Validation of professional tooth brushing test device, test methodology and analysis

B M Achimescu, S Ciortan and M Buciumeanu

"Dunărea de Jos" University of Galati, Faculty of Engineering, Domneasca 47, 800008 Galati, Romania

E-mail: mihaela.buciumeanu@ugal.ro

Abstract. The present work is focused on developing a test apparatus to simulate the contact situation of the toothbrush used in professional toothbrushing (cleaning and polishing) and a dental biomaterial. Cylindrical samples (8×5 mm) were manufactured from a resin composite (frequently used in practice) in similar manner with the preparation of dental restorations in clinical conditions. The tests were carried by using two different toothpastes: a professional toothpaste and a home used toothpaste. All the experiments were carried out for 15 min, under 280 g normal load applied on the brush and the operating speed was around 5000 rev/min. The preliminary results on the dental restorative material selected for this study indicated that the proposed system is consistent and useful for the investigation of the microabrasion processes that arise at the surface of dental biomaterials.

1. Introduction
Some of the most common procedures in clinical practice in dentistry are direct restorations, to replace lost or damaged dental tissue. At present, a wide range of direct restoration products are available on the market, with multiple indications and adapting to the requirements of both dentist and patient [1 - 3].

It is well known that the oral cavity is a complex system, as there it is the action of several factors, such as saliva (acts as lubricant), temperature (ranging from - 10 to 50 °C), pH variation (ranging from 1 to 9), contact load (ranging from 3 to 1000N), etc. [4]. Besides, there is the influence of chemical components coming from food, drinks, and also from toothpaste, mouthwash, prophylactic gels etc. [5]. Thus the restorative materials suffer degradation due to synergetic effect between mechanical and chemical interaction.

If the regular toothbrushing used minimum twice a day for 2-3 minutes is manly for cleaning, thus preventing diseases, the professional toothbrushing is fundamental for both cleaning and/or polishing results [6]. As specified by providers those products have a low abrasion of enamel and dentine in a one-step procedure.

During the professional / regular toothbrushing the dental restorations are exposed to the action of abrasive particles / compounds from the toothpastes, such as: hydrated silica, calcium carbonate, sodium bicarbonate, etc. In some cases, these may increase the surface roughness of the restorative biomaterials. An increase of roughness with time was also reported for all dental restorations [1]. Cavalcante et al. [7] reported in their study about the effect of fillers' size on surface properties after toothbrushing, that the larger filler sizes caused a higher surface roughness after toothbrushing. This

increase on roughness was also confirmed by Jain and Wadkar [8] in their study about the effect of fillers on surface roughness of a nanofilled composite and a nanohybrid composite. A rougher surface, affects the aesthetic quality of a restoration, leads to perfect place for bacteria colonization site and also increases of wear loss of the antagonist, as the asperities acts like abrasive particles [9].

The objective of this study was to design a very simple and versatile device that is able to simulate the processes that arise at the contact situation of the tooth / restorative biomaterial surface and brush during the professional cleaning or polishing. This may be also important in the case of orthodontic appliances, as the oral hygiene in this case should be more carefully carried out, as around brackets it is easy to form a bacterial colonization site.

2. Materials and preparation of the samples

2.1. Materials
In this study commercially available resin composites for dental restorations was selected, namely Filtek™Ultimate Universal dental restorative composite (3M-ESPE, St. Paul, MN, USA). As specified by the manufacturer, this type of dental restorative composite has the lowest wear rate of all leading composites. It has been mentioned that this is due to the fact that the nanoparticles used are not obtained by grinding process and some nanoparticles are fused into nanoclusters. More details regarding the compositions and also, size and volume of the fillers of this material are provided by the manufacturer. As reported by Ferracane [1] there are many applications in dentistry where resin composites are used and are subjected the polishing or brushing. For examples cavity liners, inlays, onlays, crowns, provisional restorations etc.

2.2. Production of the samples
Cylindrical samples (8 mm in diameter and 5 mm in height) were produced from resin composite by following all the instructions provided by the manufacturer. To be consistent, the same person prepared all the samples. The sample were formed in a yellow polycarbonate mould. The resin composite was placed into the mould in layers of approximately 2 mm and each layer was light-cured for 40 s. The dental curing light device used was DENTMATE WL-070 (DENTMATE TECHNOLOGY CO., LTD., Taiwan). According to the manufactured, the output wave length range of the curing light varies from 440 and 480 nm, and the intensity up to 1200 mW/cm².

After polymerization, the samples were removed from the mould and were wet ground with SiC abrasive papers (down to 4000 mesh) and then polished with diamond paste. Samples were subsequently ultrasonically cleaned in an alcohol bath for 15 min and then in distilled water for 15 min. Before the toothbrushing tests, the resin composite samples were stored in modified Fusayama artificial saliva solution for 7 days. The composition of the modified Fusayama artificial saliva solution is given elsewhere [10].

3. Results and discussions
Is well known that toothbrushing is used for preventing first the dental diseases. Besides other ingredients, the content and size of the abrasive compounds added to professional toothpastes may not affect the enamel, as they are selected to have least damaging effect, but in many situations has been reported that it affects the surface of dental restorations [8].

3.1. Presentation of the new designed toothbrush device
Figure 1 (a) shows a global view of the tooth brushing test device, while figure 1 (b – d) presents some detail views of the device during the tests. These images allow to see all the components of the device. It can be seen from figure 1 (b) that the sample (9) is mounted horizontally in the samples block holder (1). The toothbrush (3) is fixed and vertically loaded against the sample by a calibrated weight (5). The speed of the electrical motor (4) is controlled by a speed controller (7).

The device was conceived to work at ambient temperature, in laboratory environment. It is a simple and versatile device. All types of dental materials can be tested, from ceramics, polymers and

also metals. In the case of metallic biomaterials used for restorations (for example for dental crowns - metallic, metallic - ceramic, metallic - acrylic, metallic – composite, but also for orthopedic applications), it is also possible to evaluate their electrocorrosion behavior during the brushing test. In this case, the brushing device should work together with a potentiostatic assembly. This is an important aspect, as there are electrochemical reactions that occur at the surface of the metallic restorative material in the presence of physiological fluid and it may lead to degradation by corrosion and as a consequence metallic ions are realized into the body [10, 11].

Any type tool used in common practice for polishing or cleaning, such as dental polishing brushes (toothbrushes with different bristle stiffness) or rubber cups can be used with this new device. These tools for polishing / cleaning are used together with prophylactic paste which contains different amount abrasives (with various size, shape, and hardness).
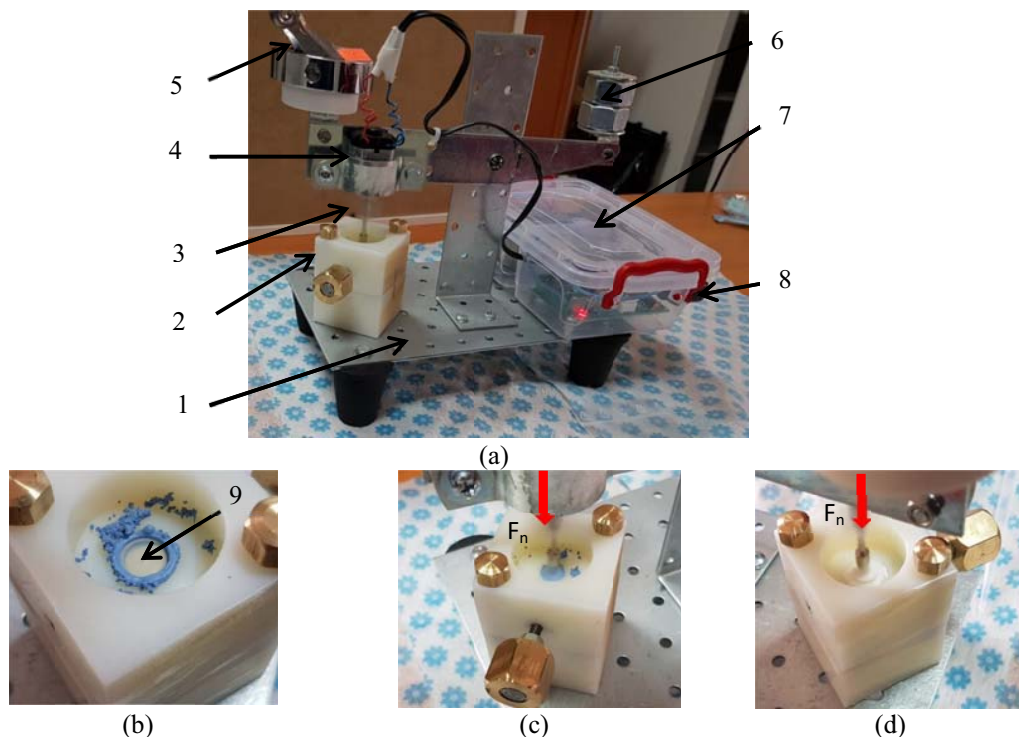

(a)

(b)   (c)   (d)

Figure 1. Images of the tooth brushing test device: (a) General view, where: 1 - Base structure; 2 - Sample block holder; 3 – Toothbrush; 4 – Electrical motor; 5 - Calibrated weight to apply normal load; 6 – Counterweight 7 – Speed controller 8 - Rotary potentiometer; 9. Sample; F_n – Normal load; (b) Detail view of the sample block holder, and (c) and (d) Detail views during the brushing tests.

3.2. Details of the toothbushing tests

Conditions for tests were selected to be as close as it is possible to the clinical conditions used by a dentist during professional cleaning and/or polishing. All the experiments were carried out with a normal load applied on the brush approximately 280 g and the operating speed was around 5000 rev / min. According to the manufacturer the time for polishing / cleaning the teeth / restorative material with Kerr Cleanic Prophylaxis Paste is around 15 min, thus the duration of each test was 15 min.

In order to see if this new device is able to simulate the professional toothbrusing, the tests were carried out by using two different toothpastes: a professional toothpaste with abrasive particles (Kerr Cleanic Prophylaxis Paste Single Dose) and a home used toothpaste (Sensodyne, GlaxoSmithKline Consumer Healthcare S.R.L). As mention by the manufacturer the Kerr Cleanic Prophylaxis Paste

during the initial seconds of use has a very high cleaning power, but after that it changes into a gentle polishing action as the Perlite particles are fragmented.

As toothbrush was selected a professional perfect filament shape and for each test was used a new toothbrush.

For comparison purposes some test were also carried out in artificial saliva solution, in order to understand the influence of the toothbrush.

Five tests were carried out for each studied condition.

3.3. Morphological analysis of the samples
Figure 2 shows the SEM images of resin composite samples before the brushing tests with two different magnifications.

From the SEM images with lower magnification (figure 2 (a)) can be seen that the surface is relatively smooth, while from the SEM image with higher magnification (figure 2 (b)) it can be observed some channels from the polishing. The intention was not to have a perfectly smooth surface, as in clinical practice after the insertion of a resin composite into a cavity, the surface will not be perfectly smooth. On the other hand, as reported by Ferracane [3] generally these composite resins are quite difficult to polish and most of the time impossible to maintain surface smoothness due to the fillers content, distribution and size.
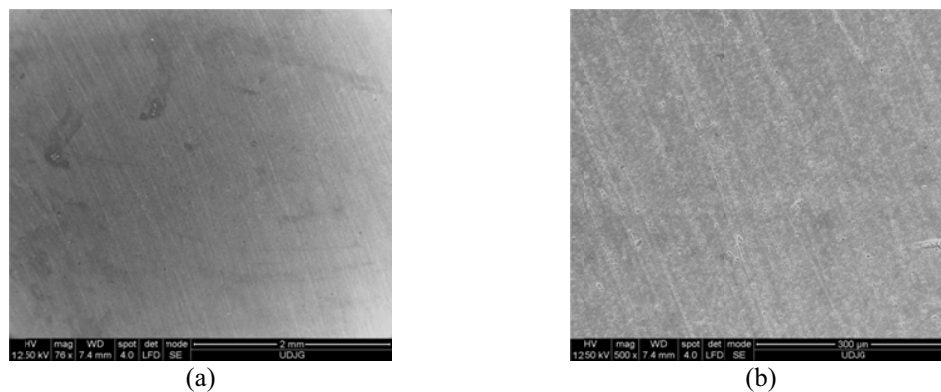

(a)   (b)

Figure 2. SEM images of as-processed resin composite representing general views at two different magnifications: (a) low magnification (76 x) and (b) higher magnification (500 x).

From the SEM image with higher magnification can be also observed some porosities (figure 2 (b)). These tiny pores are induced during the insertion of the composite resin into the cavity / mould, when air bubbles are incorporated into the material [12]. These may also increase the surface roughness of the composite.

Figure 3 shows the SEM images with two different magnifications 67 x and 500 x of the representative wear marks produced on the resin composite samples after the brushing tests for all three cases studied: professional toothpaste, Sensodyne and artificial saliva.

From the SEM images with lower magnification (figure 3 - top line), it can be seen that all the channels from the polishing were removed by the synergetic action of the brush and paste used. Only in the case of artificial saliva it still can be observed the channels from polishing (figure 3 (c)). This means that the influence of the brush is less pronounced (figure 3 (c) – bottom line) as compared to the action of the toothpastes (figure 3 (a) and (b)). After the brushing test when was used artificial saliva it was not observed any deterioration of the toothbrush, this was as stiff as in the beginning of the test.

From SEM images presented in Figure 3 can be observed grooves that are perfectly aligned to the movement of the toothbrush in all studied cases. The grooves are attributed to the abrasive wear mechanism (three-body abrasion – due to the presence of the abrasive particles from the toothpaste).

Based on qualitative analysis, the worn surface of the resin composite samples when was used the professional toothpaste reveals (figure 3 (a)) a rougher appearance than that in the case of home used toothpaste. Thus, it indicates a higher level of surface degradation when the professional toothpaste is used.
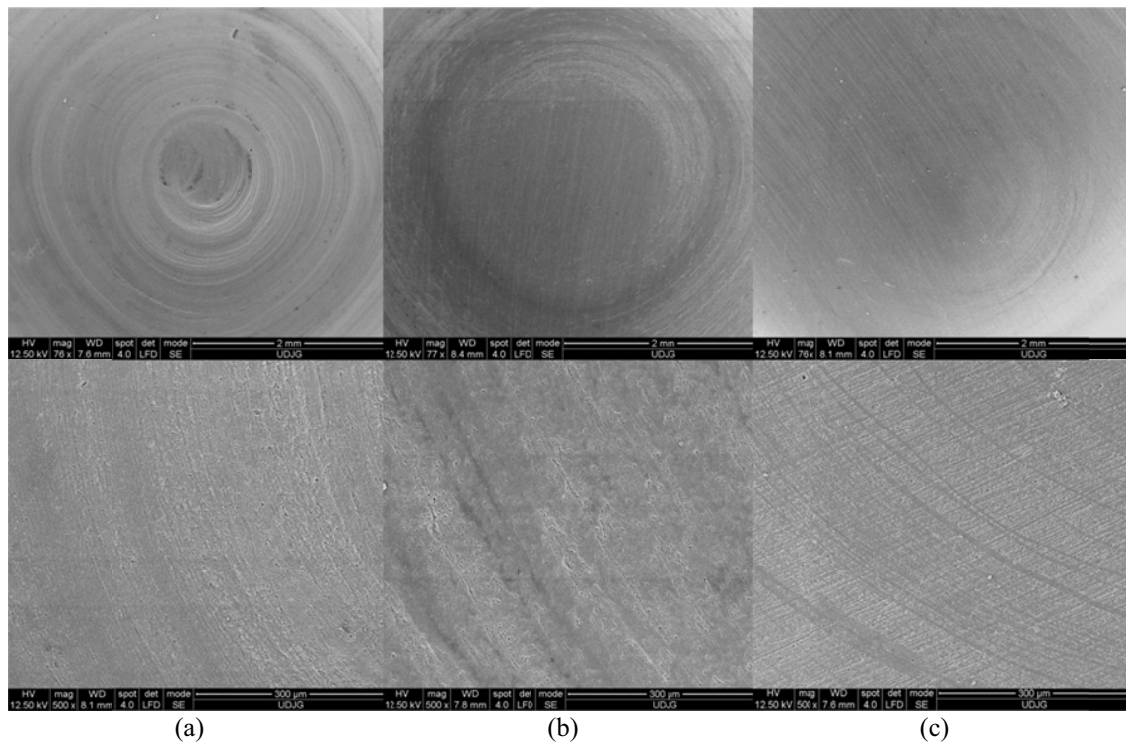

Figure 3. SEM images of the centre area of the wear track at two different magnifications (76 x – top line and 500 x - bottom line) formed after brushing tests on resin composite samples in the presence of different solutions: (a) professional toothpaste, (b) a home used toothpaste (Sensodyne) and (c) artificial saliva.

Even if locally in the case of Sensodyne toothpaste it can be observed a deeper groove in the middle of the wear track, in the case of the professional paste can be observed more grooves distributed on the wear track. The deeper groove observed in the case of Sensodyne toothpaste is due to the fact that it has a more sticky consistency then the professional toothpaste. The consistency of the Sensodyne toothpaste does not allow to the bristles of the toothbrush to spread out, the bristles remain stick and they slide in the same place. In the case of professional toothpaste, as mentioned before, it has a very high cleaning power in the beginning of the test, but after that it changes into a gentle polishing action due to the fragmentation of Perlite particle, thus changing the consistency of the paste. Thus, after few minute the bristles of the toothbrushes are more flexible and their action is spread out over the samples surface.

4. Conclusions

The design and the utilities of a newly developed test apparatus to simulate the processes that arise at the contact situation of the tooth / restorative biomaterial surface and brush in professional toothbrushing have been described.

- It is a very versatile apparatus and suitable for the study of any dental material. It can be adapted also in the case of metallic biomaterials to measure the electrochemical parameters.

- Significant differences were observed between the three studied cases. Within the limitations of the study it can be concluded that this device allows a better understanding of the influence of the tools (brushes, cups) used by dentists for cleaning, polishing etc.; the influence of toothpastes used in dentistry for cleaning the natural tooth, and also for polishing of any biomaterials used to replace a tooth (inlays, onlays, crowns, provisional restorations etc.).

- It seems that influence of the toothbrush alone without any paste is very small, as on the samples surface were observed only some slight scratches, and no damage of the toothbrush.

- Based on a qualitative analysis, the most sever abrasive wear was observed in the case materials tested with professional toothpaste, even though in the specification of the provider of the toothpaste it is mentioned that this has a low abrasion of enamel, which is the hardest substance in the human body. Maybe this degradation is due to a high amount and/or size of abrasive particles added to the paste.

Further tests and calibrations are needed in order to properly quantify the variables.

Acknowledgments

5. References

[1]   Ferracane J L 2011 *Dent. Mater.* **27** 29–38

[2]   Souza J C M, Bentes A C, Reis K, Gavinha S, Buciumeanu M, Henriques B, Silva F S and Gomes J R 2016 *Tribol. Int.* **102** 154–60

[3]   Rodrigues D S, Buciumeanu M, Martinelli A E, Nascimento R M, Henriques B, Silva FS and Souza J C M 2015 *J. Bio- Tribo-Corrosion* **1** 24

[4]   Antunes P V, Ramalho A 2003 *Wear* **255** 990–8

[5]   Xavier A M, Sunny S M, Rai K and Hegde A M 2016 *J. Clin. Exp. Dent.* **8** e312–7

[6]   Sawai M A, Bhardwaj A, Jafri Z, Sultan N and Daing A 2015 *J. Indian Soc. Periodontol* **19**   375–80

[7]   Cavalcante L, Masouras K, Watts D, Pimenta L and Silikas N 2009 *Am. J. Dent.* **22** 66–4

[8]   Jain N and Wadkar 2015 *Int. J. Dent. Oral Heal.* **1.1** 1–5

[9]   Buciumeanu M, Queiroz J R C, Martinelli A E, Silva F S and Henriques B 2017 *Tribol. Int.* **116** 192–8

[10]   Buciumeanu M, Bagheri A, Souza J C M, Silva F S and Henriques B 2016 *Tribol. Int.* **97** 423–30

[11]   Reclaru L, Unger R E, Kirkpatrick C J, Susz C, Eschler P Y, Zuercher M H, Antoniac I and Lüthy H 2012 *Mater. Sci. Eng. C* **32** 1452–60

[12]   Fleming G J P, Farooq A A and Barralet J E 2003 *Biomaterials* **24** 4173-9