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DENTAL MATERIALS

THE MEASUREMENT OF CO-EFFICIENT OF FRICTION BETWEEN CAST CO-CR ALLOY AND GUIDING PLANE MATERIALS - A PILOT STUDY

*MOHSIN ALI, BDS, MSc, PhD

ABSTRACT

The purpose of this pilot investigation was to measure the co-efficient of friction of a cast cobalt-chromium alloy specimen and three materials commonly found on the guiding surfaces of the teeth.

The static .co-efficients of friction between dental cobalt-chromium alloy (before and after electro-polishing) and tooth enamel, composite resin, and dental amalgam alloy were measured using an inclined plane method at 20 ± 1° C.

The mean measured co-efficients of friction between cobalt — chromium alloy and dental composite resin, dental enamel, and dental amalgam alloy together with their standard deviations were 0.68 ± 0.03, 0.45 ± 0.03 and 0.58 ± 0.04 respectively. Electro-polishing had no effect.

This limited experiment suggested that dental composite resin should be preferred to dental amalgam for the restoration of buccal or guiding plane surfaces of abutment teeth to enhance the retention of cobalt-chromium partial denture. However, other properties of these materials may need to be taken into account. On the basis of the results of this pilot study, further research is required to investigate the difference in values of the coefficient of friction between various types of composite resin and amalgam alloys commercially available.

Index Words: *Partial Denture Retention, Frictional Resistance, Abutment restoration.*

INTRODUCTION

In the prosthetic literature the role of friction as a mechanism of removable partial denture (RPD) retention is often cited[1-5]. As these opinions are seldom supported by research evidence, the understanding of the mechanism of friction in creating retentive forces against displacement of a partial denture has remained unclear. According to the laws of friction[6-8], the development of frictional resistance between two contacting surfaces depends on the normal force applied at the interface. It, however, does not depend on the apparent area of contact. Hence for any component of a framework to offer any resistance against displacement, it must contact the tooth surface with some force. This means that retention offered by guiding plane surfaces, for example, does not depend on their area of preparation, rather it depends on the fit of the denture guiding plate to the guiding plane surfaces on the teeth. It follows, therefore, that if a guiding plate surface has a passive fit and the displacing force acts along the selected path of removal, there will be no retention offered by the guiding planes unless the displacing force causes the denture to tilt.

In the case of clasp retention, a passively placed retentive arm in an undercut area when flexes over the bulbosity of a tooth applies normal force, hence creating frictional effects. The magnitude of this normal force depends on flexibility of the clasp (a product of its length, taper, cross-section, diameter,

* Assistant Professor, Department of Prosthodontics, King Saud University, College of Dentistry, Riyadh, Saudi Arabia.

Address for Correspondence: Dr. Mohsin Ali, Department of Prosthodontics, King Saud University, College of Dentistry, P.O Box 60169, Riyadh 11545, Saudi Arabia. Telephone: (office; 966-01-4677435, Home: 4682320) E-mail: Mohsin@ksu.edu.sa, Mohsinalidr@hotmail.com

and modulus of elasticity), depth of undercut engaged and the angle of cervical convergence of the tooth[9,10,11].

In addition to the above factors, the value of coefficient of friction between a given clasp or guiding plate material (Cobalt-Chromium alloy) and tooth surface it contacts (enamel, amalgam or composite buccal or proximal restorations) will affect the magnitude of frictional resistance. The coefficient of friction is the ratio of frictional resistance (F) offered by two sliding surfaces to the normal force (N) applied at the interface and is a constant (p = F/N) for any given pair of materials. Although a few studies have measured the coefficient of friction between various restorative materials or prosthetic tooth materials[12-14] values of coefficient of friction between enamel or other guiding plane materials and denture guiding plate material have not been reported.

The aim of this limited experiment was to measure the coefficient of friction of the cast Cobalt-Chromium (Co-Cr) alloy specimen (commonly used alloy for fabricating RPD framework) and three materials commonly found on the buccal surface or guiding plane surfaces of the teeth, i.e., enamel, amalgam alloy, and composite resin.

METHODS

The Preparation of Guiding plane Specimens

For the fabrication of amalgam (Solila Nova, non gamma 2, Dentsply, Detray, England) and composite resin (Concise, 3M, St. Paul, MN 55144, USA) specimens, a slot 5x5x2 mm was cut in a sheet of Perspex (ICI Chemicals & Polymers Ltd., Darwen, England). Another piece of Perspex was held against this slot and the material was mixed and pushed/packed in the slot through 2mm wide opening between two Perspex sheets. The sheets were held together with the help of rubber bands while the material set at room temperature. Before removing the specimen from the sheet, one surface was finished by rubbing the Perspex sheet on a piece of SiC paper (High Quality Grinding Paper, Struers Scientific Instruments, Denmark) of grade 1000. The amalgam specimens were also polished using a mixture of, firstly, glycerin and pumice and then a mixture of ZnO powder and ether over a polishing cloth (SELVYT, England). This procedure produced specimens having a surface finish comparable to guiding plane surfaces intra-orally. The rubbing was carried out by hand, while the SiC paper and polishing cloth were held on a flat glass surface. The specimens were then removed from the Perspex mould and trimmed to 4x4 (±0.1) mm. The thickness of these specimens was approximately 1.5 mm.

To construct the enamel specimens, extracted human molar teeth stored in a refrigerator were used. They were sectioned using a slow speed diamond saw to produce 1.5 mm thick sections. These sections were examined under a confocal optical microscope using a `20' water immersion objective at X200 magnification to ensure that one side of the section was through the enamel. Any section exhibiting a dentine 'window' was rejected. The sections were then trimmed to produce 4x4 mm specimens. No further finishing and polishing of enamel specimens was carried out. As the blade of the saw used for cutting tooth sections was flexible some surface irregularity was expected. However, only those specimens exhibiting good plane surfaces were selected.

Experimental Setup

In the field of Physics, using an inclined plane is an established method for measuring the static coefficient of friction (p). In this method, one of the material specimens is made to slide on the other specimen fixed to the inclined plane. The angle of the plane is increased slowly and gradually until the sliding occurs. The tangent value of the angle at which the sliding occurred is taken as the coefficient of friction (p = tan 0). Fig 1 shows the experimental set up used in this study. Basically, it consisted of a tilt table to which a brass extension was bolted. A sandblasted cast Co-Cr (Croform Excel, Davis Schottlander & Davis Ltd., Letchworth, England) plate of 25mm x 75mm was secured on the brass extension with the help of toolmaker's clamps. The guiding plane specimens were made to slide over it by increasing the

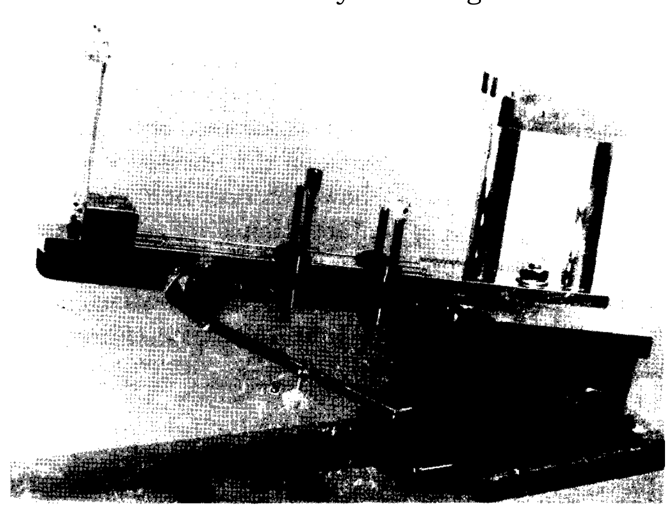

Fig. 1. The inclined plane apparatus and the experimental set-up

angle of the brass extension by winding the screw 'S'. The angle of slide was measured from the markings on the tilt table.

Fifteen repeat measurements were made for each specimen during one session and repeated on three separate sessions at 20±1C. For amalgam specimen, the surfaces were cleaned with trichlore-ethane after testing. The Co-Cr plate was then electro-polished and the procedure was repeated.

Additional tests were carried out using enamel specimens to investigate the effect of dryness of enamel on p. These were conducted using the electro-polished Co-Cr plate. Prior to testing, the enamel specimens were stored in 100% relative humidity and were tested immediately after removing from the humidor, 8 hours, and 1 week after removal.

Accuracy of the method

The value of the coefficient of friction could be affected by the presence of vibrations in the measuring system. No apparent vibrations were detected in the inclined plane apparatus used in this study which was conducted in a quiet room to minimize any vibrations due to surroundings. To verify the accuracy of the method, tests were carried out using materials of known p, stainless steel - stainless steel, glass -glass, and Perspex - Perspex. The values measured with the methodology used in this study (0.58, 0.9, and 0.8 respectively) were in good agreement with the reported values, confirming the accuracy of the method.

RESULTS

Table 1 contains the respective angles at which sliding occurred for amalgam, composite resin, and enamel specimens against sandblasted Co-Cr plate. The highest values of p were noted for the composite resin (0.68 ± 0.03), followed by amalgam (0.58 ± 0.04) and dental enamel (0.45 ± 0.03). The values of p for these materials while sliding on an electro-polished surface were virtually unchanged.

Table 2 shows that the degree of dryness of enamel specimens significantly affected the value of the coefficient of friction. However, after the loss of water from the enamel matrix in 8 hours, further dryness did not cause any notable reduction in p value (8 hours dry specimen and 1 week dry specimen).

DISCUSSION

Theoretically, a pair of materials exhibiting a higher value of p should offer greater frictional resistance under identical conditions of the fit of framework, hence should be the material of choice for restoring the buccal or guiding plane surfaces of a tooth, where indicated. Although the differences in p values were found for the restorative materials used in this pilot study, the results should be interpreted cautiously due to the limited sample size. A comprehensive study involving various types of amalgam alloys, composite resins and glass ionomers commercially available is recommended to verify the findings of this limited study.

TABLE 1: THE VALUES OF COEFFICIENT OF FRICTION BETWEEN A SANDBLASTED CO-CR PLATE AND GUIDING PLANE MATERIALS

Material	Obs.	No.	Angle (deg.)		Coeff. Friction 'p'	
			Mean	StDev	Mean	St.Dev.
Amalgam alloy	1	15	31.33	1.589	0.608	0.038
	2	15	29.76	1.400	0.571	0.032
	3	15	29.86	1.747	0.574	0.040
	All	**45**	**30.32**	**1.709**	**0.584**	**0.040**
Composite resin	1	15	33.86	1.043	0.671	0.026
	2	15	34.10	1.056	0.677	0.027
	3	15	34.66	1.190	0.691	0.030
	All	**45**	**34.21**	1.126	**0.679**	**0.028**
Enamel (100% humid)	1	15	24.40	1.454	0.453	0.030
	2	15	24.53	1.245	0.456	0.026
	3	15	24.33	1.397	0.452	0.029
	All	**45**	**24.42**	**1.339**	**0.454**	**0.028**

TABLE 2: THE CO-EFFICIENT OF FRICTION BETWEEN CO-CR ALLOY AND ENAMEL SPECIMENS STORED UNDER DIFFERENT CONDITIONS

Storage Cond.	Obs.	Angle (deg.)		Coeff. Friction 'p'	
		Mean	St.dev.	Mean	St.dev.
Stored at 100% humidity	45	24.42	1.339	0.454	0.028
8 hours dry	15	18.66	2.015	0.337	0.039
1 week dry	15	18.50	1.168	0.334	0.022

As the p values for amalgam and composite resin with Co-Cr alloy have not been previously reported, no comparison was possible. This study shows that composite resin specimen should offer greater frictional resistance against a CO-Cr plate as compared to amalgam specimen (p value being 0.68 and 0.58 respectively). Warr[12] has reported the value of m between enamel and Co-Cr as 0.3. In the present study a considerably higher value of 0.45 was found for the enamel specimen stored at 100% relative humidity. However, the experiment conducted with varying degree of dryness of enamel specimen showed that the value of p is significantly affected by the amount of water in the matrix (p was 0.33 for the 8 hours and 2 weeks dry specimens, table 2). Warr did not mention the condition of storage of extracted teeth used in his experiment. However, Koran et a1[14] reached to similar conclusion while measuring p between different pairs of various prosthetic tooth materials as they reported higher values for the wet specimens.

Clinical Significance

This pilot study has reported highest p values for composite resin specimen against Co-Cr alloy, followed by amalgam alloy and tooth enamel specimens. This means that under identical conditions of fit of the framework the frictional resistance offered by a clasp or guiding plate is expected to be lowest when in contact with un-restored enamel surface. However, if a buccal or guiding plane surfaces of an abutment tooth need to be restored, composite resin should be preferred to amalgam alloy, as it can provide better retention for a prosthesis.

CONCLUSIONS

The static coefficient of friction values between a cast Co-Cr plate and enamel specimen stored at 100 % relative humidity, a composite resin specimen, and amalgam specimen were found to be 0.45, 0.68, and 0.58 respectively. The value of p for the enamel specimen was dependent on the amount of water content in its matrix (0.33 for the dry specimens as compared to 0.45 when stored at 100% humidity). The surface finish of Co-Cr plate appeared to have little effect. This limited study has cautiously suggested the preference of composite resin for restoring the buccal and guiding plane surfaces of the abutment teeth, where indicated, for a better frictional resistance against displacement of a removable partial denture. However, other properties such as wear resistance of these materials should also be considered.

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