Original Article

Effect of cigarette smoke on the surface roughness of two different denture base materials: An *in vitro* study

Girendra Singh, Abhinav Agarwal, Manesh Lahori

Department of Prosthodontics, K.D. Dental College and Hospital, Mathura, Uttar Pradesh, India

Abstract

Aim: This study aimed to evaluate the effect of cigarette smoke on the surface roughness of two commercially available denture base materials.

Materials and Methods: A total numbers of 40 specimens were fabricated from two commercially available denture base materials: heat-cured polymethylmethacrylate and flexible denture base materials (20 for each). The specimens for each type were divided into four subgroups: subgroup I, heat-cured denture base material specimens (control group); subgroup II, flexible denture base material (control group); subgroup III, heat-cured denture base material specimen exposed to cigarette smoking group; and subgroup IV, flexible denture base material specimens exposed to cigarette smoking. The control groups were used for immersion in distilled water, and the smoke test groups were used for exposure to cigarette smoking. The smoke test group specimens were exposed to smoking in a custom-made smoking chamber using six cigarettes for each specimen. The surface roughness was measured using a profilometer, and the measurements were considered as the difference between the initial and final roughness measured before and after smoking. Paired *t* test and independent *t*-test were used to interpret differences in initial and final roughness values within and between groups respectively.

Results: Paired *t*-test showed a significant difference between initial surface roughness and final surface roughness within each subgroup.

Conclusion: The surface roughness of the specimens fabricated from the flexible denture base material was found to be more compared to heat-cured denture base specimens after exposure to cigarette smoke.

Keywords: Cigarette smoke, profilometer, surface roughness

Address for correspondence: Dr. Girendra Singh, 43-Aakash Nagar (Vishawlaxmi Nagar) Govardhan Choke, Mathura, Uttar Pradesh, India.
E-mail: girendra.coolsmart@gmail.com
Received: 25th February, 2018, **Accepted:** 13th July, 2018

INTRODUCTION

The heat-cured polymethylmethacrylate (PMMA) polymers have been the most popular choice as conventional denture base materials for nonmetallic denture fabrication since its introduction in 1937 because of low cost, less solubility, less water sorption, and ease fabrication of denture bases by simple processing techniques with acceptable physical

Access this article online	
Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/jips.jips_82_18

How to cite this article: Singh G, Agarwal A, Lahori M. Effect of cigarette smoke on the surface roughness of two different denture base materials: An *in vitro* study. J Indian Prosthodont Soc 2019;19:42-8.

and mechanical properties. Regardless of many favorable properties, residual methyl methacrylate monomer may induce hypersensitivity reactions in some patients.[1]

Selection of denture base resins is equally important along with clinician's skills in designing and fabrication of a prosthesis as the patient has to use the prosthesis for a long period. Nylon as a denture base material was first introduced in the fabrication of denture bases in the 1950s. Nylon is a type of thermoplastic polymer classified under polyamides, which are produced by the condensation reactions between a diamine and a dibasic acid. PMMA is amorphous while nylon is a crystalline polymer. This crystalline effect imparts properties such as insolubility of nylon in solvents, high heat resistance, and high strength with ductility.[2]

Nylon materials have some other advantages such as higher elasticity, less toxicity, and less polymerization shrinkage compared to heat-cured resins. On the other side, these materials also have problems such as water sorption, warpage, color deterioration, and surface roughness due to difficulty in polishing which leads to bacterial contamination.

The World Health Organization has reported cigarette smoking as a public health issue in billions of people across the world. The toxic substances of cigarettes are mainly produced during its burning, but some substances are already present in the plant. In patients with smoking habit, the denture base materials are exposed to thousands of cigarette toxic substances such as ammonia, nickel, arsenic, carbon monoxide, formaldehyde, radioactive polonium, tar, and heavy metals. According to previous investigations, cigarette smoke can affect the surface roughness, color, and microhardness of various dental restorative materials such as composites.[3]

Very few studies in literature have standardized the manner of subjecting restorative materials to cigarette smoke. These studies assessed the effect of cigarette smoke without standardizing the number of cigarettes, armamentarium used, smoke flow, and time of the smoke exposure to various restorative materials and denture base resins.[4,5]

Ideally, denture base materials should have a smooth and highly polished surface for patient's comfort and denture longevity, esthetics, oral hygiene, and low plaque retention. Surface roughness is one of the significant properties of the denture bases as they are in direct contact with the oral tissues and a rough surface may affect tissue health due to the accumulation of microorganisms. These microorganisms can lead to an increase in the pervasiveness of denture stomatitis, rate of staining, halitosis, and discomfort. Therefore, the surface roughness is a significant property for the success of complete denture.[6]

The present study is conducted to determine the influence of cigarette smoking effects on the surface roughness of two different denture base materials.

MATERIALS AND METHODS

Fabrication of wax pattern

For this study, a stainless steel mold was fabricated which provided a circular shape of 30 mm × 2 mm diameter for the preparation of acrylic disc specimens of standard dimensions [Figure 1].

Modeling wax was melted and poured in the mold, and forty wax specimens in the shape of circular discs were prepared which were further divided into two groups: twenty specimens of heat-cured denture base materials and twenty specimens of flexible denture base materials.

Fabrication of heat-cured denture base resin (DPI) specimens

Twenty wax specimens were invested in the Hanau dental flask. Dewaxing was done and packing procedures were completed using the DPI heat-cured denture base material.

The specimens were allowed to undergo short-time polymerization in water bath at 74°C for 2 h, followed by 30 min boiling in 100°C water, and then the flasks were allowed to cool at room temperature before opening.[7]

After deflasking, all the specimens were smoothened using progressively smoother sandpapers with grit numbers 150, 220, 320, 400, 600, and 1200 and polished with a lathe cut polishing machine, and surface of each specimen was polished by a standardized method, on a wet rag wheel with a slurry of pumice [Figure 2]. Then, all the specimens were immersed in distilled water at 37°C ± 1°C for 48 h followed by initial surface roughness test.

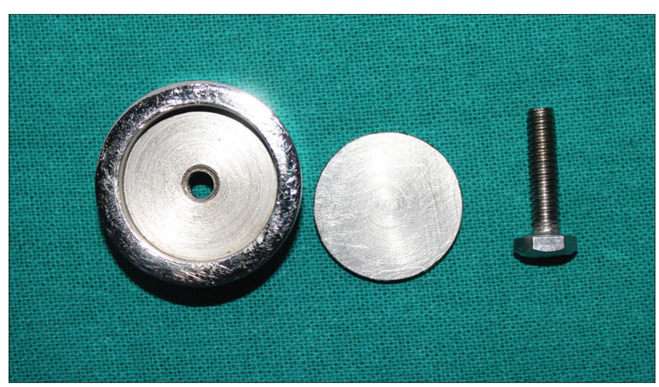

Figure 1: Split Die

Fabrication of flexible denture base material (VALPLAST) specimens

The wax specimens were invested in a special flask designed for injection molding technique and the sprue formers were attached to make the channels for the flow of the fluid into the mold. After investing, dewaxing was done by placing the flask in boiling water for 3–5 min to soften the wax. The flask was opened and flushed with clean boiling water to remove all the wax residues. Flask margins were checked to ensure that both halves fit together with intimate metal contact.

After dewaxing, a thin coat of separating agent was applied and the mold was allowed to dry completely. Later, a cartridge of suitable size was selected and sprayed with silicon to prevent adhesion of the cartridge with the cartridge carrier and to allow smooth separation. The cartridge was placed in the cartridge carrier which was later placed in an electric cartridge furnace.

The material was plasticized for 15–20 min at 550°F –560°F as per the manufacturer's instructions. This temperature was maintained for 15–20 min. Then, the cartridge was removed from the electric furnace and placed on the inlet of the flask to compress the material.[7]

The contents of the cartridge should be injected in the flask within 1 min after removal from the electric furnace or it may result in partial or no injection. Later, the levers of the press are turned rapidly to apply firm pressure until the springs of the press are fully compressed.

The pressure is maintained for 3–5 min. The flask is allowed to bench cool for at least 15–20 min before opening. The flask was opened and the specimens were retrieved and finished with vulcanite burs and green and pink mounted stones, usually used for porcelain finishing, using a rapid and light shaving motion. After finishing, specimens were polished with pumice first followed by brown tripoli and finally high luster shine was achieved by polishing with polishing cake and dry buff [Figure 3]. Then, all the specimens were immersed in distilled water at 37°C ± 1°C for 48 h followed by initial surface roughness test.[8]

All the specimens (Group I and Group II) were immersed in distilled water at 37°C ± 1°C for 48 h for residual monomer release. After incubation period, the specimens were dried with air, and initial surface roughness was measured for the polished surface of all specimens.

The initial surface roughness values were measured using a pick-up-type piezoelectric profilometer. The profilometer has a diamond stylus with a tracing length of 5–10 mm. The stylus is moved across the specimen surface with 0.8 mm

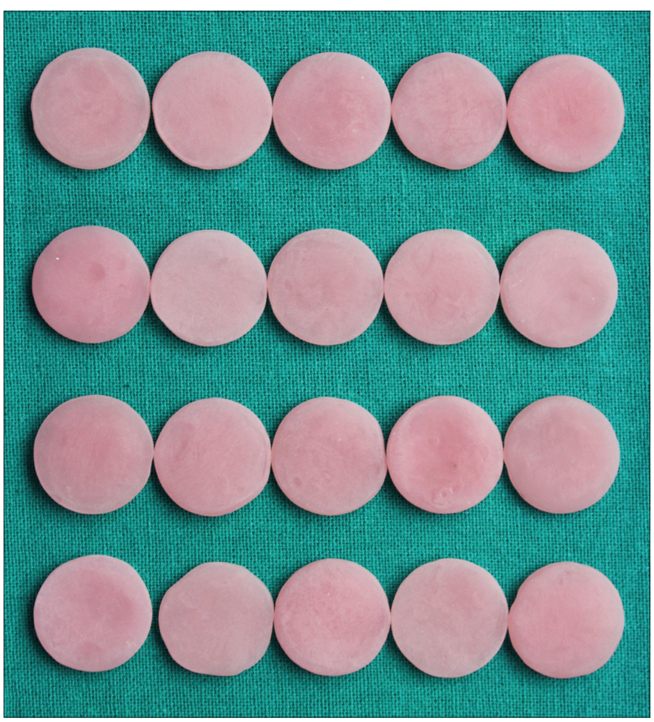

Figure 2: Heat-cured denture base specimens after finishing and polishing

Figure 3: Flexible denture base specimens after finishing and polishing

cutoff and at a speed of 0.5 mm/s. The stylus was moved across the specimen surface and three scanning lines were recorded. Each scanning line had a distance of 1 mm with each other. Later, the mean of these three readings was calculated and considered as a surface roughness value for each specimen [Figure 4].[1]

After the initial value, both specimens were randomly divided into four subgroups ($n = 10$).

- Subgroup I – Heat-cured denture base material specimens (control group)
- Subgroup II – Flexible denture base material specimens (control group)
- Subgroup III – Heat-cured denture base material specimens exposed to cigarette smoking (study group)
- Subgroup IV – Flexible denture base material specimens exposed to cigarette smoking (study group).

The control subgroup (I and II) specimens were immersed in artificial saliva for 21 days and smoke test subgroup (III and IV) specimens were subjected to smoking in a custom-made smoking chamber partially filled with artificial saliva for 21 days before measurement of final surface roughness.

Preparation of artificial saliva

Artificial saliva used in this study was prepared to closely resemble human saliva and salivary substitutes. The pH of all formulations was kept within the range of the normal pH of human saliva. The electrolytes were added to mimic those found in natural saliva. Various materials used for the preparation of artificial saliva were dipotassium hydrogen phosphate, sodium fluoride, magnesium chloride, glucose, methylparaben albumin, methyl cellulose, sodium carboxymethyl cellulose, hydroxypropylmethyl cellulose, and potassium chloride [Figure 5].[9]

Custom-made smoke chamber

An insulating material was used to fabricate the chamber to prevent the dissipation of raised temperature inside the chamber to outside. The smoke chamber had a separable lid which closed the chamber hermetically. The volume of the smoke chamber was kept as minimum as possible. An inlet was designed at the center of the lid of the chamber where lit cigarette could be snugly fitted into the cigarette holder. Another opening of the same diameter was made on the periphery of the lid of the chamber as an outlet [Figure 6].[10]

To simulate the process of smoking *in vivo*

1. The smoke chamber was connected to the vacuum system through a flow meter and a control for the vacuum system

Figure 4: Specimen undergoing surface roughness test

Figure 5: Artificial saliva

Figure 6: Custom-made smoking machine

2. The vacuum control was monitored by a flowmeter and adjusted to maintain a steady flow rate of 30 cm^3/s
3. To simulate active inhalation of smoke (puff duration) *in vivo*, the outlet was closed and the vacuum system was switched on for 2 s[11]
4. Outlet on the lid was left open for 60 s to maintain passive exhaust of smoke before the next smoke cycle was performed.[12]

Arrangement of specimens

A base was fabricated with a silicone material to support the specimen and placed in the center of the glass jar. The polished surface of the specimen was kept in direct exposure to cigarette smoke. The cigarette was closely fitted in the tube within 10 mm distance from the specimen surface, and the lid was locked. Later, the smoking chamber was assembled in a vacuum pump machine with another tube after adjusting the negative pressure (20 mmHg; 1 mmHg = 133 Pa). Six cigarettes were used and each cigarette burned in a standard time of 10 min. The aspiration time/pressure was controlled and programmed with a switch pressure and timer of the vacuum machine.[1]

Exposure of specimens to smoke

All specimens were simultaneously exposed to cigarette smoke.

- Exposure of specimens to cigarette smoke was done for 21 days
- Specimens were exposed to six cigarettes daily with an interval of 1 h between each exposure
- Nine puff cycles were performed for every cigarette. Each cycle had puff duration of 2 s and puff frequency of 1 puff every 60 s
- Exposure to smoke stopped just before filter part of burning cigarette was reached
- After each cycle of exposure, the specimens were rinsed with distilled water for 1 min and immersed in the artificial saliva at 37°C in an incubator.[4,13]

After the exposure to smoke, all the specimens were removed, washed with distilled water, and dried with air. The final surface roughness (FRa) was measured using a profilometer. The changes in the surface roughness were calculated by the difference between the initial (IRa) and final (FRa) measurements found before and after smoking test of the specimens, respectively. The data were collected and were statistically analyzed.

RESULTS

According to the null hypothesis (H_0), there was no difference in surface roughness of both the denture base materials before and after exposure to cigarette smoke.

The results of the present study were subjected to statistical analysis to interpret the difference and the significance between initial and final values in each by paired *t*-test. Independent *t*-test was used for between-group analysis.

Table 1: Initial and final surface roughness values of all specimens

Subgroup I (μm)		Subgroup II (μm)		Subgroup III (μm)		Subgroup IV (μm)	
IR	FR	IR	FR	IR	FR	IR	FR
0.164	0.513	0.248	0.748	0.204	1.323	0.275	1.907
0.158	0.496	0.265	0.879	0.169	0.976	0.259	1.783
0.165	0.516	0.242	0.735	0.192	0.956	0.286	1.470
0.185	0.566	0.285	0.923	0.209	1.400	0.297	2.060
0.203	0.636	0.227	0.728	0.199	1.467	0.289	1.867
0.198	0.611	0.283	0.873	0.221	1.477	0.286	1.903
0.167	0.519	0.232	0.711	0.195	0.939	0.301	2.137
0.203	0.650	0.286	0.897	0.183	1.059	0.302	1.967
0.164	0.564	0.276	0.884	0.194	1.167	0.299	1.513
0.193	0.621	0.295	0.908	0.180	1.247	0.270	1.943

IR: Initial, FR: Final

Descriptive statistics, including mean, standard deviation, and minimum and maximum values were calculated.

- Final surface roughness values for all the specimens were found to be more compared to initial surface roughness [Table 1]
- The mean values for all the subgroups were calculated which were found to be 0.180 μm, 0.264 μm, 0.195 μm, and 0.286 μm (initial) and 0.569 μm, 0.829 μm, 1.201 μm, and 1.855 μm (final surface roughness) for all the subgroups I, II, III, and IV, respectively; later, the difference between both initial and final surface roughness values was calculated and paired *t*-test was applied within each subgroup [Table 2]
- Paired *t*-test showed a significant difference between initial surface roughness and final surface roughness within each subgroup [Table 2]
- Independent *t*-test was applied between different groups, and the following results were obtained
  - Subgroup I and III (heat-cured denture base material specimens) – The mean initial surface roughness was not significant while the mean final surface roughness was found to be significant [Table 3]
  - Subgroup II and IV (flexible denture base material specimens) – Both mean initial and final surface roughness values were found to be significant [Table 4]
  - Subgroup I and II (heat-cured and flexible denture base material specimens before exposure to smoke) – Both mean initial and final surface roughness values were found to be significant [Table 5]
  - Subgroup III and IV (heat-cured and flexible denture base material specimens after exposed to smoke) – Both mean initial and final surface roughness values were found to be significant [Table 6].

Table 2: Mean value, standard deviation, and paired *t*-test for all subgroups

Subgroups	Mean±SD			*t*-test	*P*	Inferences
	IR value µm	FR value µm	Difference value			
Group I	0.180±0.018	0.569±0.057	0.389±0.040	30.608	0.000	S
Group II	0.264±0.025	0.829±0.086	0.565±0.063	28.419	0.000	S
Group III	0.195±0.015	1.201±0.212	1.006±0.202	15.773	0.000	S
Group IV	0.286±0.014	1.855±0.215	1.569±0.214	23.198	0.000	S

S: Significant, SD: Standard deviation, IR: Initial, FR: Final

Table 3: Comparison of mean change in surface roughness of heat-cured denture base material specimens (subgroup I and III)

Variable	Mean±SD		*t*-test	*P*	Inferences
	Subgroup I (*n*=10)	Subgroup III (*n*=10)			
IR	0.180±0.018	0.195±0.015	1.949	0.067	NS
FR	0.569±0.057	1.201±0.212	9.109	0.000	S
Difference	0.389±0.040	1.006±0.202	9.490	0.000	S

NS: Not significant, S: Significant, SD: Standard deviation, IR: Initial, FR: Final

Table 4: Comparison of mean change in surface roughness of specimens exposed to cigarette smoke (subgroup II and IV)

Variable	Mean±SD		*t*-test	*P*	Inferences
	Subgroup II (*n*=10)	Subgroup IV (*n*=10)			
IR	0.264±0.025	0.286±0.014	2.473	0.024	S
FR	0.829±0.086	1.855±0.215	14.005	0.000	S
Difference	0.565±0.063	1.569±0.214	14.246	0.000	S

S: Significant, SD: Standard deviation, IR: Initial, FR: Final

Table 5: Comparison of mean change in surface roughness of heat-cured and flexible denture base material specimens (subgroup I and II)

Variable	Mean±SD		*t*-test	*P*	Inferences
	Group I	Group II			
IR	0.180±0.018	0.264±0.025	8.636	0.000	S
FR	0.569±0.057	0.829±0.086	7.951	0.000	S
Difference	0.389±0.040	0.565±0.063	7.451	0.000	S

S: Significant, SD: Standard deviation, IR: Initial, FR: Final

Table 6: Comparison of mean change in surface roughness of heat-cured resin and flexible denture base material specimens exposed to cigarette smoke (subgroup III and IV)

Variable	Mean±SD		*t*-test	*P*	Inferences
	Subgroup III	Subgroup IV			
IR	0.195±0.015	0.286±0.014	13.910	0.000	S
FR	1.201±0.212	1.855±0.215	6.848	0.000	S
Difference	1.006±0.202	1.569±0.214	6.049	0.000	S

S: Significant, SD: Standard deviation, IR: Initial, FR: Final

DISCUSSION

PMMA is the commonly used material for the fabrication of removable prosthesis. This material has a combination of many desirable properties that accounts for its popularity and usage. Despite various advancements and research in dental materials and techniques globally, the fracture, foul odor, and allergy to PMMA could not be avoided. Due to these problems, patients seek other better denture base materials available for them.[14]

The most recent preference in denture materials has been the use of nylon-like material for the fabrication of removable dental appliances. This material generally replaces the metal and the methyl methacrylate denture base material used for standard removable partial dentures. It is nearly unbreakable, esthetically acceptable, and can be fabricated quite thin sections.

VALPLAST is a flexible denture base resin that is ideal for prosthesis. The resin is a biocompatible nylon thermoplastic with unique physical and esthetic properties that provides unlimited design versatility and eliminates the concern about acrylic allergies.[15]

There are millions of regular smokers in the world today, of which nearly 800 million are in developing countries. India is the fourth largest consumer of tobacco and the third largest producer of tobacco in the world. There are about 250 million tobacco users in India, which accounts for about 19% of the world's 1.3 billion tobacco users.[16]

Tobacco smoke is a complex mixture presenting two distinct phases. The volatile phase and the particulate phase mainly consist of tar. When burning the cigarette, the resultant smoke contains multiple components, such as nicotine, ammonia, nickel, arsenic, carbon monoxide, carbon dioxide, tar, and heavy metals. During cigarette smoking, some degree of temperature changes might be seen in the oral cavity.[1]

Thus, for this study, a customized smoking chamber with minimum possible volume and of insulating material was used to reproduce better the thermal changes that actually occur inside the mouths of smokers. During exposure to smoke, all the specimens were also placed in artificial saliva to simulate intraoral conditions.

It is known that the surface roughness of the denture base materials is one of the physical properties that may be altered because of surface degradation and considered as one of the determinant factors in the clinical longevity of the dental prosthesis. Many techniques of polishing can be performed to reduce the surface roughness of heat- and light-cured denture base materials through mechanical or chemical methods.

In this study, the effect of cigarette smoking on the surface roughness of two chemically different denture base materials was evaluated, and the results of this study showed that the exposure of both heat-cured and flexible denture base material specimens to cigarette smoke significantly increased the surface roughness values which may be attributed to the thermal changes that occur during cigarette smoking and deposition of cigarette substances on the surface of the acrylic resin and flexible material specimen.

CONCLUSION

Within the limitation of the study, the following conclusion can be drawn:
1. There was no significant difference in the mean initial surface roughness between nonexposed subgroups
2. There was a significant difference in the mean initial surface roughness between subgroups exposed to cigarette smoke
3. The mean final surface roughness in all the subgroups was found to be significantly different compared to initial surface roughness
4. In the exposed subgroups, the surface roughness of flexible denture base material specimens was found to be more compared to heat-cured denture base material specimens.

Clinical implications

All subgroups exposed to cigarette smoke significantly showed an increase in the surface roughness which may lead to biofilm accumulation and oral infection. It also affects the longevity of the denture. Therefore, adequate denture hygiene must be followed in patients with cigarette smoking habits.

Suggestion for future study

The effect of other forms of tobacco products on the surface roughness of various denture base materials can be studied and compared to each other.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Mahross HZ, Mohamed MD, Hassan AM, Baroudi K. Effect of cigarette smoke on surface roughness of different denture base materials. J Clin Diagn Res 2015;9:ZC39-42.
2. Vivek R. Polyamide as a denture base material. J Dent Med Sci 2016;15:119-21.
3. dos Bertoldo CE, Miranda D de A, Souza-Júnior EJ, Aguiar FHB, Lima DANL, Ferreira RL, *et al*. Surface hardness and color change of dental enemal exposed to cigarette smoke. Int J Dent Clin 2011;3:1-4.
4. Mathias P, Silva LD, Saraiva Lde O, Costa L, Sampaio MD, de Araujo RP, *et al*. Effect of surface sealant and repolishing procedures on the color of composite resin exposed to cigarette smoke. Gen Dent 2010;58:331-5.
5. Pereira-Cenci T, Del Bel Cury AA, Crielaard W, Ten Cate JM. Development of candida-associated denture stomatitis: New insights. J Appl Oral Sci 2008;16:86-94.
6. Casemiro AL, Gomes Martins CH, Pires-de-Souza Fde C, Panzeri H. Antimicrobial and mechanical properties of acrylic resin with incorporated siler-zinc zeolite-part I. Gerodontology 2008;25:187-94.
7. Anusavice SR. Phillips, Science of Dental Material. 12th ed., Ch. 19. W.B. Saunders Company: USA; 2012. p. 479-84.
8. Singh K, Gupta N. Injection molding technique for fabrication of flexible prosthesis from flexible thermoplastic denture base materials. World J Dent 2012;3:303-7.
9. Amal Andi SS, Hussain S, Amin Jalaluddin M. Preparation of artificial saliva formulation in: Int conference proceeding - ICB pharma II current breakthrough in pharmacy materials and analyses. Proceedings-ICB Pharma 2015;2:6-12.
10. Coresta Recommended Method No. 22 Routine Analytical Cigarette- Smoking Machine Specifications, Definitions and Standard Conditions; August, 1991.
11. Graça LM, Cardoso CG, Clode N, Calhaz-Jorge C. Acute effects of maternal cigarette smoking on fetal heart rate and fetal body movements felt by the mother. J Perinat Med 1991;19:385-90.
12. Mathias P, Costa L, Saraiva LO, Rossi TA, Cavalcanti AN, da Rocha Nogueira-Filho G, *et al*. Morphologic texture characterization allied to cigarette smoke increase pigmentation in composite resin restorations. J Esthet Restor Dent 2010;22:252-9.
13. Mathias P, Rossi TA, Cavalcanti AN, Lima MJ, Fontes CM, Nogueira-Filho Gda R, *et al*. Cigarette smoke combined with staining beverages decreases luminosity and increases pigmentation in composite resin restorations. Compend Contin Educ Dent 2011;32:66-70.
14. Singh JP, Dhiman RK, Bedi RP, Girish SH. Flexible denture base material: A viable alternative to conventional acrylic denture base material. Contemp Clin Dent 2011;2:313-7.
15. Thumati P, Padmaja S, Reddy R. Flexible denture in prosthodontics – An overview. Indian J Dent Adv 2013;5:1380-5.
16. Peter S. Essential of Preventive and Community Dentistry. 4th ed. Arya Medi Publishing House: New Delhi. 2009.