effective than the micro-filled composite when tested in the simulated oral conditions
5. After completing the SEM analysis, it is evident that the surface morphology of Z250 composite is coarser than Z350 translucent composite when subjected to particular applied loading condition.

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