DOI: 10.7860/JCDR/2022/53002.16469

Original Article

Dentistry Section

Evaluation of Hardness and Fracture Toughness of Feldspathic Porcelain by Various Surface Finishing Techniques

KHALID GHIAZ[1], VASANTHAKUMAR[2], DEEPAK KAMALANATHAN[3], T ANJAN KUMAR[4], R AKHILA[5], HARIHARAN RAMAKRISHNAN[6], NS AZHAGARASAN[7]

ABSTRACT

Introduction: Dental porcelain is fired at a high temperature inside the furnace and subsequently glazed for intraoral use as a restoration. There is no clarity on the correlation between physical properties of porcelain and its surface finishing techniques.

Aim: To evaluate surface hardness and fracture toughness of feldspathic porcelain with different porcelain surface finishing methods.

Materials and Methods: This in-vitro descriptive study was conducted between November 2018 to August 2019 at Department of Prosthodontics, Ragas Dental College and Hospital, Tamil Nadu, India, with 40 samples of Nickel Chrome (NiCr) alloy specimens, with addition of porcelain. The sample were divided into four groups S1: Unpolished, S2: Polished, S3: Autoglazed, S4: Add-on glaze according to the finishing procedures used with each group containing 10 samples. All samples were tested for surface hardness and Fracture toughness and were subjected to One-way Analysis of Variance (ANOVA), Bonferroni posthoc tests and Statistical Package of the Social Sciences (SPSS) California, USA.

Results: Mean value of fracture toughness (in $MPa^{1/2}$) for 0.2 kg load was 0.729672 for S1, 1.187567 for S2, 0.89482 for S3, 1.324399 for S4. Mean value of surface hardness (in kg/mm^2) for 1 kg load was 360.048 for S1, 519.166 for S2, 508.817 for S3, 527.916 for S4. Maximum deviation of 24.752 and error of 7.8273 was found in S4, least deviation of 10.7760 and error of 3.4077 was found in S1 group.

Conclusion: The glazed porcelain had the highest micro hardness and fracture toughness followed by polished porcelain and autoglazed porcelain.

Keywords: Dental casting technique, Dental polishing, Dental porcelain, Hardness test, Porcelain metal alloys

INTRODUCTION

Porcelain is widely used in dental practice as material of choice for an individual jacket crown, fixed long span restorations. Effective finishing and polishing of dental restorations provide three benefits of dental care: oral health, function and esthetics [1]. Main advantages of porcelain include biocompatibility, natural appearance and high resistance to wear and chemical inertness, refractive nature, hardness, susceptibility to clinical fracture and chemical inertness [2].

Disadvantages of porcelain include brittleness, lesser edge strength, high hardness resulting in more impact to the opposing teeth during mastication and abrasion of enamel of the natural opposing and adjacent teeth. The finishing and polishing of porcelain restorations are considered as an essential procedure for the final fit [2,3,4]. Some authors have concluded that finishing and polishing of porcelain restoration is considered satisfactory with usage of conventional polishing systems such as polishing cups, disks and with porcelain polishing pastes [5,6]. However, the usual method of producing the surface gloss is by the application of glazes on the surface of porcelain [4].

Porcelain which is used as metal ceramic restorative material should have adequate strength, hardness, formable to the required shape, biocompatible, resistant to the oral environment, abrasive resistance and should be able to obtain the required colour and translucency [7,8]. For dental application hardness of ceramic, similar to that of enamel is desirable to minimise the wear of the resulting ceramic restoration and reduce the wear damage that can be produced on enamel by the ceramic restoration [8,9].

It is also considered that the surface flaws induced at the time of surface finish leads to brittleness and reduces the flexural strength, micro hardness and thereby reducing the fracture toughness values. However it is mandatory and essential that high surface finish with an increase in esthetic value is achieved by the method of polishing and glazing [8,10].

Considering these facts at the background, this study was conducted with the aim to evaluate two important physical properties namely micro hardness and fracture toughness and their relation to various methods of finishing and polishing such as conventional usage of polishing materials on porcelain, glazing with vitreous materials and also auto glazing. Objectives of the study included intra group comparison and inter group comparison of microhardness and fracture hardness of feldspathic porcelain following four different polishing techniques and identification of the viable and acceptable polishing method.

MATERIALS AND METHODS

This in-vitro descriptive study was conducted between November 2018 to August 2019 at Department of Prosthodontics, Ragas Dental College and Hospital, Tamil Nadu, India. A sample size of 60 was included in the present study.

Inclusion and Exclusion criteria: The inclusion criteria included uniformly fired casting samples without any distortion, uniformly fired opaque porcelain samples, uniformly fired dentin ceramic samples. Inadequately fired porcelain samples, inadequately polished porcelain samples requiring repolishing were excluded. Twenty samples were discarded from study based on the exclusion criteria through visual inspection. Finally, forty samples were considered and selected and they were further divided into four groups of 10 samples each.

Study Procedure

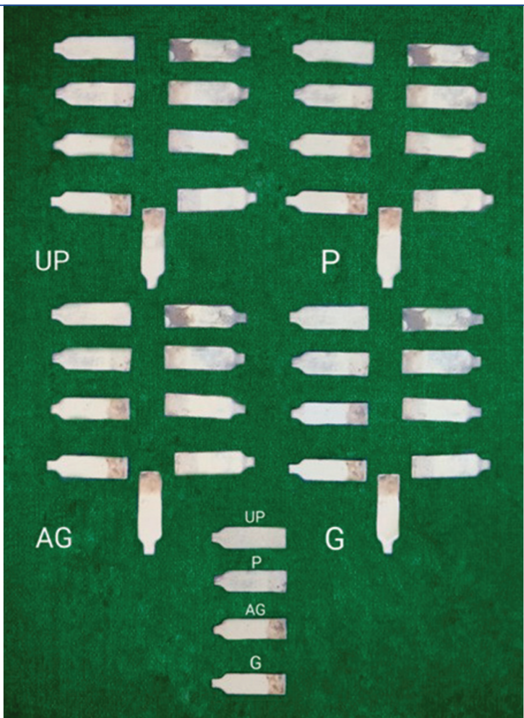
The preparation of specimens for testing and for conducting the study of metal ceramic were made in two stages. The first stage in the preparation of the specimens was the making of the alloy substructure. The second stage was fusion of porcelain to the alloy structure, so the entire unit comprised of porcelain fused to alloy structure, as the final specimen to test the important physical properties.

The NiCr alloy samples were made from acrylic resin pattern. A stainless steel die was prepared for the fabrication of resin specimens of equal size and shape of the metal substructure. Sample preparation was done as per American Society for Testing and Materials (ASTM), specifications for materials [11]. These acrylic patterns have a better dimensional stability than the wax pattern [11]. The dimensions of the patterns were 40 mm length and 10 mm width at one end. Thus, a total of 60 resin patterns were fabricated.

Each of the acrylic patterns were attached to a standardised wax sprue former of 5 mm length and diameter of 2.5 mm. The sprue was attached at the narrow portion of each acrylic pattern. Thus, group of 10 resin patterns were taken up and sprue formers were attached to each one of the resin pattern at one time for casting purpose. In each group 10 patterns were arranged in circular configuration and all the samples were connected to a conical form to which a crucible former was attached. The crucible former assembled with the sprues with the resin patterns were attached to the casting ring with 100 mm height and 3.5 inch diameter. The patterns were sprayed with debubbliser to improve the wetting of the patterns.

This whole assembly of 10 such sprued plastic patterns were invested in graphite free phosphate bonded precision investment material, Heravest universal N (Heraeus kulzer, Germany). The ring was preheated and held at the final temperature for 50 minutes for complete burn out. The burnout ring was kept in the induction casting machine and adjusted for alignment with the preheated crucible held in the casting machine. The alloy pellets were kept in the crucible and the weights were balanced. The casting temperature of the alloy was adjusted at 1500C [11]. Once the alloy had melted the lever was released to cast the metal in the mold.

The casting ring was allowed to cool to room temperature and divested. The sprues were severed and nodules removed. All the casting specimen were trimmed and finished with a thickness of 2 mm. Ten samples were obtained from each casting. Likewise six castings were made in a phased manner to produce a total of 60 samples made with nickel chromium alloy [Table/Fig-1]. The samples were coded for ease of identification. The specimens were held under vacuum for two minutes at 960°C. With temperature increase of 70°C per minute according to the manufacturer instructions to form oxide layer.



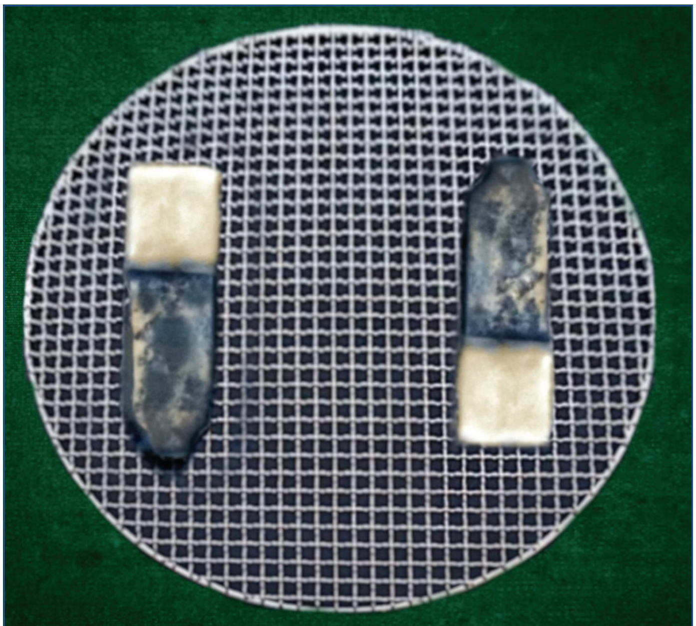
[Table/Fig-1]: Casted metal samples before preparation of working slot.

A custom mold was fabricated with clear methyl methacrylate. It consisted of a slot of 40×10×2 mm, which would facilitate the uniformity in the porcelain buildup. The working end of the metal samples, were grounded to 1 cm×0.5 mm and made to fit into the slot. When metal specimens were placed in the slot a uniform space of 2 mm remained in the slot between the top of the mold and metal and in the test site alone the metal was 0.5 mm [Table/Fig-2]. Porcelain powders were to be mixed with the modular liquid and filled in the mold. The mold was then placed on the mechanical vibrator and the porcelain condensed. A glass slab was placed on the mold surface to make the porcelain surface smooth and of uniform thickness.

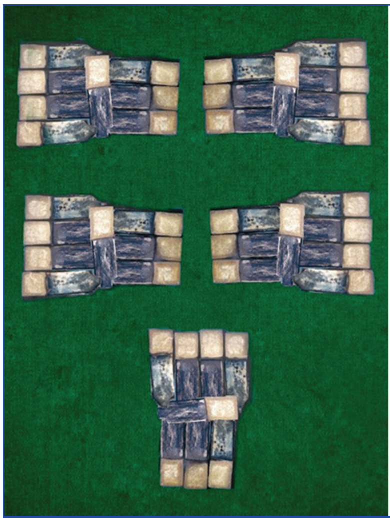
[Table/Fig-2]: Metal samples with the preparation slots.

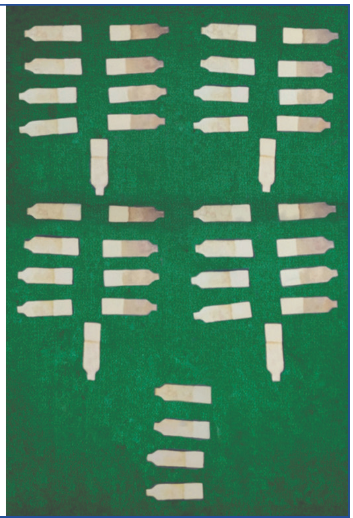
Specimens were trimmed flush at the top of the mold with a glass slab, which would give the approximate uniform thickness to all the porcelain samples. The thickness was further measured with the micrometer for the uniformity in all samples at nine points and the thickness of ceramic was totally 1.5 mm for all the 40 samples and were divided into four groups of 10 each as UP-unpolished, P-polished, AG-autoglazed, G-glazed.

The porcelain bearing surface of the alloy specimen was air abraded to simulate standard laboratory procedure. Further all the samples were steam cleaned to remove any surface impurities small amount of opaque porcelain paste was mixed with the special liquid. It was applied on the metal surface with the ceramic brush. Wash opaque was painted on the metal as a thin coating; no attempt was made to completely mask the metal. After firing the wash opaque a second layer of opaque was applied to completely mask the metal. The specimen was gently vibrated to evenly spread the paste. The second firing too was done as per manufacturers instructions. The thickness of opaque layer was found to be 0.3 mm after two firings [Table/Fig-3]. The same procedure was follow for the application of opaque layer on all the 40 alloy specimens. Following this, dentin porcelain was added and all the 40 specimens and were fired according to the manufacturer's instructions. Total thickness of sample was 2.0 mm (0.5 metal+0.3 opaque+0.8 dentine+0.4 enamel) [Table/Fig-4-6].



[Table/Fig-3]: Representative samples after start of ceramic work.





[Table/Fig-4]: Complete overview of samples added with opaque; **[Table/Fig-5]:** Representative ceramic added samples; **[Table/Fig-6]:** Complete overview of fired ceramic samples. (Images from left to right)

Among the 40 specimens, 10 specimens were taken for the study group coded as S1: UP unpolished, 10 specimens were taken and coded as S2: P, were polished with conventional polishing system to produce glossy appearance on the surface, by using finishing and polishing kit (Shofu, USA) and diamond polishing paste and finally they were all steam cleansed. Third group of 10 specimens, S3 were taken for study group coded as AG was given a surface finish with auto glazing according to the manufacturer recommended autoglazing firing temperature. The fourth, group of specimens of 10 members, S4 was coded as G and glazing was done by applying add on glazing material and were fired according to the manufacturer's recommended glazing temperature.

Study Parameters

Hardness was measured by indentation method. Hardness was indicated though Vicker's Hardness Number (VHN) Kg/mm^2. In Vicker's hardness test, two different loads of 0.2 kg and 1 kg was used. Diamond in the shape of a square pyramid is used as the indentor. The method of analysis of VHN is the load, divided by the area of indentation. The indentation was square in shape. The length of the diagonals of the indentation (sides of the diamond) are measured and averaged. Vicker's test is used for brittle materials but not suitable for elastic materials [9-14].

Fracture toughness or the critical stress intensity is a mechanical property that describes the ability of a material containing crack to resist further propagation and is given in the units of stress times the square root of crack length is MPa.m$^{1/2}$, Klc-0.16 ha^2 c$^{3/2}$, where K_{Ic}-fracture toughness, h-hardness value, a-radius of impression, c-height of the crack [12-16].

STATISTICAL ANALYSIS

Statistical analysis was done using One way ANOVA and Posthoc Bonferroni tests (IBM SPSS, Los Angeles, California). A value of $p<0.05$ was considered significant.

RESULTS

Values of micro hardness in kg/m^2 of porcelain, tested under 0.2 kg load, that have been finished using various techniques within the samples tested for S1, mean was 475.064. For S2 group, mean was 662.54. Within the samples tested for S3, mean was 641.224. Within the samples tested for S4, mean was 668.069 [Table/Fig-7].

The values of fracture toughness for 0.2 kg load are shown in [Table/Fig-8]. The fracture toughness has been shown in Mpa$^{1/2}$". The fracture toughness in S1 with a mean value was 0.729672, fracture toughness in S2, with mean value was 1.187567. Fracture toughness in S3 with a mean value was 0.894827. Fracture toughness in S4 with the mean value was 1.324399.

	VHN (kgmm^2)			
Specimen no.	Unpolished S1	Polished S2	Autoglazed S3	Add-on glaze S4
1.	480.33	637.32	622.84	640.8
2.	465.11	665.13	643.23	666.78
3.	496.21	627.42	644.45	632.11
4.	476.12	657.11	651.28	710.02
5.	480.32	665.11	648.12	685.11
6.	466.12	702.46	668.16	691.21
7.	482.12	688.11	623.11	677.54
8.	477.23	680.49	646.13	671.76
9.	468.14	665.14	620.8	640.17
10.	458.94	637.11	644.12	665.19
Average	475.064	662.54	641.224	668.069

[Table/Fig-7]: Vickers hardnes number by indentation method-for 0.2 kg load for 20 seconds.

Specimen no.	Unpolished S1	Polished S2	Autoglazed S3	Add-on glaze S4
1	0.737761	1.142361	0.869172	1.27034
2.	0.714384	1.192209	0.897626	1.321844
3.	0.762152	1.124616	0.899329	1.253113
4.	0.731294	1.177834	0.90886	1.407564
5.	0. 737745	1.192173	0.90445	1.358182
6.	0.715935	1.259121	0.932416	1.370275
7.	0.74051	1.2334	0.869549	1.343175
8.	0.732999	1.219741	0.901673	1.331716
9.	0.719038	1.192227	0.866325	1.269091
10.	0.704907	1.141985	0.898868	1.318692
Average	0.729672	1.187567	0.894827	1.324399

[Table/Fig-8]: Fracture toughness for 0.2 kg load- VHN- MPa$^{1/2}$.

Values of micro hardness of porcelain, tested under 1 kg load that have been finished using various techniques are shown in [Table/Fig-9]. Within the samples tested for S1, mean was 360.048. Within the samples tested for S2, mean was 519.166. Within the samples tested for S3, mean was 508.817. Within the samples tested for S4, mean was 527.916.

The values of fracture toughness of porcelain for l kg load. The mean value for S1 was 0.553014 was shown in [Table/Fig-10]. Fracture toughness in S2 mean value was 0.930577. In S3 the mean value was 0.710053. in S4 mean value was 1.046556.

There were significant differences in values of surface hardness and fracture toughness between these four groups ($p<0.05$) [Table/Fig-11].

VHN (kgmm²)				
Specimen no.	Unpolished S1	Polished S2	Autoglazed S3	Add-on glaze S4
1.	376.32	504.83	491.76	498.13
2.	347.64	493.14	517.22	524.56
3.	375.73	485.93	515.96	497.11
4.	357.34	512.39	522.21	564.23
5.	365.34	515.78	517.45	547.32
6.	352.82	569.42	537.95	554.12
7.	367.42	547.27	488.43	531.78
8.	357.88	537.29	505.67	538.95
9.	357.21	532.23	488.65	495.21
10.	342.78	493.38	502.87	527.75
Average	360.048	519.166	508.817	527.916

[Table/Fig-9]: Vickers hardness number by indentation method for 1 kg load for 20 seconds.

Specimen no.	Unpolished S1	Polished S2	Autoglazed S3	Add-on glaze S4
1.	0.578007	0.90488	0.68625	0.987507
2.	0.533956	0.883927	0.721779	1.039903
3.	0.577101	0.871003	0.720021	0.985485
4.	0.548855	0.918431	0.728743	1.118546
5.	0.561142	0.924508	0.7221	1.085023
6.	0.541912	1.020654	0.750708	1.098503
7.	0.564337	0.980952	0.681603	1.054216
8.	0.549684	0.963063	0.705661	1.06843
9.	0.548655	0.953993	0.68191	0.981719
10.	0.526491	0.884357	0.701754	1.046227
Average	0.553014	0.930577	0.710053	1.046556

[Table/Fig-10]: Fracture toughness for 1 kg load- $MPa^{1/2}$.
Through VHN

There were significant differences in values of surface hardness and fracture toughness between these four groups [Table/Fig-12].

Intergroup comparison of microhardness and fracture toughness between the four groups at 0.2 kg load has been presented n [Table/Fig-13]. When S1 (unpolished) was compared with the rest, it was found to have a significant mean difference with all the other groups. The values of mean difference were all in negative, proving that this group is significantly inferior to the rest. When S2 (polished) was compared with the rest of the groups, it was found to be significantly superior to S1. It's difference with the rest of the groups was not significant. When S3 (autoglazed) was compared with the rest of the groups, it was found to be significantly superior to S1, and significantly inferior to S4. It's difference with S2 was not significant. When S4 (glazed) was compared with the rest of the groups, it was found to be significantly superior to S1 and S3. It's difference with the S2 was not significant.

Intergroup comparison of microhardness and fracture toughness between the four groups at 1 kg load has been presented in [Table/Fig-14]. For fracture toughness when S1 (unpolished) was compared with the rest, it was found to have a significant difference with all the other groups. When S2 (polished) was compared with the rest of the groups, it was found to be superior to S1. It's difference with the rest of the groups was insignificant. When S3 (autoglazed) was compared with the rest of the groups, it was found to be significantly superior to S1, and significantly inferior to S4. It's difference with S2 was not significant. When S4 (glazed) was compared with the rest of the groups, it was found to be significantly superior to S1 and S3. It's difference with the S2 was not significant.

DISCUSSION

The outcome of the present study indicated preferential use of glazed porcelain over other types of polishing techniques for porcelain.

Analysing the results of hardness value obtained showed that glazed material could be considered harder than that of conventional polishing. Anusaivice also mentioned that autoglazed (or) self glazed medium fusing feldspathic porcelain is much stronger than ground and rough, non glazed porcelain [11]. If the material was unpolished or if the glaze, was removed by grinding, the hardness and fracture toughness was 25-35% less than that of the porcelain with the glaze layer intact. The glaze is effective in decreasing the crack propagation which in the outer surface because the surface flaws may be bridged and the surface will be under a state of comprehensive stress [11].

Results of this study indicated that porcelain with conventional highly polished surface with Shofu ceramic polishing kit and diamond polishing paste (S2), have comparably higher values of 519.166 as hardness and 0.930577 as fracture toughness value than that of the autoglazed shown in a value of 508.817 as hardness and 0.710053 as fracture toughness under 1 kg load. It is assumed that both type of glazing whether self (or) autoglazing produces smoother surface

Groups		N	Mean	Std. Deviation	Std. Error	Lower bound	Upper bound	Minimum	Maximum
VHN	Unpolished	10	475.0640	10.7760	3.4077	467.3553	482.7727	458.94	496.21
	Polished	10	662.5400	23.8871	7.5538	645.4522	679.6278	627.42	702.46
	Autoglazed	10	641.2240	14.9233	4.7192	630.5485	651.8995	620.80	668.16
	Glazed	10	668.0690	24.7522	7.8273	650.3623	685.7757	632.11	710.02
	Total	40	611.7243	82.6998	13.0760	585.2756	638.1729	458.94	710.02
Fracture toughness	Unpolished	10	0.7297	1.655E-02	5.234E-03	0.7178	0.7415	0.70	0.76
	Polished	10	1.1876	4.282E-02	1.354E-02	1.1569	1.2182	1.12	1.26
	Autoglazed	10	0.8948	2.083E-02	6.586E-03	0.8799	0.9097	0.87	0.93
	Glazed	10	1.3244	4.907E-02	1.552E-02	1.2893	1.3595	1.25	1.41
	Total	40	1.0341	0.2398	3.792E-02	0.9574	1.1108	0.70	1.41

Parameters	Sum of squares	Df	Mean square	F	p-value
VHN between groups	253032.3	3	84344.102	221.653	0.0213*
Within groups	13698.850	36	380.524		
Total	266731.2	39			
Fracture toughness between groups	2.199	3	0.733	592.475	0.0110*
Within groups	4.454E-02	36	1.237E-03		
Total	2.244	39			

[Table/Fig-11]: Analysis of mean, SD, and F values for surface roughness and fracture toughness for four groups using ANOVA-0.2 kg.
p<0.05 is significant; E- Designated margin in error

Groups		N	Mean	Std. Deviation	Std. Error	95% Confidence interval for mean		Minimum	Maximum
						Lower bound	Upper bound		
VHN	Unpolished	10	360.0480	11.1431	3.5237	352.0766	368.0193	342.7800	376.3200
	Polished	10	519.1660	26.9242	8.5142	499.9055	538.4264	485.9300	569.4200
	Autoglazed	10	508.8170	16.2713	5.1454	497.1771	520.4568	488.4300	537.9500
	Add-on glaze	10	527.9180	24.5761	7.7716	510.3372	545.4987	495.2100	564.2300
	Total	40	478.9872	72.6617	11.4888	455.7488	502.2256	342.7800	569.4200
Fracture toughness	Unpolished	10	0.553	0.01711	0.0054	0.5407	0.5652	0.5265	0.5780
	Polished	10	0.9305	0.04826	0.0152	0.8960	0.9651	0.8710	1.0207
	Autoglazed	10	0.7106	0.02402	0.0075	0.6935	0.7278	0.6816	0.7571
	Add-on glaze	10	1.0465	0.04870	0.0154	1.0117	1.0814	0.9818	1.1185
	Total	40	0.8102	0.19704	0.0311	0.7471	0.8732	0.5265	1.1185
Parameters				Sum of squares		df	Mean squares	F	p-value* <0.05 sig
VHN		Between groups		190449.094		3	63483.031	147.821	<0.001*
		Within groups		15460.487		36	429.458		
		Total		205909.581		39			0.0113*
Fracture toughness		Between groups		1.464		3	0.488	350.348	0.0313*
		Within groups		0.050		36	0.001		
		Total		1.514		39			

[Table/Fig-12]: Analysis of mean, SD, and F values for surface roughness and fracture toughness for four groups using ANOVA: 1 kg.

Dependent variable		Mean difference (I-J)	Std. Error	Significance	95% Confidence interval	
(I) GP	(J) GP				Lower bound	Upper bound
VHN	Unpolished	187.4760	8.7238	0.017*	-211.8326	-163.1194
	Autoglazed	-166.1600	8.7238	0.032*	-190.5166	-141.8034
	Glazed	-193.0050	8.7238	0.029*	-217.3616	-168.6484
Polished	Unpolished	187.4760	8.7238	0.027*	163.1194	211.8326
	Autoglazed	21.3160	8.7238	0.117	-3.0406	45.6726
	Glazed	-5.5290	8.7238	1.000	-29.8856	18.8276
Autoglazed	Unpolished	166.1600	8.7238	0.011*	141.8034	190.5166
	Polished	-21.3160	8.7238	0.117	-45.6726	3.0406
	Glazed	-26.8450	8.7238	0.024*	-51.2016	-2.4884
Glazed	Unpolished	193.0050	8.7238	0.023*	168.6484	217.3616
	Polished	5.5290	8.7238	1.000	-18.8276	29.8856
	Autoglazed	26.8450	8.7238	0.024*	2.4884	51.2016
KC unpolished	Polished	-0.4579	1.573E-02	0.012*	-0.5018	-0.4140
	Autoglazed	-0.1652	1.573E-02	0.011*	-0.2091	-0.1212
	Glazed	-0.5947	1.573E-02	0.016*	-0.6386	-0.5508
Polished	Unpolished	0.4579	1.573E-02	0.019*	0.4140	0.5018
	Autoglazed	0.2927	1.573E-02	0.010*	0.2488	0.3367
	Glazed	-0.1368	1.573E-02	0.019*	-0.1808	-9.2914E-02
Autoglazed	Unpolished	0.1652	1.573E-02	0.022*	0.1212	0.2091
	Polished	-0.2927	1.573E-02	0.106	-0.3367	-0.2488
	Glazed	-0.4296	1.573E-02	0.109	-0.4735	-0.3857
Glazed	Unpolished	0.5947	1.573E-02	0.106	0.5508	0.6386
	Polished	0.1368	1.573E-02	0.012*	9.291E-02	0.1808
	Autoglazed	0.4296	1.573E-02	0.017*	0.3857	0.4737

[Table/Fig-13]: Bonferroni post HOC multiple comparison tests for surface roughness and fracture toughness for four groups: 0.2 kg.
The mean difference is significant at the 0.05 level

Dependent variable	(I) Group 1	(J) Group 1	Mean difference (I-J)	Std. Error	Sig.	95% Confidence interval	
						Lower bound	Upper bound
VHN	Unpolished	Polished	159.1180*	9.2677	0.021*	-184.9933	-133.2426
		Autoglazed	148.7690*	9.2677	0.101	-174.6443	-122.8936
		Add-on glaze	167.8700*	9.2677	0.011*	-193.7453	-141.9946
	Polished	Unpolished	159.1180*	9.2677	0.021*	133.2426	184.9933
		Autoglazed	10.3490	9.2677	1.000	-15.5263	36.2243

		Add-on glaze	-8.7520	9.2677	1.000	-34.6273	17.1233
	Auto glazed	Unpolished	148.7690*	9.2677	0.011*	122.8936	174.6443
		Polished	-10.3490	9.2677	1.000	-36.2243	15.5263
		Add-on glaze	-19.1010	9.2677	0.279	-44.9763	6.7743
	Add-on glaze	Unpolished	167.8700*	9.2677	0.011*	141.9946	193.7453
		Polished	8.7520	9.2677	1.000	-17.1233	34.6273
		Autoglazed	19.1010	9.2677	0.279	-6.7743	44.9763
Fracture toughness	Unpolished	Polished	-0.37756*	0.0166	0.001*	-0.4241	-0.3309
		Autoglazed	-0.1576*	0.0166	0.001*	-0.2042	-0.1110
		add-on glaze	-0.4935*	0.0166	0.001*	-0.5401	-0.4469
	Polished	Unpolished	0.3775*	0.0166	0.100	0.3309	0.4241
		Autoglazed	0.2198*	0.0166	0.011*	0.1732	0.2664
		Add-on glaze	-0.1159*	0.0166	0.013*	-0.1625	-0.0693
	Auto glazed	Unpolished	0.1576*	0.0166	0.016*	0.1110	0.2042
		Polished	-0.2198*	0.0166	0.0198	-0.2664	-0.1732
		Add-on glaze	-0.3358*	0.0166	0.021*	-0.3824	-0.2892
	Add-on glaze	Unpolished	0.4935*	0.0166	0.021*	0.4469	0.5401
		Polished	0.1159*	0.0166	0.032*	0.0693	0.1625
		Autoglazed	0.3358*	0.0166	0.053	0.2892	0.3824

[Table/Fig-14]: Bonferroni post HOC multiple comparison tests for surface roughness and fracture toughness for four groups:1 kg.
*The mean difference is significant at the 0.05 level

than any mechanical polishing agents (or) technique. In the case of self glazing a minimum fitted surface could arise due to the mismatch in the thermal coefficient of expansion as surface silica particles a higher temperature flows more than that of inner core of silica. In such conditions if the glaze has lower coefficient of thermal expansion than that of the body porcelain, it will be put under compressive stress on cooling. On such occasion tensile stress develop and the tendency is to develop crazing on the surface of the self glaze. Crazing is apparently shown as micro cracks or through conventional mechanical polishing flaws which would expose such cracks. This observation is of clinical importance because after the porcelain fused metal prosthesis is cemented in the mouth, it is a common practice for the operator to adjust the occlusion by grinding the surface of the porcelain with diamond burs and polishing it with a polishing kit [11-14].

Deleterious effects of the rough and ground porcelain includes increased susceptibility for fracture due to propagation of microcracks, increase in wear of opposing restoration and/or tooth and discoloration due to more plaque accumulation. Increased wear of opposing teeth, loss of vertical dimension and interceptive contacts due to unglazed porcelain teeth induces traumatic occlusion in complete denture [15-18]. Additional firing for glazing may have a deleterious effect on the porcelain itself like devitrification. Moreover, reglazing is more time consuming as the chair side time, transportation, and laboratory time are involved. Grinding process removes glazed superficial surface. Ideally, it is advised to be re-glazed to get the smooth surface [19-25].

In a previous study, different polishing kits used reduced the average roughness by approximately 77% [20]. It was concluded that corrected porcelain surfaces should ideally be reglazed, alternatively, polish the surfaces before final cementation .this study and the current study had utilized Shofu kit for polishing, but hardness and fracture toughness was not included in their study. Sethi S et al., explained that polishing of feldspathic porcelain surface will lead to a finish similar to a reglazed surface. Therefore chairside polishing can be a good alternative to reglazing for finishing adjusted porcelain surface [26]. Manjuran NG and Sreelal T, concluded that polishing with feldspathic porcelain adjustment kit followed by diamond particle impregnated wax, created surfaces significantly smoother than the glazed specimens [27]. Rani V et al., elaborated the fact that after adjustment of ceramic restorations in dental clinics, diamond polishing paste, when used after porcelain adjustment kit, could provide the marked finish equal to glazed or reglazed surface [28]. Kalia P et al., concluded abraded specimens of feldspathic, after polishing using pearl finish polishing paste and soflex disc became smoother than glazed specimens [29]. Facts and conclusions derived from these studies are different from current study. This could be attributed due to difference in brands of feldspathic porcelains and their composition used, operator style of polishing. Comparison of previous studies had been done in [Table/Fig-15] [20,26-29].

S. No.	Author's name and year	Place of study	Sample size	Polishing techniques compared	Parameters compared	Parental acceptance of BMT (Conclusion)
1.	Haralur SB, 2012 [20]	Saudi Arabia	36	Manual polishing, autoglazing, overglazing	Surface roughness	Manual polishing reduces roughness by 77%.
2.	Sethi S et al., 2013 [26]	India	20	Autoglaze, reglaze, chairside polishing	Surface roughness	Chairside polishing good alternative to reglazing.
3.	Manjuran NG and Sreelal T, 2014 [27]	India	77	Manual polishing, glazing	Surface roughness, colour stability	Polishing with porcelain adjustment kit followed by diamond particle-impregnated wax, created surfaces smoother than the glazed specimens.
4.	Rani V et al., 2021 [28]	India	50	Glazing, reglazing, surface polishing	Surface roughness	Diamond polishing paste, used after porcelain adjustment kit, could provide the finish equal to glazed or reglazed.
5.	Kalia P et al., 2021 [29]	India	30	Glazing, abrading and polishing	Surface roughness, colour stability	Abraded specimens from all three groups after manual polishing became smoother than glazed specimens.
6.	Present study	India	40	Unpolished, polished, add on glaze, auto glaze	Surface roughness, fracture toughness	Glazed porcelain exhibited significant and highest micro-hardness and fracture toughness when compared with other finishing and polishing techniques.

[Table/Fig-15]: Comparison of previous studies [20,26-29].

Limitation(s)

This study included interpretation of only two mechanical properties of porcelain following finishing methods. More properties including ultimate tensile strength and ductility should be included in future studies. Only one type of porcelain and alloy was used in this study. Artificial saliva was not used in this study to simulate clinical situation.

CONCLUSION(S)

Within the limitations of the study, it can be concluded that glazed porcelain exhibited significant and highest micro-hardness and fracture toughness when compared with other finishing and polishing techniques. Polished porcelain exhibited significant and lesser values for microhardness and fracture toughness, than glazed porcelain and was second best. Glazed porcelain should be used whenever possible for porcelain fused to metal, for fixed single and multiple anterior and posterior long span restorations for greater durability and clinical longevity.

REFERENCES

[1] Singh A, Sengupta B, Kuckreja H, Kuckreja KB. An in vitro study to compare glazed and polished surfaces of feldspathic porcelain and comparing three different polishing systems. Indian J Dent Sci. 2017;9:S21-26.
[2] Bajraktarova-Valjakova E, Korunoska-Stevkovska V, Kapusevska B, Gigovski N, Bajraktarova-Misevska C, Grozdanov A. Contemporary dental ceramic materials, a review: Chemical composition, physical and mechanical properties, indications for use. Open Access Maced J Med Sci. 2018;6(9):1742-55.
[3] Bagby M, Marshall SJ, Marshall Jr GW. Metal ceramic compatibility: A review of the literature. J Prosthet Dent. 1990;63(1):21-25.
[4] Campbell SD. Evaluation of surface roughness and polishing techniques for new ceramic materials. J Prosthet Dent. 1989;61(5):563-68.
[5] Al-Wahadni A, Muir Martin D. Glazing and finishing dental porcelain: A literature review. J Can Dent Assoc. 1998;64:580-83.
[6] Baharav H, Laufer BZ, Pilo R, Cardash HS. Effect of glaze thickness on the fracture toughness and hardness of alumina-reinforced porcelain. J Prosthet Dent. 1999;81(5):515-19.
[7] Barghi N, Alexander L, Draugh RA. When to glaze-an electron microscope study. J Prosthet Dent. 1976;35(6):648-53.
[8] Chu F, Frankel N, Smales RJ. Surface roughness and flexural strength of self-glazed, polished, and reglazed In-Ceram/Vitadur Alpha porcelain laminates. Int J Prosthodont. 2000;13(1):66-71.
[9] Tuncdemir AR, Dilber E, Kara HB, Ozturk AN. The effects of porcelain polishing techniques on the color and surface texture of different porcelain systems. Material Sciences and Applications. 2012;3(5):294-300.
[10] Fuzzi M, Zaccheroni Z, Vallania G. Scanning electron microscopy and profilometer evaluation of glazed and polished dental porcelain. Int J Prosthodont. 1996;9(5):452-58.
[11] Phillips , Book of Dental Materials, 2021, 13th edition, Elsevier pub.
[12] Griggs JA, Thompson JY, Anusavice KJ. Effects of flaw size and autoglaze treatment on porcelain strength. J Dent Res. 1996;75(6):1414-17.
[13] Jagger DC, Harrison A. An in vitro investigation into the wear effects of unglazed, glazed, and polished porcelain on human enamel. J Prosthet Dent. 1994;72(3):320-23.
[14] Magne P, Oh WS, Pintado MR, DeLong R. Wear of enamel and veneering ceramics after laboratory and chairside finishing procedures. J Prosthet Dent. 1999;82(6):669-79.
[15] Bottino MC, Valandro LF, Kantorski KZ, Scotti R, Bottino MA. Evaluation of the effects of finishing and polishing systems on ceramic surface roughness. J Dent Res. 2003;B133.
[16] Giordano II RA, Pelletier L, Campbell S, Pober R. Flexural strength of an infused ceramic, glass ceramic, and feldspathic porcelain. J Prosthet Dent. 1995;73(5):411-18.
[17] Williamson RT, Kovarik RE, Mitchell RJ. Effects of grinding, polishing, and overglazing on the flexure strength of a high-leucite feldspathic porcelain. Int J Prosthodont. 1996;9(1);30-37.
[18] Hobo S. Distortion of occlusal porcelain during glazing. J Prosthet Dent. 1982;47(2):154-56.
[19] Al Wahadni AM, Martin DM. An in-vitro investigation into the wear effects of glazed, unglazed and refinished dental porcelain on an opposing material. J Oral Rehabil. 1999;26(6):538-46.
[20] Haralur SB. Evaluation of efficiency of manual polishing over autoglazed and overglazed porcelain and its effect on plaque accumulation. J Adv Prosthodont. 2012;4(4):179-86.
[21] Magne RZ, Shahwan SK. An evaluation of the effects of different polishing materials and glazing techniques on the fracture toughness of dental porcelain surfaces. J Bagh College Dentistry. 2012;24(4):01-05.
[22] Alzhrani AM, Badr N. Hardness and fracture toughness of heat pressable and machinable dental all-ceramics. Int J Health Sci Res. 2019;9(11):159-67.
[23] Ueda H, Shinya A, Tohyama Y, Yokozuka S. Toughness of porcelain using indentation method. Int J Pros. 1996:10(7):196-98.
[24] Albakry M, Guazzato M, Swain MV. Fracture toughness and hardness evaluation of three pressable all-ceramic dental materials. J Dent. 2003;31(3):181-88.
[25] Seghi RR, Denry IL, Rosenstiel SF. Relative fracture toughness and hardness of new dental ceramics. J Prosthet Dent. 1995;74(2):145-50.
[26] Sethi S, Kakade D, Jambhekar S, Jain V. An in vitro investigation to compare the surface roughness of auto glazed, reglazed and chair side polished surfaces of Ivoclar and Vita feldspathic porcelain. J Indian Prosthodont Soc. 2013;13(4):478-85.
[27] Manjuran NG, Sreelal T. An in vitro study to identify a ceramic polishing protocol effecting smoothness superior to glazed surface. J Indian Prosthodont Soc. 2014;14(3):219-27.
[28] Rani V, Mittal S, Sukhija U. An in vitro evaluation to compare the surface roughness of glazed, reglazed and chair side polished surfaces of dental porcelain. Contemp Clin Dent. 2021;12(2):164-68.
[29] Kalia P, Nair KC, Jaiswal D, Tikmani C, Banerjee D, Bera R. A comparative study on the effect of polishing systems on the color and surface texture of different porcelain systems - feldspathic, pressable, and computer-aided design/computer-aided manufacturing. J Indian Prosthodont Soc. 2021;21(2):173-79.

PARTICULARS OF CONTRIBUTORS:

1. Professor and Head, Department of Prosthodontics, Priyadarshini Dental College and Hospital, Chennai, Tamil Nadu, India.
2. Professor Emeritus, Department of Prosthodontics, Ragas Dental College and Hospital, Chennai, Tamil Nadu, India.
3. Reader, Department of Prosthodontics, Chettinad Dental College and Hospital, Chennai, Tamil Nadu, India.
4. Lecturer, Department of Prosthodontics, Priyadarshini Dental College and Hospital, Chennai, Tamil Nadu, India.
5. Consultant Prosthodontist, Private Practice, Chennai, Tamil Nadu, India.
6. Professor, Department of Prosthodontics, Ragas Dental College and Hospital, Chennai, Tamil Nadu, India.
7. Professor and Head, Department of Prosthodontics, Ragas Dental College and Hospital, Chennai, Tamil Nadu, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Hariharan Ramakrishnan,
Professor, Department of Prosthodontics, Ragas Dental College and Hospital,
East Coast Road, Uthandi, Chennai-600119, Tamil Nadu, India.
E-mail: abcv2005@yahoo.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Oct 27, 2021
- Manual Googling: Mar 23, 2022
- iThenticate Software: May 19, 2022 (11%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? NA
- Was informed consent obtained from the subjects involved in the study? NA
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Oct 26, 2021**
Date of Peer Review: **Jan 07, 2022**
Date of Acceptance: **Mar 29, 2022**
Date of Publishing: **Jun 01, 2022**