Effect of Dentifrice on Surface Roughness of Dental Casting Alloys and Glass Ceramics

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Abstract

Background: The surface roughness of metal surface is of clinical importance in the process of bacterial retention which facilitate caries and periodontitis.
Objective: To evaluate and compare the tooth brush induced surface roughness of Cobalt-Chromium alloy (Co-Cr), Nickel-Chromium alloy (Ni-Cr) and ceramic surface before and after brushing using toothpaste and toothpowder.
Materials and Methods:Master die with 40 x 15 x 5 mm for casting of Cobalt Chromium, Nickel Chromium metal and 40 x 15 x 3 mm for metal substructure for ceramic was made. A total of 60 samples were made and divided into Group .1 (Ni-Cr),group.2(Co-Cr) and Group.3 (ceramic).Each group is further subdivided into Group.a (brushed in a slurry of toothpaste), Group.b (brushed in a slurry of toothpowder).The length of the hard bristles was 35 mm. The surface roughness after brushing was analyzed using profilometer at 0.5 min/s. The surface roughness of test samples in each sub-group before brushing and after brushing were compared using paired T test. In each group the Ra, Rv and Rp values between subgroups were compared by independent samples test (t-test).
Result: The significant value p <0.001 considered as statistically significant.
Conclusion: Nickel-Chromium alloys produced more surface roughness compared to Cobalt-Chromium and ceramic after brushing in toothpaste and toothpowder.

Keywords: Artificial saliva, Ceramic, Cobalt-Chromium, Nickel-Chromium, Surface roughness.
DOI Number:10.14704/nq.2022.20.8.NQ44406 **NeuroQuantology 2022; 20(8): 3765-3773**

Introduction

One of the widely accepted options in replacing missing teeth or to treat carious teeth in preventing loss of masticatory function is the use of cast dental restorations. Over the years, base metal alloys such as Cobalt-Chromium, Nickel-Chromium alloys and ceramics are commonly used for

fabrication of inlays, metal crowns, metal ceramic restorations (PFM) and have proven to be a huge success[Won Uket al, 2017].Maintenance of cast metal restorations in the oral cavity play a vital role in the success of the restorations. One of the important procedures in maintenance phase is effective toothbrushing of teeth[Kaur et al,2014].

Plaque accumulation around natural dentition and around cast restorations can lead to periodontal breakdown and soft tissue inflammation. Hence, efficient mechanical plaque removal by toothbrushing is the most important oral hygiene measures to prevent the onset and progression of dental diseases and there by maintaining the health of stomatognathic system[Ricardo et al, 2009].The amount of force and the duration of time used by the brush are the two important factors determines the effectiveness of brushing. Interestingly, brushing with an abrasive toothpaste or toothpowder plays a vital role in the changes of surface roughness observed with the surface of the restorative materials[Gansset al, 2009].

The estimated a normal brushing force for manual brushes to be approximately 1 to 3 pounds (453 to 1,359 gm.) and the forces applied to the teeth with an automatic toothbrush can average upto106 gm[Bizhanget al,2017].In particular, fixed dental prosthesis have lost its luster, more roughness and staining with different materials.The surface roughness of intraoral hard surfaces is of clinical importance in the process of bacterial retention[Haroonet al,2014].

Initial colonization of micro-organisms over restorative surfaces starts from the surface irregularities where bacteria are strongly adherent and protected[Julioet al, 2017].The threshold surface roughness for bacterial plaque retention was 0.2µm above which leads to increase in bacterial retention and 0.3µm can be detected by the tip of the patient's tongue[Joneset al, 2004].The current restorative materials offer improved resistance to wear, none of the materials have matched the wear resistance of the natural dentition. Little information is available about the influence of the toothbrush and abrasive on the surface texture of cast restorations like Cobalt-Chromium, Nickel-Chromium based alloys and also ceramics.

In recent years, improved formulations have offered near life-like restorations with very good fracture resistance. While the materials offer good hardness, strength and esthetics but poor wear resistance against the mechanical forces. Hence this study was done to evaluate the surface roughness of most commonly used Nickel-Chromium, Cobalt-Chromium alloys and ceramics after effective toothbrushing using hard toothbrush with toothpaste and toothpowder in an artificial saliva.A hypothesis was formulated that the surface roughness of Nickel Chromium alloys, Cobalt Chromium alloys and ceramics will be the same after tooth brushing.

Materials and Methods

Master die preparation

A Master die with 40 x 15 x 5 mm (Figure.1)for evaluation of Cobalt Chromium, Nickel Chromium alloy and 40 x 15 x 3 mm for metal substructure for ceramic. The master die was duplicated using putty light body elastomeric impression material (Aquasil, Dentsply,India). Then the moltencasting wax (Kronenwachs, BEGO,Germany) was poured into the mould space which was allowed to set. The A total of 60 samples were made and divided into Group.1 (Ni-Cr), Group.2 (Co-Cr) and Group.3 (ceramic).Each group is further subdivided into Group.a (brushed in a slurry of toothpaste and Group.b (brushed in a slurry of toothpowder).

40mm

Figure.1 Schematic representation of master die

Fabrication ofsamples

Each wax pattern was first attached to separate runner bar, then each runner bar was fixed to crucible former about 6 cm in diameter. Debubblizer (Unicat surfactant, Delta labsIndia)was applied on the wax pattern and ceramic liner was placed along the casting ring. Phosphate bonded investment powder and liquid (Maruvest-Vest)was mixed in vacuum mixer and gently poured into the casting ring with attached wax patterns. The set casting ring waskept in a burnout (Sirio Dental snc -Italy), which was transferred at 850 degrees to induction casting machine (Ivaclar,Vivadent) and the casting was completed. Cobalt chromium alloy-Co-64%,Cr-28.6%,Mo-5%,Si-1%,Fe-<2%,Others-2%(Magnum Ceramics,25039Travagliato(BS)-Italy) and Nickel-chromium alloysNi -76%,Cr -12%,Mo -7.5%,Si -1.5%,C- <1%,Others-2%(Wironit,Bego,Bremen,Germany) pellets were used for casting of 20 wax patterns each. After casting, they were sand blasted with 110 µm Aluminium oxide powder (BegoKorax) and polished using alumina paste. Each sample was cleaned in ultra-sonic cleanser and air dried to remove surface debris before profilometry testing.

Ceramic layering

Ceramic layering of 2mm thickness was done over each metal substructure measuring 40x15x3 mm. The ceramic powder-liquid slurry (IPS d.Sign,IvovlarVivadent,Liechtenstein) was added layer by layer until 2mm thick,over the sandblasted surface after adding an opaque layer. The samples were kept inside the ceramic furnace and fired at 930 degree Celsius for 2 cycles. The ceramic layer on each sample was checked for irregularities and gently smoothened Then glazing was completed at 920 degree Celsius in furnace.

Brushing technique

The samples in each subgroup were brushed with slurry of toothpaste or tooth powder in artificial saliva.Toothpaste and toothpowder were added at a ratio of 1 g per 10 ml of artificial saliva. They were brushed for 48 hours in tooth abrasion machine, using hard toothbrush with 200 gm of applied pressure at 90 strokes/min to simulate the clinical conditions for 2 minutes of brushing, twice a day for 2 years, with 200 g of brushing force. After brushing the test samples were cleaned in an ultrasonic cleanser to remove any surface particles across the sample surface, then dried in air after brushing and before measurement of surface roughness.

Evaluation of surface roughness

The surface roughness was analyzedbefore and after brushing with profilometer (Perthometer S2) over a traced path of 10 mm at 4 locations distributed equally across the length of the test sample. Each trace path contained 4000 points and the scanning rate of the stylus was 0.5 min/s. Arithmetic mean of the absolute departures of the roughness profile below the mean line (Ra), maximum depth of the profile below the mean line within the sample length (Rv) and the maximum height of the profile above the mean line within the sample length (Rp).

Statistical analysis used

To analyze the Ra, Rv and Rp, SPSS version 22.0 was used. (IBM; Armonk, New York, United State) The Ra, Rv and Rp values for all the test samples in each sub-group before and after brushing were compared using paired samples test (t-test). In each group the Ra, Rv and Rp values between subgroups were compared by independent

samples test (t-test) and the surface roughness of multiple groupscomparison was done using 1-way ANOVA test.

Results

The significance value for surface roughness for Cobalt-Chromium samples (Group-I) before and after brushing using toothpasteand tooth powder showed significant value P <0.001 for Ra and Rp,hence there was a significant difference in surface roughness among the sub-groupsbefore and after brushing. (Table.1)The significance value for surface roughness for Nickel-Chromium samples (Group-II) before and after brushing using toothpaste and tooth powder showed significant value P value >0.001 for Ra and Rv, hence there was insignificant difference in surface roughness among the sub-groups before and after brushing.(Table.2) The significance value for surface roughness for ceramic samples (Group-III) before and after brushing using toothpaste and tooth powder showed significant value P value<0.001 for Ra and Rp, hence there was a significant difference in surface roughness among the sub-groups before and after brushing. (Table.3)

Table:1 Mean, standard deviation of surface roughness of Cobalt-Chromium before and after brushing using toothpaste and tooth powder

Type	Parameter	Number of Samples	Mean	Standard Deviation	Sig.(2-tailed) (P -Value)
Tooth Paste	Pair 1: Ra Before brushing Ra After brushing	10 10	.30740 .78360	.043306 .295697	.001
	Pair 2: Rv Before brushing Rv After brushing	10 10	.8310 2.3270	.12547 1.44175	.008
	Pair 3: Rp Before brushing Rp After brushing	10 10	.7164 .22594	.22552 1.34941	.001
Tooth Powder	Pair 1: Ra Before brushing Ra After brushing	10 10	.30830 1.30500	.037157 .404913	.000
	Pair 2: Rv Before brushing Rv After brushing	10 10	.8120 3.0930	.15054 .63477	.000
	Pair 3: Rp Before brushing Rp After brushing	10 10	.8010 3.1230	.08543 .84799	.000

Table:2 Mean, standard deviation of surface roughness of Nickel-Chromium before and after brushing using toothpaste

Type	Parameter	Number of Samples	Mean	Standard Deviation	Sig.(2-tailed) (P-Value)
Tooth Paste	Pair 1: Ra Before brushing Ra After brushing	10 10	.28030 .32380	.041583 .063205	0.02
	Pair 2: Rv Before brushing Rv After brushing	10 10	.9712 1.1980	.19460 .45828	0.01
	Pair 3: Rp Before brushing Rp After brushing	10 10	1.2360 1.1820	.62074 .39791	.000

Tooth Powder	Pair 1: Ra Before brushing Ra After brushing	10 10	.30160 .41650	.045600 .102890	.02
	Pair 2: Rv Before brushing Rv After brushing	10 10	1.0030 1.2368	.28095 .38063	.000
	Pair 3: Rp Before brushing Rp After brushing	10 10	.8593 1.2973	.27166 .45823	.000

Table:3 Mean, standard deviation of surface roughness of ceramic before and after brushing using toothpaste and tooth powder

Type	Parameter	Number of Samples	Mean	Standard Deviation	Sig.(2-tailed) (P -Value)
Tooth Paste	Pair 1: Ra Before brushing Ra After brushing	10 10	.22350 .29500	.040665 .054510	.001
	Pair 2: Rv Before brushing Rv After brushing	10 10	.7380 .7940	.17599 .09594	.000
	Pair 3: Rp Before brushing Rp After brushing	10 10	.7760 .7910	.11404 .12905	.01
Tooth Powder	Pair 1: Ra Before brushing Ra After brushing	10 10	.23990 .30680	.53750 .044148	.000
	Pair 2: Rv Before brushing Rv After brushing	10 10	.7920 .8630	.16424 .10264	.001
	Pair 3: Rp Before brushing Rp After brushing	10 10	.7870 .8270	.10894 .12320	.001

Independent samples test for equality of means in Cobalt-Chromium samples (Group-I) after brushing with toothpaste (Subgroup-I a) and toothpowder (Subgroup-I b). The equality of means showed significant difference for Ra, Rv and Rp as the P-value<0.001.(Table.4).But the independent Samples Test for equality of means in Nickel-Chromium and ceramic samples (Group-II) after brushing with toothpaste (Subgroup-II a) and toothpowder (Subgroup-II b) showed insignificant difference for Ra, Rv and Rp as the P value >0.001.(Table.5 and 6).

Table:4 Independent Samples Test for equality of means for Cobalt-Chromium samples after brushing with toothpaste and toothpowder

Parameter	Levine's Test for Equality of Variances		t- Test for Equality of Means		
	F	Sig.	T	df	Sig.(2-tailed)
Ra- after brushing Equal variances assumed Equal variances not assumed	2.594	.125	-3.288 -3.288	18 16.474	.000 .000

Rv- after brushing Equal variances assumed Equal variances not assumed	1.673	.212	-1.538 -1.538	18 12.363	.010 .000
Rp- after brushing Equal variances assumed Equal variances not assumed	1.407	.251	-1.050 -1.050	18 15.149	.000 .000

Table:5 Independent Samples Test for equality of means for Nickel-Chromium samples after brushing with toothpaste and toothpowder

Parameter	Levine's Test for Equality of Variances		t- Test For Equality Of Means		
	F	Sig.	T	df	Sig.(2-tailed)
Ra- after brushing Equal variances assumed Equal variances not assumed	2.963	.102	-2.310 -2.310	18 14.946	.033 .036
Rv- after brushing Equal variances assumed Equal variances not assumed	.211	.652	-.206 -.206	18 17.413	.839 .839
Rp- after brushing Equal variances assumed Equal variances not assumed	.011	.918	-.601 -.601	18 17.653	.555 .556

Table: 6 Independent samples test for equality of means for ceramic samples after brushing with toothpaste and toothpowder

Parameter	Levine's Test for Equality of Variances		t- Test for Equality of Means		
	F	Sig.	T	df	Sig.(2-tailed)
Ra- after brushing Equal variances assumed Equal variances not assumed	.742	400	-.532 -.532	18 17.255	.601 .602
Rv- after brushing Equal variances assumed Equal variances not assumed	.203	.658	-1.553 -1.553	18 17.919	.138 .138
Rp- after brushing Equal variances assumed Equal variances not assumed	.081	.779	-.638 -.638	18 17.961	.531 .531

Discussion

The excessive amount of wear and surface roughness changes innatural teeth and restorative materials has significant effect on functional, biological, and esthetic of the masticatory system[Brancoet al,2020].Today tooth brushing with dentifrice is the common oral hygiene habit practiced by people all over world to prevent accumulation of dental plaque and gingival disease, thereby providing a huge scope for research analysis.

Caranzaet al in 2002noted that when toothbrush is considered as most frequently used mechanical device to keep good oral hygiene, any contact with tooth and mechanical device can lead to tooth abrasion. Further they observed that improper use of toothbrush can lead to soft tissue and hard tissue damage. Dyer et al in2000found that brushing method, brushing force, brush type, filament toughness, brushing time and interval are important in toothbrush abrasion. John. Wataha in 2008observed the susceptibility of nickel-based alloys to chemico-mechanical stresses and the common intraoral stress such as toothbrushing adversely affects the surfaces of the alloys. Aker and Aker in 1980found that normal toothbrushing with a common dentifrice has the ability to wear away color-corrective porcelain stains applied to the surface of metal-ceramic restorations.Further, the wear resistance of Cobalt-Chromium and glass ceramic surface to brushing force is still not clear.

Studies have suggested a strong correlation between tooth wear and the cleaning power of dentifrices. Alciara Alicein 2008in his study mentioned that surface roughness resulting from toothbrushing with abrasives represent an important oral health related problem.Annette in2013has estimated a normal brushing force for manual brushes to be approximately 1lbs to 3 lbs (453gm to 1,359gm), which act on the abrading tooth surface. Any fixed restorations in oral cavity are subjected to brushing forces every daywhich is inevitable. Rebecca Taylor in 1998found that substratum roughness of prosthodontic restorations significantly influences bacterial retention. Surface roughness of the restoration makes niches in which microorganisms are lodged and hidden from shear forces.

Hard toothbrush types to cause abrasion mostly,while others indicated soft types to have high abrasion when exposed to toothpaste[Michaelet al,2018,John, 2000].But the literature showed that toothbrush type to have no effect on abrasion (Henniequin et al,2017).On reviewing the literature, the surface hardness of heat polymerized PMMA provisional resin reinforced with Zirconia, Titanium oxide and Aluminum oxide showed more than the conventional PMMA resin[Asmathet al,2022].In the present study, it was found that there is increase in surface roughness of all the three restorative materials, after brushing in toothpaste slurry. The mean surface roughness changes in ceramic, Cobalt-Chromium alloy and Nickel-Chromium alloy were 0.29500 µm (Ra), 0.78360 µm (Ra) and 0.32830 µm (Ra) respectively. These were the significant changes (P<0.001) after brushing, suggesting rise in surface roughness of the restorative materials after brushing lead to adhesion of micro-organisms.

Alessandra et alin 2008in his study noted that brushing with dentifrice is atriple-body abrasion process, in which the free abrasive particles slide between the tooth and the bristlesof the brush. The abrasive particles size, pressure and the speed are the important factors that determine the surface roughness of any materials.

The present study also supported that, brushing with toothpowder slurry caused more abrasion in all the groups, with maximum surface roughness changes upto1.926 µm(Ra) noted in Nickel-Chromium alloys, and it was highly significant (P<0.001).This is because of the abrasive particle size in toothpowder.

As there was a difference in dentifrice abrasion and abrasive concentration, brushing with toothpowdershowed significant increase in surface roughness in all groups(P<.05) with average post brushing values of Cobalt-Chromium, Nickel-Chromium and ceramic was

1.3050 µm, 0.41650µm and 3.0680µm respectively. Hence, the results of the present study showed that there was a rise in surface roughness in toothpowder than toothpaste slurry.

From a clinical aspect, the changes insurface roughness of the Ni-Cr, Co-Cr based alloys and ceramic material was surprising with the use of hard toothbrush, given its exceptional hardness and high physical strength. The results of the present study suggestedthat individuals with Ni-Cr, Co-Cr based and ceramic restorations may benefit from using soft toothbrushes and toothpastes with low abrasivity. This might prove helpful if the margins of the restorations are in close contact with the gingival tissues.

The results the present study proved that the existence of critical relationships between toothbrushing, wear resistance of restorative materials, and abrasives. The results showed after brushing mean Rv for Cobalt-Chromium, Nickel-Chromium and ceramic as 3.0930µm, 1.2368µm and .8630µm respectively in toothpowder slurry. In toothpaste slurry the after brushing results showed mean Rv as 2.3270µm, 1.1980µm and, .7940µm for Cobalt-Chromium, Nickel-Chromium and ceramic samples.

While the clinical significance of these results is the development of a sensitive in-vitro method to measure the potential abrasive characteristics of toothbrushes on restorative materials has been demonstrated. As it should provide a useful tool for the calculations of surface roughness with various brush designs, in future further studies and analysis are required with different parameters involving brushing forces and wear resistance of different restorative materials.

Limitations of the study are that the actual temperature changes, brushing force and brushing technique varies with each individual which can have an effect in toothbrush abrasion.The brushing force varies with each individual and can vary while using soft toothbrush and hard toothbrush, variations in brush design and difference in bristle tuft is likely to vary the degree of surface abrasion,influence of saliva on the PH changes of the dentifrice medium can have some effect to the brushing abrasion, but artificial salivary substitute was used in the present study.

Conclusion

The surface roughness of Cobalt-Chromium alloy after brushing with toothpaste in artificial saliva was 0.78360µm(Ra) and in toothpowder was 1.30500µm(Ra), Nickel-Chromium alloy showed surface roughness with toothpaste was 0.32830µm(Ra) and in toothpowder was 0.41650µm(Ra) and ceramic surface showed surface roughness in toothpaste was 0.29500µm(Ra) and in toothpowder was 0.30680µm(Ra). Hence the surface roughness was statistically significant for Cobalt Chromium and ceramic after and before brushing with tooth paste and powder.

Acknowledgment: Nil

Conflicts of interest: The authors declared that there is no conflict of interest

Source of support: Nil

References

Alciara Alice DAY, Nemre Adas S, Simon Ides C, Mario Alexandre CS. [2008]. Invitro evaluation of the abrasiveness of a commercial low-abrasive dentifrice and an experimental dentifrice containing vegetable oil. Braz J Oral Sci.7, 1526-30.

Alessandra Miranda DA, Hitor P, Celio jesus DP, Jose Daniel BD, Carlos Jose S, Alfredo Julio F.[2008]. Assessment invitro of brushing of dental surface roughness alteration by laser interferometry. Braz Oral Res. 22,11-17.

Annette Wiegand , John Patrik MB, Florin E, Thomas A.[2013]. Brushing force of manual and sonic toothbrushes affects dental hard tissue abrasion. Clin Oral Investig.17,815-16.

AsmathJehan, Ahila SC, Muthukumar B. [2022]. Evaluation of flexural strength and surface hardness of heat activated provisional PMMA resin reinforced with nanoparticles-an in vitro study. J. Med. P'ceutical Allied Sci. 11, 4340-48.

Bizhang M, Schmidt I, Chun Y-HP, Arnold WH, Zimmer S. [2017]. Toothbrush abrasivity in a long-term simulation on human dentin depends on brushing mode and bristle arrangement. PLoS ONE.12, 1-9

Branco AC, Colaço R, Figueiredo-Pina CG, Serro AP. [2020]. A state-of-the-art review on the wear of the occlusal surfaces of natural teeth and prosthetic crowns. Materials.13,1-7.
Dal PivaAMdO et al. [2021].Toothbrushing wear resistance of stained CAD/CAM ceramics. Coatings.11,1-13.
Dyer D, Addy M, Newcombe RG. [2000]. Studies invitro of abrasion by different manual toothbrush heads and a standard toothpaste. J clin periodontal. 27,99-103.
Ganss C, Schlueter N, Preiss S, Klimek J.[2009]. Tooth brushing habits in uninstructed adults - frequency, technique, duration and force. Clin Oral Investig.13,203-208.
Haroon Rashid.[2014]. The effect of surface roughness on ceramics used in dentistry: A review of literature.Eur J Dent. 8,571-579.
Hennequin HNL et al. [2017].The effects of different levels of brush end rounding on gingival abrasion: a double-blind randomized clinical trial. IntJDentHygiene.15,335-44. 19.
John CW. [2000]. Biocompatibility of dental casting alloys:a review. J Prosthet Dent.83,223-34.
John CW, Pettra EL, Rejina LWM, Jill BL, Donald GM. [2008]. Brushing induced surface roughness of nickel, palladium and gold based dental casting alloys. J Prosthet Den.99,455-60.
14.
Jones CS, Billington RW, Pearson GJ.[2004]. The in vivo perception of roughness of restorations. British Dent J.196,42-45.
Julio CM et al. [2016].Biofilm formation on different materials used in oral rehabilitation.Braz Dent J. 27,141-47.
Kaur S, Singh K, Suman N, Kaur M.[2014]. Management of severely worn dentition-a review. Ind J Compre Dent Care. 4, 67-69.
Lucchetti MC et al. [2015].Cobalt-chromium alloys in dentistry: An evaluation of metal ion release. J Prosthet Dent.114,602-8
Michael Newman, Henry Takei, Perry Klokkevold, Fermin Carranza. [2018]. Newman and Carranza's Clinical Periodontology.13 th edition, Saunders.
Ricardo Palmier T, Flavia Rocha FT.[2009].Antimicrobial agents used in the control of periodontal biofilms: effective adjuncts to mechanical plaque control. Braz Oral Res.23, 39-48
Won Uk P, Hui Geun P, Kyu Hong H, Jingming Z, Jong Kook L.[2017]. Interfacial property of dental Cobalt-Chromium alloys and their bonding strength with porcelains.J Nanosci Nanotechnol.17,2585-588.