The effect of tooth brushing and thermal cycling on a luster change of ceromers finished with different methods

Lee-Ra Cho, DDS, Yang-Jin Yi, DDS
Department of Prosthodontics, College of Dentistry, Kangnung National University, Kangnung, Korea

Statement of problem. Luster loss in esthetic anterior ceromer restoration can occur and can be related with rough surface texture. Understanding durability of surface finishing methods like polishing and surface coating have critical importance.
Purpose. This study evaluated the effect of tooth brushing and thermal cycling on surface luster of 3 ceromer systems (Artglass, Targis, Sculpture) treated with different surface finishing methods.
Material and methods. Seventy-two samples were prepared: 12 for control group Z100, 12 for Artglass, 24 for Targis, and 24 for Sculpture. Half of the Targis and Sculpture were polished according to the manufacturer' s recommendation. The rest of the samples were coated with staining and glazing solution for Targis and Sculpture, respectively. All specimens were subjected to 10,000 cycles between 5℃ and 55℃ with 30 seconds dwell time. Tooth brushing abrasion tests were performed in a customized tooth brushing machine with 500g back-and forth for 20,000 cycle. Luster comparisons were based on grading after direct observation, and light reflection area was measured with Image analysis software.
Results. All materials showed an decrease in luster grade after thermal cycling and tooth brushing. The post-tooth brushing results revealed that the glazed Sculpture had greater mean luster grade than did any other groups. While, the stained Targis group showed greatest changes after tooth brushing ($p < 0.05$), polished Targis and Sculpture did not show significant changes. However, glazed Sculpture showed discretely fallen out glaze resin.
Conclusion. From the results of this study, all of the ceromer specimens were much glossy than control composite group after tooth brushing. coatings used for Targis and Sculpture had not durability for long term use.

CLINICAL IMPLICATIONS

Ceromer might have much luster than composite after long term use. But, surface coatings like a staining and glazing would be worn or fallen out in times.

Fiber-reinforced composite (FRC) formulations were developed to serve as structural components for various dental appliances such as splints and prosthodontic framework[1,2]. This material provides the clinician with a durable, flexible, and esthetic alternative to conventional porcelain fused to metal crowns. A new material can be used in conjunction with FRC systems, so-called 'ceromer' (polymer glass ceramic) materials have become available for fabrication of inlays, onlays, crowns and veneers[3-5]. The ceromer material which is a second generation indirect composite resin contains silanized, microhybrid inorganic fillers embedded in a light-curing organic matrix[6,7]. Due to high filler content, the ceromer has considerably improved mechanical properties. Moreover, curing method and physical property have been improved with the use of light-heat-gas (N_2) which has more complete polymerization and less polymerization shrinkage than the composite material. The commercial ceromers had variable filler contents and size(Table 1).

While ceramic as an esthetic restorative material is so brittle that it is easy to fracture and wears occluding teeth, ceromer has better shock absorption ability and does not cause attrition of teeth. It has translucency and improved color stability over conventional composite resins. These materials can be bonded to dentin and enamel for excellent retention and seal. The thermal expansion coefficient and the moduli of elasticity of the ceromer are quite similar to that of dentin[10]. When subjected to intraoral stress, the material exhibits a deformation capacity that is similar to that of a natural tooth, which reduces the fracture-inducing stress between restorations and dentition.

However, it has several clinical problems. Though, there is a study that the ceromer material was similar to enamel in surface texture and wear resistance in the occlusal contact and non-contact regions, it shows lower abrasion resistance in clinical dentistry[3]. The hardness of the ceromer is inferior to that of the enamel, and it has weaker wear resistance, which may cause problems, if it is used for a long term[11]. If it has lower tooth brush wear resistance, ceromer restorations have shown persistent roughness after long term use. This roughness invites staining of the body and

Table 1. Comparison of commercial ceromers[3,7-9].

Brand name	Monomer	Filler content (wt%)	Filler	Filler size
Artglass	UDMA Methacrylic ester PCDMA	70	Silicone dioxide Barium alumina silica glass	0.7 μm
Sculpture	TEGDMA Ethoxylated A DMA	79	Barium borosilicate glass Hydrophobic amorphous silica	0.6μm
Targis	Bis-GMA Decandiol UDMA	75-85	Barium-aluminum silicon glass Mixed oxide Silicon dioxide	1mm 200nm 40nm

margins of the restoration and contributes to plaque retention. Roughened surface texture could also be importance for the esthetic properties, since it affects the reflection of light and the apparent shade of a translucent material. On the esthetically important facial surfaces of anterior teeth, it is probable that such abrasion plays an important role in degradation of the surface finish.

The surface of the restoration should be finished to a high surface luster to prevent discoloration, reduce wear of the opposing enamel, deter crack propagation and to enhance patient comfort. Various methods for finishing the composite resins were developed[12-15]. While glazing the ceramic surfaces is effective to fill the surface flaw and to increase the surface luster, the usual finishing method of the ceromer is polishing with some instruments. However, it was supposed that finish coatings over polished ceromers would assist in increasing the surface luster and overcoming the surface roughness. Moreover, it was presumed that the staining liquid also might act like a glazing solution because both of two are consisted of unfilled resin.

It was reported the conventional composites would look dull after some years, irrespective of their initial luster[16]. Researchers have reported surface roughness and loss of luster may be caused by tooth brush dentifrice[17,18]. To date, however, no published studies have evaluated the effects of tooth brushing on the surface luster of ceromer treated by different technique. The purpose of this study was to determine the effect of tooth brushing and thermal cycling on surface luster of 3 ceromer systems treated with different surface finishing methods.

MATERIAL AND METHOD

The material used was three A2 shade dentin ceromer and Z100 composite resin as a control group (Table 2). The material was filled in splitted metal mold(6(radius) × 2.5mm) on a glass slide. To remove excess material, it was pressed with Mylar strip, and a second glass slide was positioned on top of the material. These specimens were polymerized according to manufacturer' s instructions. Twelve specimens of Artglass and control group and 24 specimens of Targis and Sculpture were made. After curing, the specimens were stored for a minimum 3 days in air at room temperature and finally in deionized water for 7 days. The surfaces of all specimens were metallographically polished(Automat, Buhler, Germany) with 200, 400 grit and to a final finish with 600 grit silicone carbide paper under running water.

Targis and Sculpture specimens were randomly divided into 2 groups of 12 specimens each. They were then polished using sequential finishing instruments followed to the manufacturer' s rec-

Table 2. Commercial ceromers used in this study.

Species	Code	Brand name	Curing (time)	Characte -ristic	Manufacturer
Ceromer	Art	Artglass	Light (10min)		Kulzer, Germany
	Ta-pol	Targis	Light & Heat	polishing	Ivoclar,
	Ta-gl	Targis	(25 min)	staining	Richitenschetein
	Sc-pol	Sculpture	Light & Heat	polishing	Generic pentron,
	Sc-gl	Sculpture	under N_2 (15 min)	glazing	USA
Composite resin	Z100	Z100	Light (2 min)		3M, USA

ommendations (Table 3). Twelve specimens of Targis and Sculpture were then glazed with staining and glazing liquid, respectively. All specimen' s preparation, finishing and polishing procedures were done by the same investigator in order to reduce variability. After all specimens were polished, they were thoroughly rinsed with tap water and allowed to dry for 24 hours before measurement of the luster.

Luster was evaluated by one examiner with direct vision with luster guide made in the laboratory. The surface luster of the ceromers were ordinally graded from 1 to 10. Each grade indicate as follows; grade 1 for dull appearance, grade 3 for matte-sheen, grade 6 for relatively glossy, grade 10 for high glossy. One investigator evaluated the luster grade under northern-exposure sunlight in the middle portion of a day. Another luster evaluation method measuring reflected area under same light source was adopted. The light source and detector both set at 45 degrees. All specimens were photomicrographed with CCD camera and analyzed by a image analysis software. The same scale of brightness was set and reflected area were calculated.

Before tooth brushing test, all specimens thermocycled 10,000 times at temperatures of 5℃ and 55℃. A dwell time of 30 seconds in each water bath was used. Brushing was performed in a customized tooth brushing machine. This gave horizontal back-and-forth movement of a soft nylon toothbrush (Oral-B Soft, USA) in a water/dentifrice slurry at room temperature (23 ±1℃). The slurry consisted of a dentifrice (Fresh, Lucky, Korea), with a medium abrasivity index and water in the ratio 1 : 3 by volume. Brush

Table 3. Instruments for polishing procedure.

Materials	Instruments		Manufacturer
Z100	Shofu Supersnap polishing set		
	Medium grit	5000 rpm/ 20 s	Shofu, D sseldorf, Germany
	Fine grit	5000 rpm/ 20 s	
	Super fine grit	5000 rpm/ 20 s	
Artglass	Art-Glass tool kit		
	Polisher (Prepol)	5000 rpm/ 120 s	Kulzer, Wehrheim, Germany
	Polisher (Mepol)	5000 rpm/ 60 s	
	Polisher (Hipol)	5000 rpm/ 120 s	
Targis	Big silicone point (BL-R3)	5000 rpm/ 120 s	Shofu, D sseldorf, Germany
	Robinson brush (brown)	5000 rpm/ 120 s	Renfert, Germany
	Silicone wheels, white		Ash/Dentsply, York, USA
	Linen brush and Polishing paste green		Ivoclar, Schaan, Liechtenstein
	Linen brush and Polishing paste blue		Ditto
Sculpture	Big silicone point (BL-R3)	5000 rpm/ 120 s	Shofu, D sseldorf, Germany
	Robinson brush (brown)	5000 rpm/ 120 s	Renfert, Germany
	Polishing buffers		

load was 500g (average brushing force), stroke length 20mm, and stroke rate 150rpm/min. The test was run up to 20,000 cycles. A fresh slurry and toothbrush was used for every test. After the test, all specimens were ultrasonically cleaned for 5min, were rinsed in distilled water, carefully wiped dry. Then, luster of specimens were evaluated with the same method described earlier.

Data on luster grade and reflected surface area were analyzed using one-way ANOVA to determine whether significant differences existed at the 95% confidence level. When differences were significant, multiple comparison test was done by Scheffe's method (α<0.05). Then, comparison of the luster value of the before and after testing was done using the Student's t-test.

Following luster analysis, each of the samples was sputter-coated with about 20nm of gold and viewed in a scanning electron microscope(LEO 420, UK) at 1,500 magnifications.

RESULTS

All specimens produced less glossy surface after tooth brushing irrespective of the type of the ceromers. The mean and confidence interval of luster grade before and after tooth brushing are presented in Table 4 and Fig. 1. One way ANOVA test showed that there were significant differences of the luster grade values between the ceromers. Then, Post hoc Sheffe tests were performed on the ceromer types; a difference was demonstrated among all groups. For surface luster grade before tooth brushing, the highest luster grades were recorded for the glazed Sculpture, followed by stained Targis. The lowest grades were recorded for Targis polishing group. No difference was evident between the polished Sculpture and the control group. The post-tooth brushing results revealed that the glazed Sculpture had greater mean luster than did any other groups. While, the stained Targis group showed greatest changes after tooth brushing, polished Targis and Sculpture did not show significant changes.

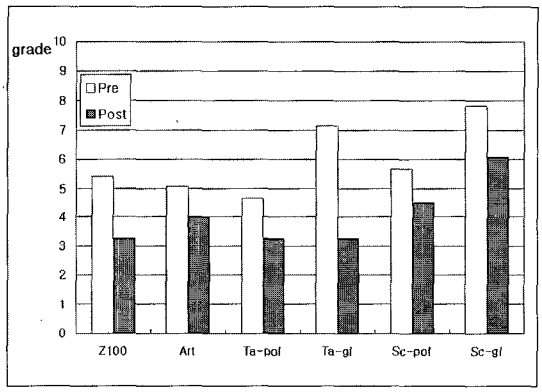

Fig. 1. Luster grade changes of ceromers.

Table 4. Surface luster grade of ceromers : Mean (95% Confidence interval).

	Before		After		Δ
Z100	5.4 (5.1 , 5.7)	b	3.3 (3.0 , 3.5)	a	*
Art	5.1 (4.8 , 5.4)	a, b	4.0 (3.6 , 4.4)	a, b	*
Ta-pol	4.7 (4.4 , 5.0)	a	3.3 (3.0 , 3.5)	a	*
Ta-gl	7.2 (6.7 , 7.6)	c	3.3 (3.0 , 3.5)	a	*
Sc-pol	5.7 (5.4 , 6.0)	b	4.5 (4.1 , 4.9)	b	*
Sc-gl	7.8 (7.6 , 8.1)	c	6.1 (5.4 , 6.8)	c	*

a, b, c indicates homogeneous subsets for α=.05

* means p<.05, NS = nonsignificant by Student's t test at 95% confidence level

Δ means the difference between before and after tooth brushing

The results of the light reflection areas are shown in Table 5 and Figure 2. The order of luster grade were not correspondent to that of the reflected area. At the baseline, Targis and Sculpture group irrespective of surface finishing methods presented larger area than Artglass and Z100. However, light reflection area showed some changes after tooth brushing. A dramatic decrease in the reflected area of the polished Targis was obtained. In contrast, stained Targis did not show statistically significant changes. Though glazed Sculpture groups showed high luster grade, it demonstrated smaller light reflection area than polished Sculpture and stained Targis group.

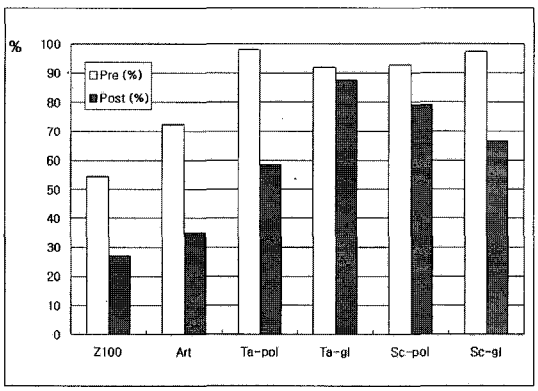

Fig. 2. Reflected area change of ceromers (%).

Moreover, it had the larger standard deviation than any other groups. It was suggested that glazed Sculpture had an uneven luster on contrast to the even luster of the specimens before tooth brushing. When the reflected area of ceromers after tooth brushing was compared, stained Targis had the largest area, followed by polished Sculpture and glazed Sculpture. All of the ceromers showed larger area than the specimens of the control group, Z100.

Figure 3 is a representative SEM picture depicting the surface of the ceromers before and after tooth brushing. The microstructures of the various ceromers ranged considerably. For example, the filler of Targis were larger than any other groups and of Sculpture were smallest. All materials presented roughened surface after tooth brushing. In the polished Targis, protruded filler particles were appeared. Rather, this phenomenon was less appeared in stained Targis. Peripheral parts of the surface glaze coatings fell apart in lumps. The pattern of discrete light reflecting areas could be interpreted as corresponding to a residual glazed surface of Sculpture.

DISCUSSION

Fabrication of fixed partial dentures without metal substructures offers the optical advantage of

Table 5. Percentile light reflection area of ceromers : Mean (95% Confidence interval).

	Before		After		Δ
Z100	54.4 (52.6 , 56.0)	a	26.9 (25.0 , 28.8)	a	*
Art	72.5 (68.1 , 76.9)	b	35.0 (32.9 , 37.2)	a	*
Ta-pol	98.0 (96.2 , 99.7)	d	58.7 (57.3 , 60.0)	b	*
Ta-gl	91.9 (88.5 , 95.2)	c	87.6 (79.8 , 95.4)	c	NS
Sc-pol	92.8 (91.2 , 94.4)	c, d	79.4 (76.5 , 82.3)	c	*
Sc-gl	97.2 (96.0 , 98.4)	c, d	66.7 (55.8 , 77.6)	b	*

a, b, c indicates homogeneous subsets for α=.05

* means p<.05, NS = nonsignificant by Student's t test at 95% confidence level

Δ means the difference between before and after tooth brushing

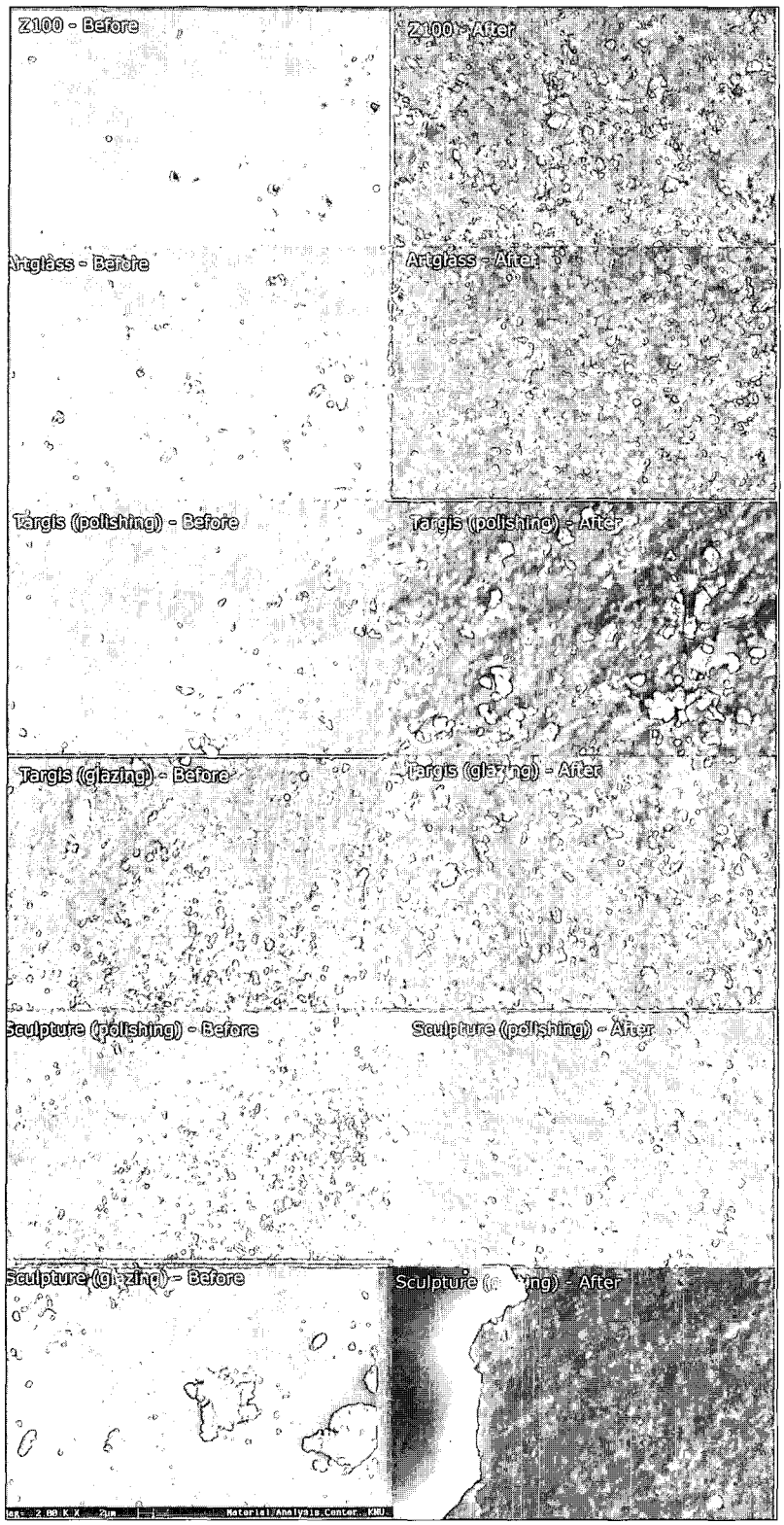

Fig. 3. Scanning electron micrographs of the ceromers before and after tooth brushing.

more natural light dynamics and decrease the potential biologic incompatibility. Clinical observations over 4-year periods have shown that ceromer restorations had equal longevity to ceramic restorations[19]. The modulus of elasticity of ceromer is quite similar to that of dentin. And so, ceromers are more resilient than brittle ceramic, which makes them less likely to fracture. In clinical dentistry, however, inappropriate use of adjusting instruments leave deep scratches on the surface. It means that ceromer had lower surface hardness and abrasion resistance.

Wear can be defined as 'the ultimate consequence of interaction between surfaces which is manifested in gradual removal of material'[20]. Most common type of wear mechanism is three body abrasion. In general, three body wear like a tooth brushing is proportional to the hardness of the materials in contact, the geometry of the abrasive particles, the load and the sliding distance[21]. In this study, the other conditions were the same, while the hardness of the materials were various. It was suggested that material removal and the resultant surface texture were partly caused by different surface hardness[22]. Ceromers contain hard filler phases within a softer matrix. In the wear condition, the hard filler particles may remain intact and transmit the sliding force to the surrounding matrix, resulting in microcracking. Eventually the cracked matrix is no longer able to retain the particles, which are then displaced. And then, this displaced filler particles could be acted like a abrader. Therefore, it was presumed that large filler particled ceromer might have the increased the wear rate. It seems the reason why polished Targis showed greatest changes in luster and light reflected area. In contrast, stained Targis showed greatest luster change and least change in light reflection area. It was possible by that stain coating filled the irregular pittings and flaws within the blended fillers at the baseline. However, superficial layer of the upper part on the pittings might worn out by the brushing. And so, it looked dull in spite of slight decreased light reflection area. Therefore, it was suggested that it acted like a protection layer from exfoliating larger fillers, which was seen in polished Targis specimens.

Tooth brush abrasion of older types of restorative materials has been reported in dental literature[23]. Aker studied the tooth brushing abrasion of composites and reported that the composite has the filler as blending of large and submicron particles produced high wear rate similar to large filler resin[24]. Our findings that Targis, the ceromer with blended type filler showed greatest change in light reflection area are supported by the results of Aker. Ehrnford found that the surface of composite, which had glass filler were more smooth and lustrous than the surrounding resin[18]. Goldstein demonstrated that the surface topography of a composite and acrylic resin were altered by routine tooth brushing and were various depending on the type of dentifrice[17]. In this study, we selected the dentifrice with medium abrasivity to simulate conventional oral environment.

Whitehead reported that tooth pastes left a surface on the composites which may be prone to crack propagation[25]. Roughened surface by tooth brushing could invite the several problems. The increase in surface roughness after tooth brushing would suggest that surface stains would be more easily retained[26]. Also, the attraction of dental plaque to roughened surface restorations is of serious concern. If roughened surface exists on occlusal surface, wear rate of occluding teeth would be increased. Our results suggests that tooth brushing could affect the surface luster of ceromer as well.

Luster is not a physically determined unit, but rather a physiologically and psychologically determined one. A direct measurement is therefore very difficult. Luster occurs in substances when

the beam of light which is incident can be thrown back at directly the same angle as the angle of incidence of the surface. Generally, if there is greater roughness on the surface, the beam of light is repeatedly deflected and comes off the surface at a different angle to the angle of incidence. In this study, however, luster grade did not coincide with the light reflection area. Though glazed Sculpture groups presented high luster grade, it demonstrated small light reflection area. At the periphery of the some specimens, glaze coatings were fallen out discretely. These finding was possible by the fact that if large continuous flat areas with surface coatings were existed, it looked glossy in spite of real light reflection area was small. Moreover, this group achieved uneven luster and showed various worn out patterns. These were consistent with those of Ehrnford[18]. From the findings of our results, it was suggested that luster grade was overall impression, while reflected area was the amount of the accurate surface reflected the light. Light reflection of polished Targis was dramatically decreased after brushing. This suggested the possibility that larger filler exfoliated during tooth brushing. Staining liquid of Targis supposed to play an part in protecting the surface. Rather staining liquid of Targis was very thin solution, glazing liquid of Sculpture was so sticky and did not spread well. After curing, it showed glossy surface. However, if it faced to abrader, peripheral portion of glaze resin coatings might wear out. This were also supported by the SEM pictures.

Apparently, the finishing and polishing procedures contribute to the appearance of the color and gloss of a dental restorations. However, there were many reports illustrating the composite resins cannot be finished with an absolutely smooth surface. Moreover, restoration materials containing fillers had shown persistent roughness after finishing. Weitman reported plaque accumulation on composite samples with a surface roughness of 0.7 to 1.44μm[27]. Therefore, many researchers had effort to determine the most clinically acceptable finishing technique for a composite resin and ceromer. Some previous studies have found that microfilled composite resins are more efficiently polished with aluminum-oxide disks[14,15,28]. While, some other researchers reported that diamond and carbide burs were appropriate instrument for hybrid composites to achieve a smoother surface[29]. Ashe et al suggested that diamond finishing burs achieved comparable smoothness, on the other hand, carbide burs damaged the surface of the glass ceramic insert composite restorations[13]. However, no one system was incapable of creating the best surface for all materials.

There were few reports on the appropriate finishing and polishing methods for ceromer. Recently, Behr and colleagues compared several lab-side and chair-side polishing methods for Targis[30]. They recommended the pumice-stone and brush with polishing paste or fine diamond bur for lab side finishing, while aluminum oxide disk for chair side. We adopted the lab side finishing method according to their recommendation. However, all the polishing methods used in their and our study were originally designed for composite materials and not for the ceromer material.

Resin finish coatings like a glazing or staining liquid have been used over finished composites to assist in overcoming surface roughness. Bassionuy et al recommended covering the restoration with a fine layer of glaze resin to ensure a smoother surface[31]. By Garman's 1 year clinical study, this resin coating maintained their color match, and luster and smoothness were significantly better than uncoated composite restorations[32]. However, durability of surface coating in long term use should be considered for material selection. It was also related with the discoloration and stain, esthetic appearance in long term. At the baseline, the coating methods like

staining or glazing generated the higher gloss surface, while the polishing methods produced lower luster. Glaze coating of Sculpture showed fallen out discontinuously. We also found that craze was appeared on the all of the glaze coatings in spite of high gloss. From the results currently obtained, coatings used for Targis and Sculpture did not fulfilled their objectives in terms of durability. However, staining liquid were worth protecting fillers from abrasion.

It has been shown that water sorption may affect the mechanical properties of composite resin[33]. Soderholm reported that the coupling agent between the filler and the supporting resin matrix commonly undergoes hydrolytic decomposition in water[34]. Moreover, Montes-G demonstrated that thermal cycling significantly decreased toothbrush abrasion wear resistance of both glass-filled and quartz-filled composite resin[35]. Rather, Shinkai et al showed that heat treatment by thermal cycling 1,000 times might lead to increase the wear resistance in one material[36]. This suggested that thermocycling might have not only negative but also positive effect on the physical properties simultaneously. However in this investigation, it was presumed that negative effect were dominant because we tested more times. Gale et al suggested that approximately 10,000 thermal cycles per year were appropriate for simulatory oral environment[37]. Thermocycling obviously increased the effect of tooth brushing on ceromers. Actually, glazed Sculpture showed worn out surface, which was not supposed by only tooth brushing.

One limitation of our study is that luster grading by direct vision were supposed to be subjective. Although all specimens used in this study had same shade, they showed different color could detected with naked eye. Miscellaneous color change might affect the luster grade. Further studies to develop the method of comparing luster objectively are needed. Moreover, all the polishing methods used in this study were originally designed for composite materials and not for the ceromer material. Therefore, the luster grades in this study can only lead to a conclusion regarding the relative comparison of finished ceromer surface.

Previous studies have found that some instruments with polishing were appropriate finishing method for Targis[30]. Along with our results in suspicious durability of Sculpture glaze coating, it was suggested that same polishing method with Targis would be better for other ceromers as well.

CONCLUSIONS

Within the limits of this study, the following conclusions were drawn:

1. Luster and light reflection area of ceromer specimens were affected by tooth brushing. However, ceromer showed higher gloss and light reflection than control composite group after tooth brushing.
2. Glazed Sculpture had the greatest mean luster, while the stained Targis group showed highest luster changes after tooth brushing. Sculpture groups showed higher gloss than Targis groups irrespective of finishing methods.
3. Light reflection area did not coincide with the luster grade. Stained Targis showed greatest light reflection area, followed by the polished Sculpture.
4. Surface coatings used for Targis and Sculpture had not durability for long term use. At the periphery, glaze of Sculpture were fallen out discontinuously. However, stain of Targis acted like a protection layer from exfoliating filler particles.

Acknowledgements

The author wishes to acknowledge the financial support of the Korea Research Foundation made in the program year of 1999.

REFERENCES

1. Freilich MA, Goldberg AJ. The use of pre-impregnated, fiber-reinforced composite in the fabrication of a periodontal splint: a preliminary report, Pract Periondontics Aesthet Dent 1997;9:873-6.
2. Freilich MA, Karmaker AC, Burstone CJ et al. Development and clinical applications of a light-polymerized fiber-reinforced composite, J Prosthet Dent 1998;80:311-8.
3. Krejci I, Boretti R, Lutz F, et al. Adhesive crowns and fixed partial dentures of optimized composite resin with glass fiber-bonded framework, Qunit Dent Tec 1999;107-27.
4. Krejci I, Boretti R, Giezendanner P, et al. Adhesive crowns and fixed partial dentures fabricated of ceromer/FRC: clinical and laboratory procedures, Pract Periondontics Aesthet Dent 1998;10:487-98.
5. Trinkler TF, Roberts M. Aesthetic restoration with full-coverage porcelain veneers and a ceromer/fiber-reinforced composite framework: a case report, Pract Periondontics Aesthet Dent 1998;10:547-54.
6. Shannon A. Ceromers used with indirect resins/ceramics: Materials, clinical applications, and prep guidelines, Dent Today 1998;Mar:60-5.
7. Touati B, Aidan N. Second generation laboratory composite resins for indirect restoration, J Esthet Dent 1997;9:108-18.
8. Miara P. Aesthetic guidelines for second-generation indirect inlay and onlay composite restorations, Pract Periondontics Aesthet Dent 1998;10:423-31.
9. Armstrong DJ, Kimball D. Fiber-reinforced polymerceramic fixed partial dentures in the esthetic zone: A clinical and laboratory case perspective, Qunit Dent Tec 1999;95-106.
10. Krejci I, Gautschi L, Lutz F. Wear and marginal adaptation of composite resin inlays. J Prosthet Dent 1994;72:233-44.
11. Willems G, Lambrechts P, Braem M, Vanherle G. Composite resins in the 21st century. Quint Int 1993;24:641-58.
12. Yap AU, Sau CW, Lye KW. Effects of finishing/polishing time on surface characteristics of tooth-coloured restoratives. J Oral Rehabil. 1998;25:456-61.
13. Ashe MJ, Tripp GA, Eichmiller FC, George LA, Meiers JC. Surface roughness of glass-ceramic insert-composite restorations. J Am Dent Aoosc 1996;127:1495-500.
14. Bouvier D, Duprez JP, Lissac M. Comparative evaluation of polishing systems on the surface of three aesthetic materials. J Oral Rehabil 1997;24:888-94.
15. Stoddard JW, Johnson GH. An evlaluation of polishing agents for composite resins. J Prosthet Dent 1991;65:491-5.
16. Eames WV, O' Neal SJ, Rogers LB. Composite plain talk. J Am Dent Assoc 1976;92:550-4.
17. Goldstein GR, Lerner T. The effect of toothbrushing on a hybrid composite resin. J Prosthet Dent 1991;66:498-500.
18. Ehrnford L. Surface microstructure of composite resins after toothbrush-dentifrice abrasion. Acta Odontol Scand 1983;41:241-245.
19. Boretti R, Krejici I, Lutz F. Clinical and scanning electron microscopic evaluation of fine hybrid composite restorations in posterior teeth after four years of wear [abstract 222]. J Dent Res 1997;76:41.
20. Mair LH, Stolarski TA, Vowles RW, Lloyd CH. Wear: mechanisms, manifestations and measurement. Report of a workshop. J Dnet 1996;24:141-8.
21. Abebe M, Appl FC. Theoretical analysis of the basic mechanics of the abrasive processes. Part 1: General model. Wear 1988;126:251-66.
22. Milleding P, AhlgrenF, Wennerberg A, Ö rtengren U, Karlsson S. Microhardness and surface topography of a composite resin cement after water storage. Int J Prosthodont 1998;1:21-6.
23. Heath JR, Wilson HJ. Abrasion of restorative materials by toothpaste. J Oral Rehabil 1976;3:121-138.
24. Aker JR. New composite resins: comparison of their resistance to toothbrush abrasion and characteristics of abraded surfaces. J Am Dent Assoc 1982;105:633-635.
25. Whitehead SA, Shearer AC, Watts DC, Wilson NH. Surface texture changes of a composite brushed with 'tooth whitening' dentifrices. Dent Mater 1996;12:315-318.
26. Hachiya Y, Iwaku M, Hosoda H, Fusayama T. Relation of finish to discolouration of composite resins. J Prosthet Dent 1984;52:811-814.
27. Weitman KC, Eames WB. Plaque accumulation on composite surfaces after various finishing procedures. J Am Dent Assoc 1975;91:101-106.
28. Berastegui E, Canalda C, Brau E, Miquel C. Surface roughness of finished composite resins. J Prosthet Dent 1992;68:742-749.
29. Kaplan BA, Goldstein GR. Vijayaraghavan TV, Nelson IK. The effect of three polishing systems on the surface roughness of four hybrid composites: A profilometric and scanning electron microscopy study. J Prosthet Dent 1996;76:34-38.
30. Behr M, Rosentritt A, Leibrock S, Schneider-feyrer, Handel G. Finishing and polishing of the ceromer material Targis. Lab-side and chair-side methods. J Oral Rehabil. 1999;26:1-6.
31. Bassionuy MA, Grant AA. The surface of a visible light-cured composite resin. J Prosthet Dent 1980;44:175-182.
32. Garman TA, Fairhurst CW, Heuer G, Williams HA, Beglau DL. A comparison of glazing materials for composite restorations. J Am Dent Assoc 1977;95:950-6.
33. Chadwick RG. Thermocycling-the effects upon the compressive strength and abrasion resistance of three composite resins. J Oral Rehabil 1994;21:533-43.

34. Soderholm KJ, Zigan M, Ragan M, Fischlschweiger W, Bergman M. Hydrolytic degradation of dental composites. J Dent Res 1984;63:1248-54.
35. Montes-G GM, Draugn RA. In vitro surface degradation of composites by water and thermal cycling. Dent Mater 1986;2:193-7.
36. Shinkai K, Suzuki S, Leinfelder KR. Katoh Y. How heat treatment and thermal cycling affect wear of composite resin inlays. J Am Dent Assoc 1994;125:1467-72.
37. Gale MS, Darvell BW. Thermal cycling procedures for laboratory testing of dental restorations J Dent 1999;27:89-99.

Reprint request to:
Dr. Lee-Ra Cho
Deptment. of Prosthodontics, College of Dentistry,
Kangnung National University
123, Chibyun-Dong Kangnung, Kangwon-Do, Korea
E-mail: lila@kangnung.ac.kr