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INFLUENCE OF BRUSHING FORCE ON ABRASIVE WEAR OF TEETH

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ABSTRACT

The present work aims to study the effect of the brushing force on the mechanical wear of teeth during polishing. Teeth specimens were brushed using three different types of tooth pastes. Tooth paste A contained pumice of (30 – 40) µm particle size. Paste B contained 8 wt % of hydrated silica abrasive of (10 – 12) µm particle size. Type C paste is an abrasive-free paste. The abrasives used were standard Arizona sand (ACFTD) of 0 - 80 µm and (ACCTD) of 0 - 200 µm particle size. Alumina particles of (1 - 3 µm) and sand with particle sizes of (11 – 13 µm, 15 – 20 µm, 20 – 24 µm, 28 – 32 µm and 42 – 52 µm) were used to fabricate eight different pastes. The abrasives were added at a 10 wt. % concentration. The brushing speed used in the experiments was 150 strokes/min. The contact forces used were 3 and 5 N in the presence of water.

Based on the observations in the present work, it was found that the influence of the force on the abrasive wear of the teeth increased with increasing abrasive particle size. The most pronounced influence was displayed by paste A that contaminated by abrasive of 30 – 40 µm particle size. Paste B displayed slight wear increase with increasing the acting load. Besides, abrasives of wide range of particle sizes such as air cleaner fine test dust (0 – 80 µm) and air cleaner coarse test dust (0 – 200 µm) showed lower wear than paste A. In condition of adhesion, significant wear increase was observed for paste-free abrasives. When adding abrasive to tooth paste, it is recommended to avoid the abrasive particle sizes ranging from 20 - 50 µm to reduce the excessive abrasive wear occurred during polishing the teeth.

KEYWORDS

Abrasive wear, acrylic teeth, tooth paste, abrasive, brushing force.

INTRODUCTION

Tooth wear has a multi-factorial etiology involving the interplay of attrition, erosion and abrasion, [1, 2]. When two-body abrasion occurs in the mouth whenever there is tooth-to-tooth contact, this is what most dentists call attrition. Abrasion wear may also occur when there is an abrasive slurry interposed between two surfaces, such that the two solid surfaces are not actually in contact, this is called three-body abrasion, with food acting as the abrasive agent, and occurs in the mouth during mastication. Abrasion is the key physiological wear mechanism that is present in dental materials during normal masticatory function, [3, 4]. But erosion is defined as loss of tooth structure by chemical dissolution without involvement of bacteria.

Historically, the dental literature has revealed various causes of tooth wear, yet it has failed to provide a conclusive method of differentiation and diagnosis of the condition, [5]. The categories of tooth wear encountered most commonly in dental practice are abrasion and erosion. The major causes of wear from abrasion are bruxism and tooth paste abuse, and the major causes of wear from erosion are regurgitation, coke-swishing and fruit-mulling. Tooth wear, in particular erosion, has been reported to be widespread in children in the UK, [6]. Wear may affect either dentition, but epidemiological measurement has proved difficult. Tooth enamel erosion occurs only in susceptible individuals regardless of food and beverage consumption patterns, that is, consumption of an acidic drink or food alone is highly unlikely to cause erosion, [7].

Resin composites were first introduced as anterior restorative materials, but are more and more used in posterior teeth, as amalgam replacements. Wear of dental composites includes such diverse phenomena as adhesion, abrasion and fatigue. These mechanisms may operate either alone or in combination. Most of the performed studies involve commercial composite materials and focus on the effect of curing time, and their reflection on the abrasive wear behavior. The wear compatibility of both materials in contact should be one of the concerns of the wear studies, [8]. However, the majority of studies do not consider the wear produced on the antagonist material, [9]. Fiber-reinforced composites demonstrated a high resistance to wear and may therefore be advantageous for dental applications, where high wear resistance is essential to functionality.

Teeth are usually cleaned using a tooth paste, consisting of abrasive particles in a carrier fluid, with a filament based toothbrush. Toothbrush and toothpaste effectiveness is typically assessed using *in vitro* tests carried out on tooth brushing simulators or by using *in vivo* tests. A number of different simulators have been developed, [10 - 13]. Most of these simulators work by mechanically loading and moving a toothbrush head over a test specimen, which is typically made from dentine, enamel or acrylic. The performance of a brush design is usually compared with that of a standard brush using standard toothpaste.

A toothbrush/dentifrice abrasion machine was developed to be used in dental research laboratory. The toothbrush/dentifrice abrasion machine was finally used to measure different longevity of tooth brush, [14]. It was experimentally shown that the mechanism can be used for highly accurate position and speed applications. Wear is a complex process that can hardly be simulated while controlling all variables, [15]. Especially the extrapolation of the in-vitro wear results to the in-vivo situation is difficult because there is a lot of interplay with biological factors that are difficult to mimic.

Laboratory mastication simulation allows the investigation of single parameters of the wear processes, though it has to be borne in mind that even *in vitro* wear simulations show considerable variability, [16]. Ideal dental restorative materials yield wear resistance similar to that of tooth tissues. For improving the wear resistance of restorative materials and for minimizing filler exfoliation during wear processes filler shape, size and volume have been modified extensively in the recent years. The influence of surface sealants on the surface roughness of resin composite restorations before and after mechanical tooth brushing was verified and the superficial topography using atomic force microscope was evaluated, [17]. Proper finishing and polishing of restorations is desirable for aesthetic considerations and maintenance of oral health, [18], ensuring a restoration's longevity by preventing recurrent decay and periodontal disease.

It was found that the mechanical wear of teeth increased with increasing the velocity of brushing due to the accelerated motion of abrasive particles, [19]. Increasing the particle size of abrasives increased the mechanical wear of teeth. This behavior may be due to the increased abrading action of particles. The increase in force leads to increase in mechanical wear of teeth. This due to increasing the depth of cut which lead to increase in material removed from the teeth. Increasing the brushing time of the plaque specimen decreased the surface roughness of the specimen due to removing the peaks of the surface asperities.

The aim of the present work is to investigate the effect of the acting force of brushing on the abrasive wear of teeth in order to have a proper degree of polishing without more wear for enamel of the teeth.

EXPERIMENTAL

The test rig used in the present work is a brushing machine which provides reciprocating motion for the brush. The brushing machine consists of an electric motor (300–3100 strokes/min). A container is made from Perspex sheets and connected to the motor. The container contains the brush clamp. The tested tooth clamp is a small chuck. The details of the brushing machine are illustrated in Fig. 1. The teeth specimens are artificial teeth (acrylic). The tooth was brushed in presence of the tested toothpaste and water as lubricating medium.

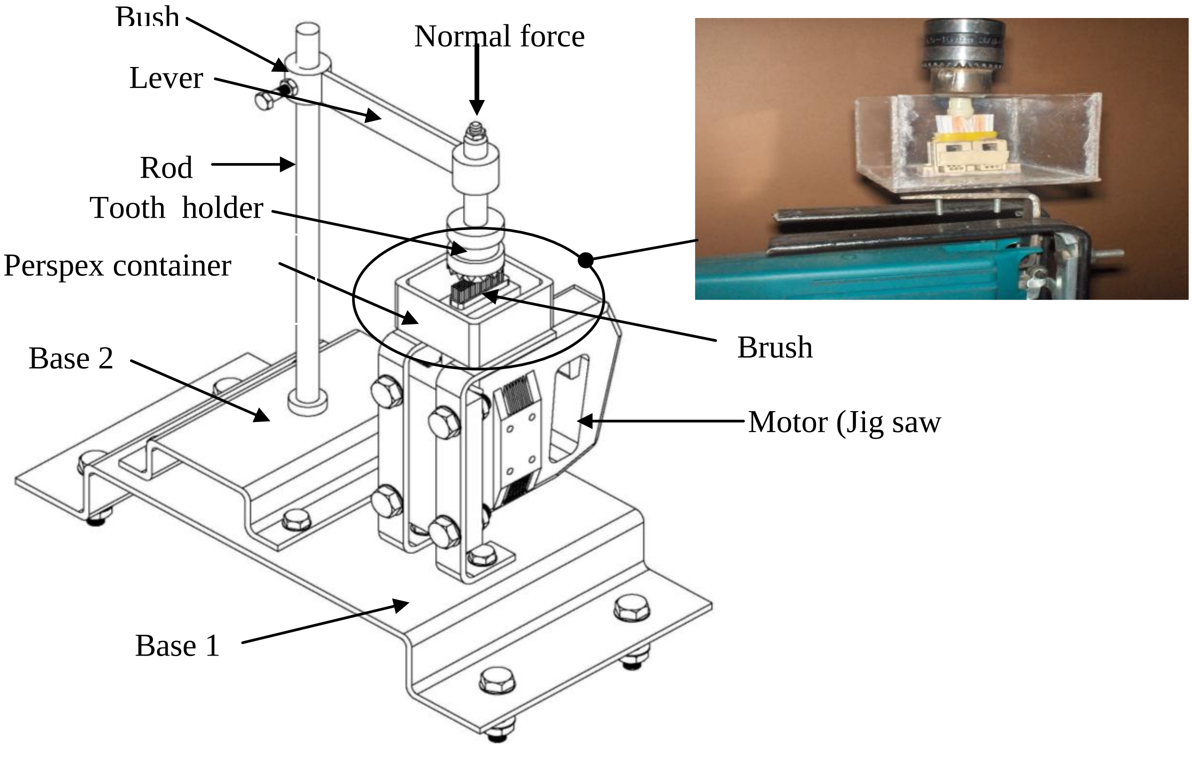

Fig. 1 The schematic diagram of the brushing machine

The tooth pastes A and B were used as reference. The tested pastes were prepared by adding eight abrasives of different particle sizes to paste C. Table 1 shows the particle size of abrasives added to the toothpaste. The properties of the two reference pastes are shown in Table 2. Wear tests were carried out at 150 strokes/min simulating to the

process of brushing the teeth. Tests were carried out at 3 and 5 N normal force of the brush on the teeth. The tested time was 30 minutes.

Table 1 The particle size of the abrasive used in experiments.

Types of paste	Abrasive type	Particle size	wt. %
Paste A (Egyptian)	Pumice	(30 – 40) µm	10
Paste B (German)	Hydrated silica	(10 – 12) µm	8
Paste C_1	Alumina	(1 – 3) µm	10
Paste C_2	Sand	(11 – 13) µm	10
Paste C_3	Sand	(15 – 20) µm	10
Paste C_4	Sand	(20 – 24) µm	10
Paste C_5	Sand	(28 – 32) µm	10
Paste C_6	Sand	(42 – 52) µm	10
Paste C_7	Arizona sand(ACFTD)	(0 - 80) µm	10
Paste C_8	Arizona sand(ACFTD)	(0 – 200) µm	10
Paste C	-	Without abrasive	-

Table 2 The properties of the tooth paste A and B.

Paste type	Particle size of abrasive	contents	concentration wt. %
Paste A	(30 – 40) µm	A blend of the well known and reliable standard substances pumice and calcium carbonate.	10 %
Paste B	(10 – 12) µm	Aqua, sorbitol, hydrated silica, glycerin, tetra potassium pyrophosphate, sodium lauryl sulfate, PEG-12, tetra sodium pyrophosphate, aroma, cellulose gum, sodium saccharin, sodium fluoride, C177891.	8 %

RESULTS AND DISCUSSION

The mechanical wear of acrylic tooth brushed by using past A with Pumice abrasives of (30 – 40) µm particle size is shown in Fig. 2. Generally, it can be noticed that wear slightly increased with increasing the acting force. At a force of 3 N the mechanical wear reached 16.6 mg at speed of 150 stroke/min, after 30 minutes .This value increased to 22 mg at force of 5 N. This was attributed to the force increase which caused the increase of the depth of cut and consequently the volume of material removed from the teeth increased. Amount of increasing in depth of cut depended on the shape of particle size where the sharp edge particle provided an increased value for depth of cut than the round one.

For acrylic tooth brushed using paste B with hydrated silica abrasives of (10 – 12) µm particle size Fig. 3, it is observed that, the mechanical wear of teeth increased with increasing the force which increased the increase of the depth of cut. The value of wear reached 6.2 mg at a force of 3N, at 30 minutes. As the force increased to 5 N, wear increased to 6.5 mg at 30 minutes in the presence of water.

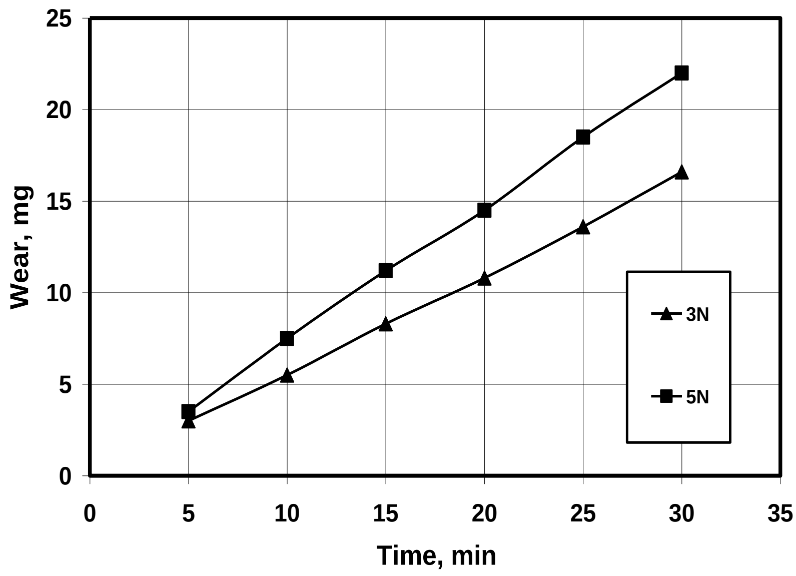

Fig. 2 Wear of acrylic tooth using tooth paste A.

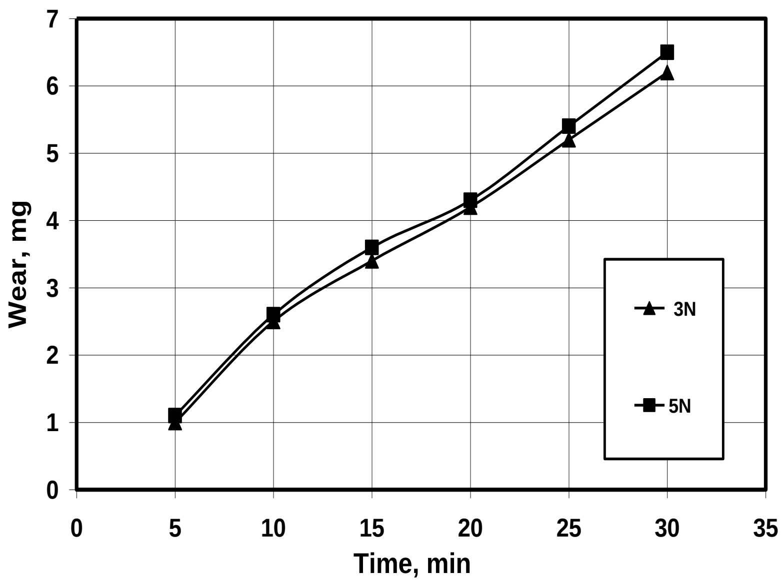

Fig. 3 Wear of acrylic tooth using tooth paste B.

Figure 4 shows the mechanical wear of acrylic tooth brushed by using paste C_1 contaminated by alumina abrasives of (1 – 3) µm particle size. Wear values were 4.3 and 5.6 mg at forces of 3 and 5 N respectively. The minimum values of wear were obtained for these particles due to their small size and round shape of their corners.

For acrylic tooth brushed by paste C_2 contaminated by silica abrasives of (11 – 13) µm particle size, Fig. 5, it is observed that, the value of wear reached 6.8 mg at a force of 3 N. With increasing the force to 5 N wear increased to 7.2. The wear increase relative to the alumina abrasive is attributed to the fact that as the particle size increases wear increases.

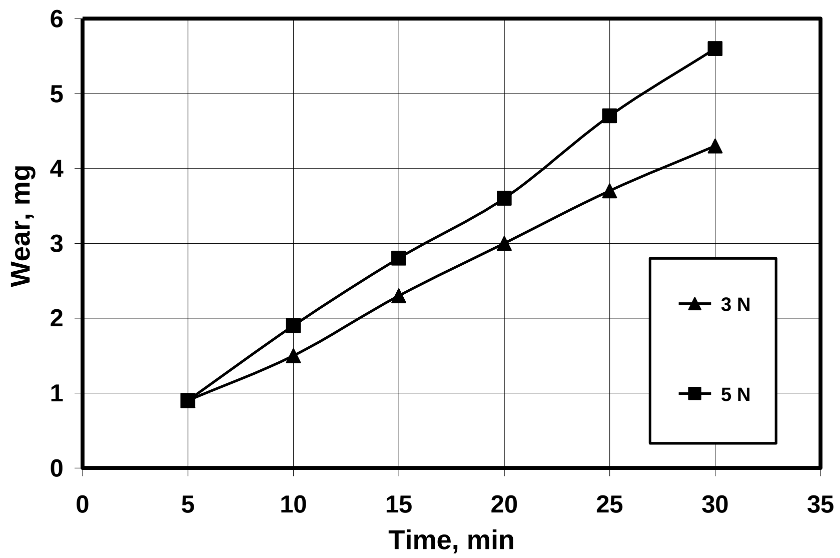

Fig. 4 Wear of acrylic tooth using tooth paste C_1 by alumina abrasives of (1 – 3) µm particle size.

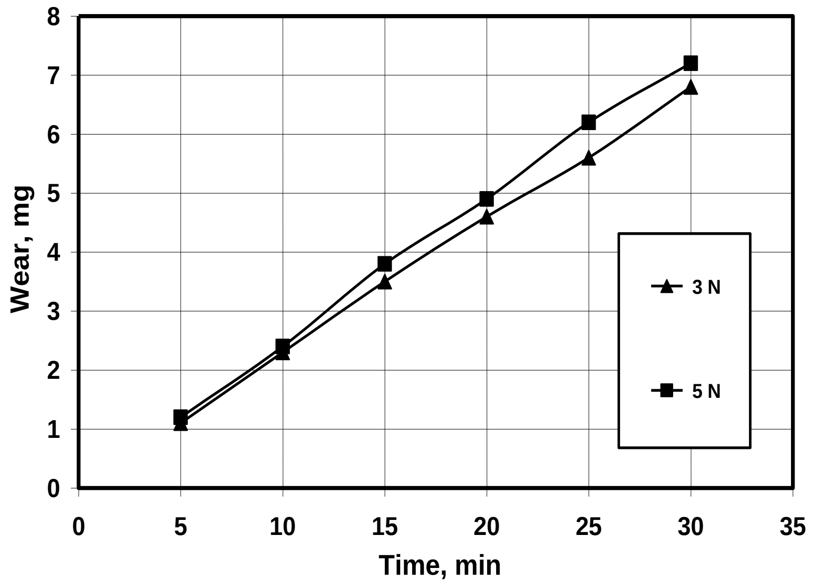

Fig. 5 Wear of acrylic tooth using tooth paste C_2 by silica abrasives of particle size (11 – 13) µm.

For acrylic tooth brushed using paste C_3 with silica abrasives of particle size (15 – 20) µm, Fig. 6, it is observed that, the difference between the wear values displayed by the loads 3 and 5 N showed significant increase. With increasing the force to 5 N, the wear increased to 10.7 mg at 30 minutes in presence of Water.

Fig. 7 shows the mechanical wear of acrylic tooth brushed by using paste C_4 with silica abrasives of particle size (20 – 24) µm. It is observed that, the same behaviour for Fig.3.30. The value of wear reached 8.5 mg at a force of 3 N, at 30 minutes. With increasing the force to 5 N, wear increased to 11 mg at 30 minutes in presence of water.

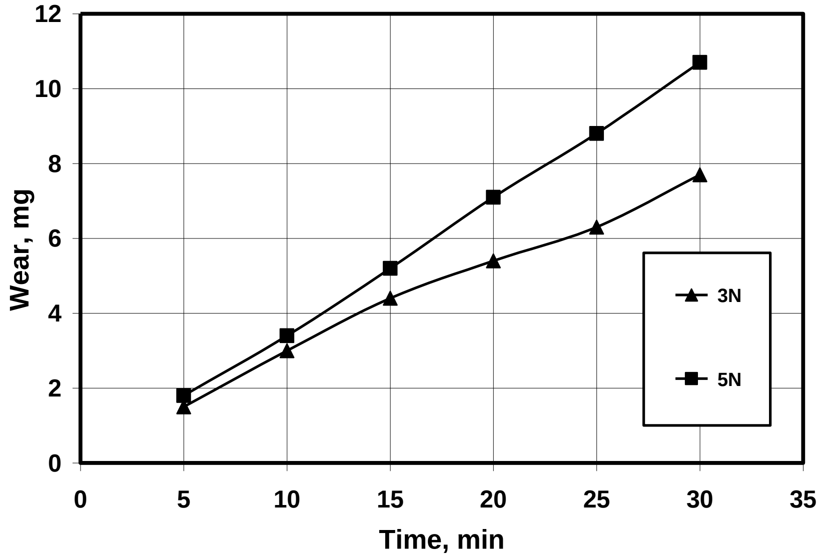

Fig. 6 Wear of acrylic tooth using tooth paste C_3 by silica abrasives of (15 – 20) µm particle size.

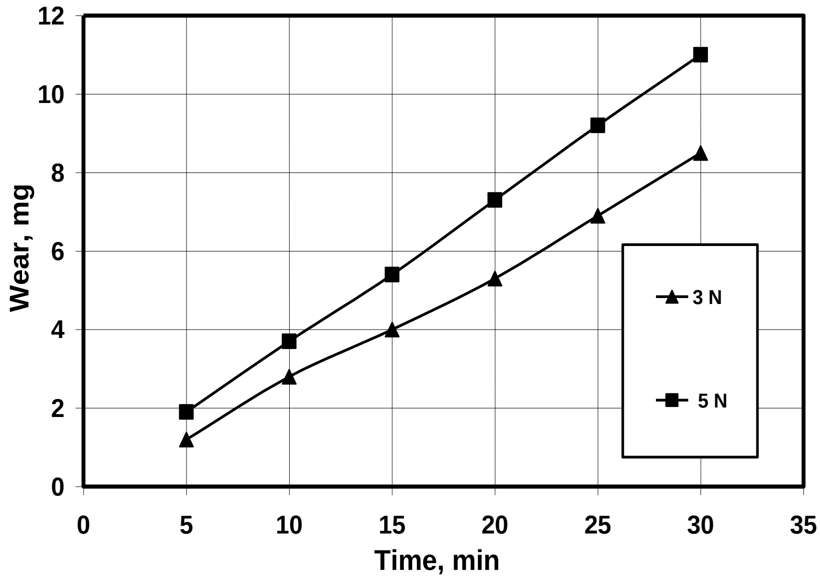

Fig. 7 Wear of acrylic tooth using tooth paste C_4 by silica abrasives of (20 – 24) µm particle size in presence of water.

Figure 9 shows the mechanical wear of acrylic tooth brushed by using paste C_6 with silica abrasives of (42 - 52) µm particle size. Generally, it can be noticed that the wear slightly increased with increasing the force. At a force of 3 N the mechanical wear reached 9.8 mg at speed of 150 strokes/min, at 30 minutes. This value increased at force of 5 N and reached to 12.5 mg. Wear values increased with increasing abrasive particle size. This behaviour might be attributed to the fact that as the particle size increases the depth of penetration of the particle inside the sliding surfaces increases and consequently the volume of material removed increases.

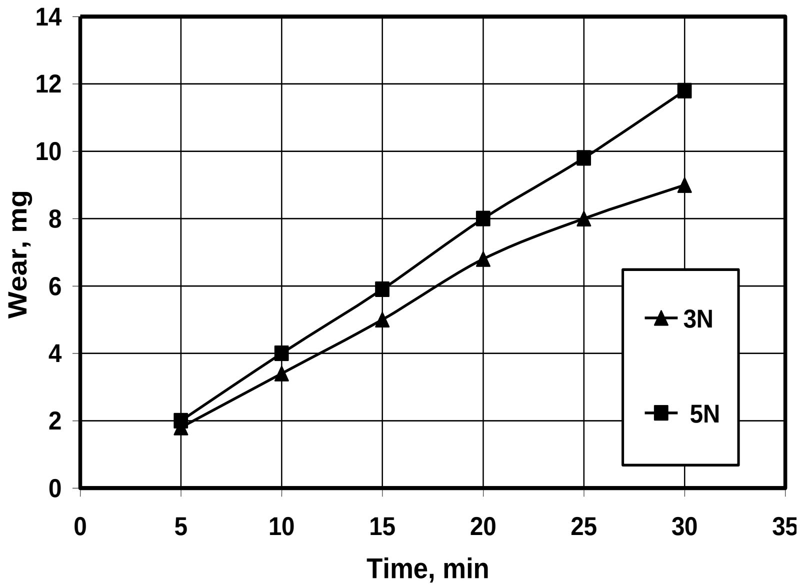

Fig. 8 Wear of acrylic tooth using tooth paste C_5 by silica abrasives of (28 – 32) µm particle size.

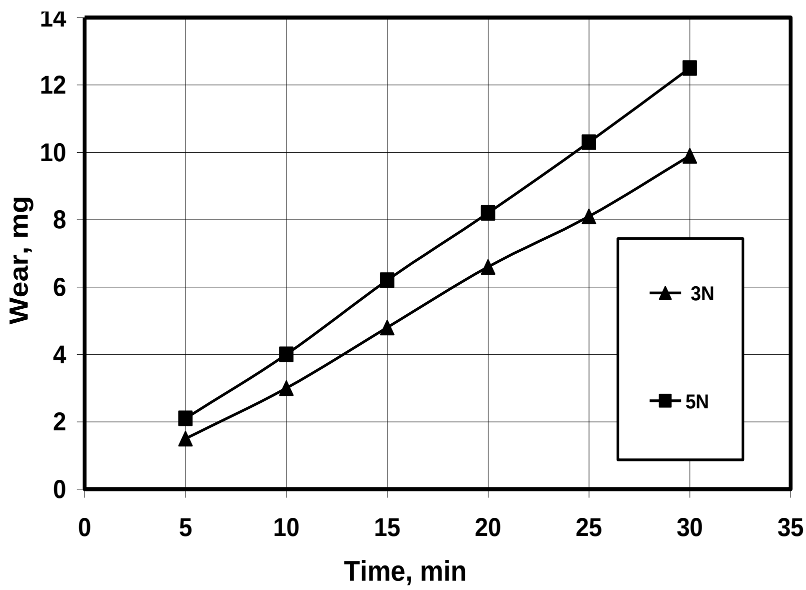

Fig. 9 Wear of acrylic tooth using tooth paste C_6 by silica abrasives of (42 – 52) µm particle size.

For acrylic tooth brushed using paste C_7 contaminated by Arizona sand (ACFTD) abrasives of (0 – 80) µm particle size Fig. 10, it is observed that, the value of wear reached 10 mg at a force of 3 N, at 30 minutes. With increasing the force to 5 N, wear increased to 12.8 mg. Wear displayed represented the highest values among the tested abrasives. Tooth paste C_6 contaminated the by silica abrasives of (42 – 52) µm particle size displayed the same values. This observation recommends that it is necessary to avoid abrasives of such critical particle size to prevent the excessive wear of toot durinf polishing.

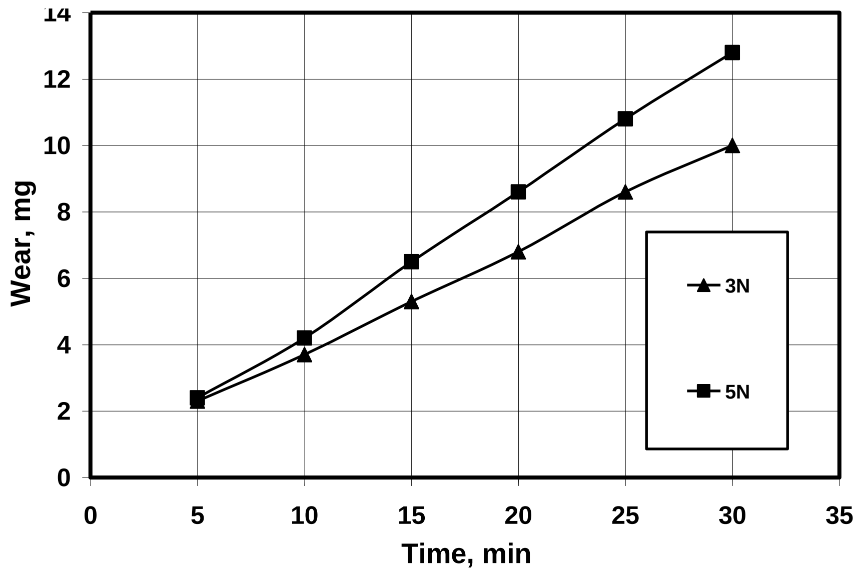

Fig. 10 Wear of acrylic tooth using tooth paste C_7 by Arizona sand (ACFTD) abrasives of (0 – 80) µm particle size.

Wear of the acrylic tooth brushed in the presence of paste C_8 contaminated by Arizona sand (ACFTD) of (0 – 200) µm particle size is shown in Fig. 11. Generally, it can be noticed that wear slightly increased with increasing the force. The difference between wear values observed at force values of 3 and 5 N was insignificance in contradiction to the condition of using Arzona sand (ACFTD) of (0 – 80) µm particle size as shown in Fig. 10.

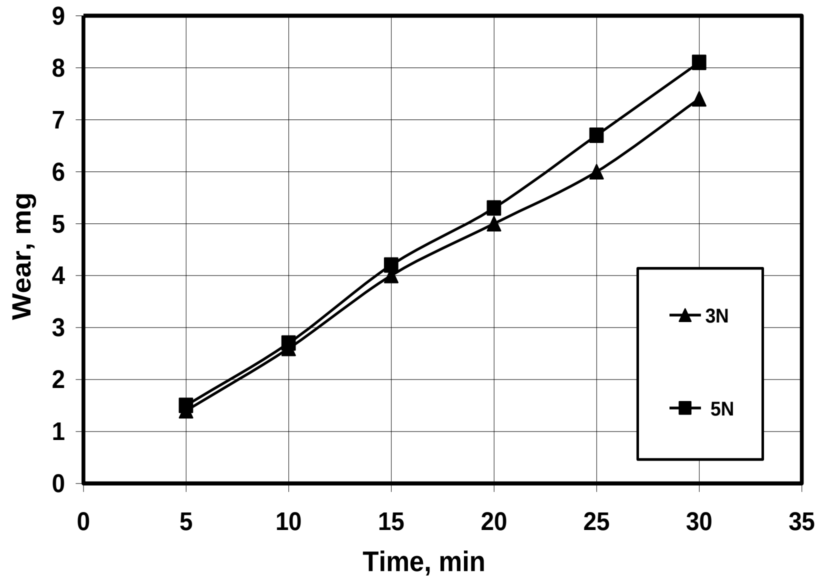

Fig. 11 Wear of acrylic tooth using tooth paste C_8 by Arizona sand (ACFTD) abrasives of (0 – 200) µm particle size.

Figure 12 shows the mechanical wear for acrylic tooth using tooth paste C (without abrasives). In this condition wear was of adhesive type. In spite of absence of abrasives wear increased from 1.2 to 2.0 mg as the force increased from 3 to 5 N. In this case two

body abrasion was occurred between brush and tooth. Wear was caused by the plastic deformation of the peaks of asperities of the tooth which facilitated material removal.

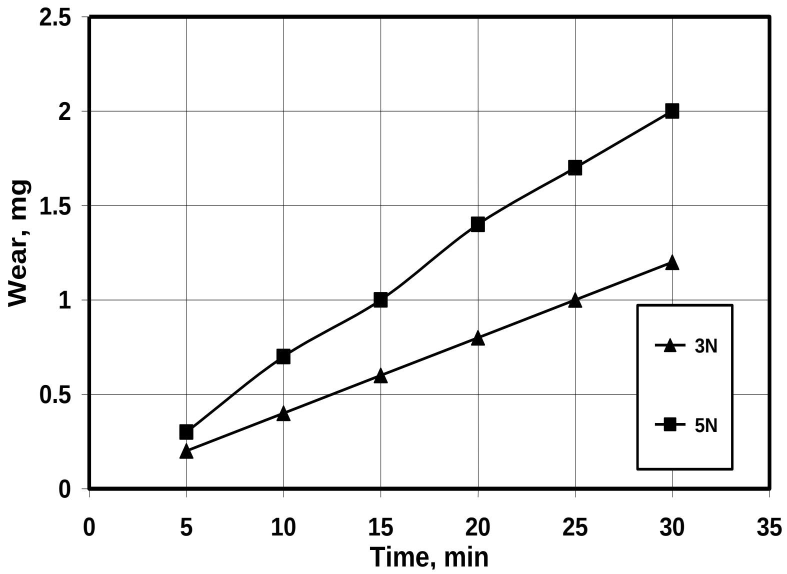

Fig. 12 Wear of acrylic tooth using tooth paste C (without abrasives).

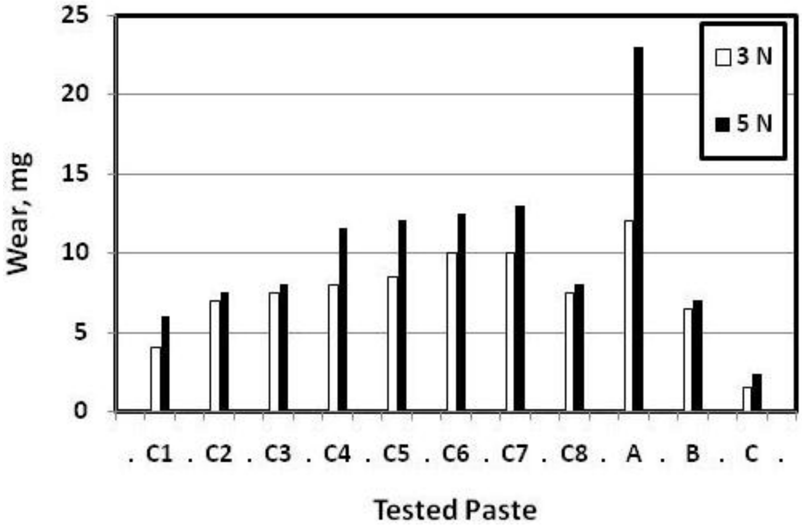

Fig. 13 A comparison between the all types of pastes used in the experiment brushed at acting force of 3N and 5N.

Figure 13 illustrates the comparison between all the tested pastes used in the experiment brushed at acting force of 3N and 5N, where wear showed different trends with increasing the acting force for the different particle size of abrasive contaminating the pastes. Paste A represented the stronger effect of the force acting the tooth, where wear showed double the value when the acting force increased from 3 N to 5 N. The was attributed to the increasing force which causes increasing depth of cut and then sudden increase might be from the sharp corners of abrasive contaminated in the paste A. Moderate wear was observed for paste B, which recommend that paste to be safely used in tooth polishing

CONCLUSIONS

Based on the results of this work, the following conclusions can be withdrawn:

1. The influence of the force on the abrasive wear of the teeth increased with increasing abrasive particle size. The most pronounced influence was displayed by paste A that contaminated by abrasive of 30 – 40 µm particle size.

2. Abrasives of wide range of particle size such as air cleaner fine test dust (0 – 80 µm) and air cleaner coarse test dust (0 – 200 µm) showed lower wear than paste A.

3. Paste B displayed slight wear increase with increasing the acting load.

4. Significant wear increase was observed for Paste free of abrasives.

5. It is recommended to avoid the abrasive particle sizes ranging from 20 - 50 µm to reduce the wear occurred when polishing the teeth.

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