# Marginal accuracy and fracture strength of Targis/Vectris Crowns prepared with different preparation designs

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**Statement of problem.** Targis / Vectris restorations provide excellent esthetics. Marginal accuracy is significantly influenced by the preparation design. There were no studies to examine the effect of preparation design on the marginal discrepancy and fracture strength of Targis / Vectris crowns.

**Purpose.** This study evaluated the marginal accuracy before and after cementation, and the fracture strength of FRC / Ceromer(Targis / Vectris) crowns according to different preparation design.

**Material and method.** Three metal dies with different convergence angles(6°, 10°, 15°) were prepared. Total 30 (10 for each angle) Targis / Vectris crowns were made. The restorations were evaluated for adaptation of the margin before and after cementation, then were compressively loaded to failure. Fracture surfaces of the crowns were examined using a SEM.

**Results.** The mean marginal gap was 49¥m for 6°, 55§> for 10° and 70§> for 15° and in clinically acceptable level. The mean marginal gap increased significantly after cementation. The increasing amount during cementation was the largest in the 6° group. The crowns on 6o convergence angle had a significantly higher fracture strength than the crowns on 15° angle. Mean fracture strength of total crowns regardless of convergence angle was 1390 N, which was higher than all-ceramic crowns. SEM observation showed two-mode fracture pattern.

**Conclusion.** From the results of this study, all of the FRC / Ceromer crowns had clinically acceptable marginal accuracy and could withstand the bite force. Moreover, less convergent angle than all-ceramic crown might be recommended for preparation procedure.

**Key Words**
Targis / Vectris, marginal accuracy, fracture strength marginal gap

Several esthetic restorative system including all-ceramic systems have become available for restoration of anterior teeth. Recently introduced FRC / Ceromer (fiber reinforced composite / ceramic optimized polymer) system provide an attractive alternative to ceramic and resin materials, which have enhanced the physical properties, good esthetics and improved durability.[1-10]

The FRC, pre-impregnated fiber embedded in a resin matrix, have excellent flexural strength.[3-5] It can be used for posterior crown or for anterior fixed partial denture.[6-9] The ceromer material, second generation indirect composite resin, contains silanized microhybrid inorganic filler embedded in a light curable organic matrix.[10,11] The ceromer have improved mechanical properties comparing to composite resin or ceramic, due to high filler contents(¡75%) and optimal polymerization process.[8-10] One of the FRC/Ceromer is Vectris/Targis system developed by Ivoclar in 1996. 6 This system provides excellent esthetics and translucent appearance. However, there are few reports on long term results and clinical guideline to success for this system.

The fracture resistance and marginal fit is one of the most important criteria for the long term success of restoration.[13-16] The presence of marginal gap exposes the luting agent to the oral environment, thus leading to a more aggressive rate of cement dissolution. The resultant microleakage permits the percolation of food and bacteria and becomes weak cement seal. Consequently, caries and periodontitis could compromise the longevity of the tooth.[17,18] The marginal discrepancies of various restorations have been studied. The results showed a high variation within on crown system but most of the test results have clinically acceptable margin.[13-17,19,20]

The fracture strength of materials also remains important factor. This is dependent on the modulus of elasticity of the supporting substructure,[21] properties of the luting agent,[22] preparation design, void, surface roughness, residual stress and the thickness of restoration.[23] There were some reports on the clinical guidelines to the all-ceramic crown. Doyl et al.[24,25] reported that larger the occlusal convergence angle of abutment presented the greater fracture load of Dicor.

However, there were seldom reported that fracture strength and marginal accuracy of FRC/Ceromer crown. The purpose of this study was to examine the fracture strength and marginal adaptation of FRC/Ceromer with different preparation design.

## MATERIAL AND METHODS

### 1. Die preparation

Three maxillary right central incisor ivorine teeth were prepared for full coverage FRC/Ceromer crowns. The abutment preparation design was the same used for all-ceramic crown. Two millimeter incisal reduction was followed by a circular 1 mm rounded shoulder margin preparation. Three different axial convergence angle, which was 6°, 10° and 15° were prepared. All sharp margins were rounded and finished 0.5mm apical to the cemento-enamel junction. The prepared teeth were then duplicated in pattern resin (Duralay, Dental Mfg. USA). These pattern resin abutments were sprued, invested and casted with non-precious alloy(NPG, Aalbadent, USA). Metal dies were polished and finished with the milling machine (T3, Degussa, Germany). The marginal integrity of the dies was carefully examined under the laboratory microscope with X10 magnification.

To consider all possible source of errors in the process of manufacturing, this study followed clinical procedure. The master metal die was duplicated with additional silicone impression material (Examix, GC, Japan) using a customized impression tray. The impressions were poured into type ¥‡ dental stone in twice (Diekeen, Dentsply, USA). The first poured 30 master stone dies were used to produced FRC/Ceromer crowns. Due to frequent fracture during making the FRC substructure, the second poured stone dies were used for this purpose. Silicone putty index for the same dimension crown was made using ivorine teeth.

**2. Crown fabrication**

Die hardener and die separator were applied on the duplicated stone dies. Vectris¡ single¡ were positioned on stone die surrounded by silicone putty index and adapted in Vectris VS1 unit (Ivoclar-Vivadent, Schaan Lichtenstein) and cured with vacuum pressure, light polymerization for 15 minutes. The Vectris substructure was ground up to 1 mm above from the margins and sandblasted with 50§> $Al_2O_3$ at 1 bar pressure for 20s and were cleaned using steam cleaner. The Vectris substructure was placed on the master stone die, which was coated with separating solution, and brushed with a surface active liquid (Vectris wetting agent).

Targis base was applicated and then Targis Dentin and Enamel incrementally built up on the conditioned Vectris substructure. Each layer was pre-polymerized with a halogen light source (Targis Quick, Ivoclar-Vivadent, Schaan, Lichtenstein) for 10 seconds. The build up procedure was completed using silicone putty index. The final restoration was post-cured in a Targis Power Oven (Ivoclar-Vivadent, Schaan, Lichtenstein) with Program 1 at 90¡ for 25 minutes. After post-curing, final polishing was performed with stone points and rubber and wheel instruments following the manufacture¡¯s recommendation.

**3. Analysis of marginal accuracy**

To measure marginal accuracy, the finished crowns were placed on their respective metal master die in 10 N fixed pressure before cementation. The gap between the external edge of the structure and the preparation limit was defined as the standard for marginal accuracy. The marginal gap of each restoration was reproduced ¡¿40 magnification using stereomicroscope (Olympus, USA)and the image captured with CCD camera. Then, a video image of the marginal gap was blindly examined using image analysis soft ware at 48 measuring point around each specimen. For the prevention of parallax error, each die was mounted in 8 different direction jig. Measurement error was¡ 5§>.

**4. Crown cementation**

After the analysis of the marginal accuracy, the crowns were luted to the master metal die using dual curing resin cement (Variolink II, Ivoclar-Vivadent, Schaan, Lichtenstein) following the manufacture¡¯s recommendation. During the cementation procedure, the crowns were secured with constant pressure of 10 N for 1 minute and polymerized with a light exposure of 60s per crown. After removing the excess cement and cleaning the restoration margin, a post-cementation marginal gap analysis was executed as the same manner described earlier. All cemented samples were stored in at room temperature for 24 hours prior to fracture loading.

**5. Analysis of fracture strength**

After the analysis of the margin gap before and after cementation, fracture strength testing of FRC/ceromer crown was carried out using a UTM (Zwick Z010, Zwick Gmbh, Ulm, Germany) at a crosshead speed of 5 mm/min. For the failure determination, break detector level was set at a 10% loss of maximum force. The metal dies were fitted into mounting base with the long axis of the crown 36¡ã relative to the horizontal plane to simulate the average inter-incisal angle.

The crowns were loaded at 1mm cervically from incisal edge using a mandibular incisor shaped testing jig. Small amount of petroleum jelly was applied between jig and crown surface to reduce the effect of surface roughness.

All crowns were loaded until catastrophic failure occurred. The testing machine was automatically recorded the fracture force in Newtons, and the mode of fracture was noted.

The fracture of the crowns was then examined using a scanning electron microscope (S-3000N, Hitachi, Japan) to analyze the pattern of failure.

### 6. Statistical analysis

Data on marginal accuracy and fracture strength were analyzed using two-way and 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 ;$lmethod (¥≤ 0.05). Moreover, results of marginal accuracy prior to cementation and after cementation were compared with paired Student ;$lt-test at 95% confidence level.

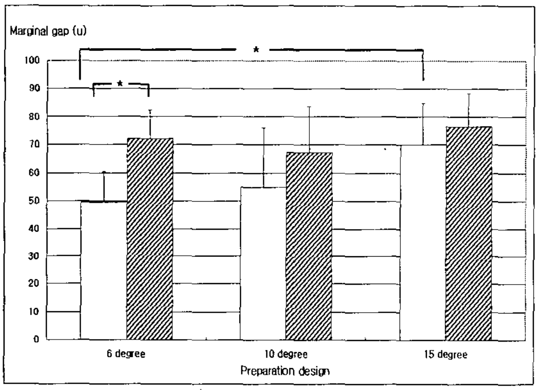

**Fig. 1.** Mean marginal gap before and after cementation (* : P < .05).

## RESULTS

### Marginal Accuracy

Over the 3000 measurements, the marginal gap ranged from 0 to 149§>. Fig. 1 showed the cementation in each convergence angle were in clinically acceptable level; 49 §> for 6°, 55 §> for 10° and 70§> for 15°. It showed increasing pattern with the convergence angle of preparation. Marginal opening between 6° and 15° convergence angle showed a significant difference by the Sheffe test (P < .05).

The mean of the pre-cementation gap was 5§> for three convergence angle, while post-cementation gap was 71§>. The mean marginal gap increased significantly after cementation (P < .05). The marginal gap between the convergence angle after cementation did not show a significant difference. The mean post-cementation increase in marginal discrepancies was 22§> in the 6° group, 13§> in the 10° group and 6§> in the 15° group. This difference in vertical lift between the 6° group and 10°, 15° groups was significant (P < .05). Figure 2a to 2b was characteristic examples of the stereomicroscopic findings.

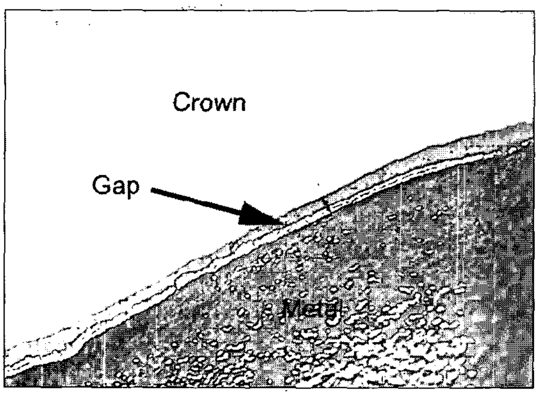

**Fig. 2a.** Specimen prior to cementation having a marginal discrepancy of about 50㎛ in this area (original magnification ×40)

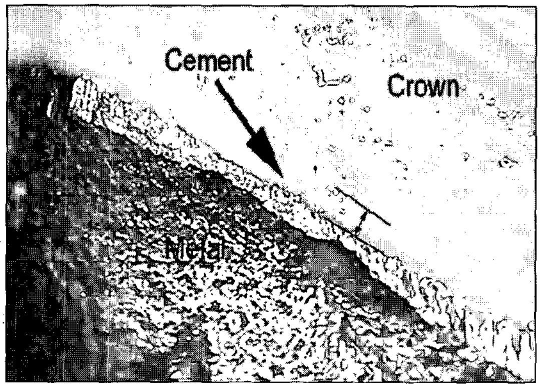

**Fig. 2b.** Specimen cemented having a marginal discrepancy of about 60㎛ in this area (original magnification ×40)

### The Fracture Strength

Three groups of crowns were loaded until catastrophic failure occurred. The mean compressive fracture strength for all groups was demonstrated in Table I. The crowns on 6° convergence angle had a significantly higher fracture strength than the crowns on 15° angle. Mean fracture strength of total crowns regardless of convergence angle was 1390 N, which was higher than all-ceramic crowns.

Due to composite characteristics of Targis/Vectris, failure pattern was different from all-ceramic crowns. It's failure pattern was occurred two-mode. Crack pattern and chipping of the Targis layer was initially produced on the loading (Fig. 3a). Then, adhesive failure between Targis and Vectris was followed. Most crowns showed adhesive failure. Fiber orientation aligned at 45° of 'Single' was disappeared on the fracture surface (Fig. 3b). From the SEM observation, some crowns showed adhesive failure between Targis base and Targis dentin layer (Fig. 3c).

Table I. Fracture strength of Targis/Vectris crown with different convergence angle

| Convergence angle | Mean Fracture strength ± S.D (N) |
|---|---|
| 6° | 1542.7 ± 192.8 |
| 10° | 1366.0 ± 206.7 |
| 15° | 1262.6 ± 218.8 |

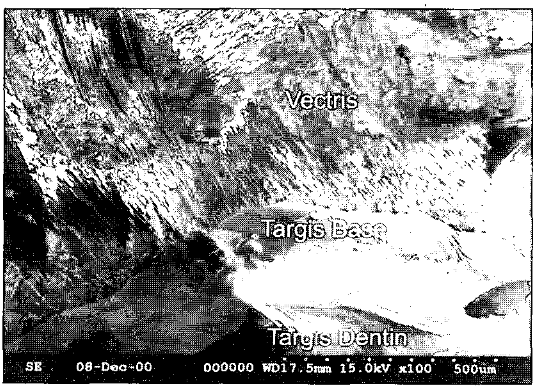

**Fig. 3b.** Fracture surface revealed the adhesive failure between Targis and Vectris layer.

## DISCUSSION

Recent developments in FRC/Ceromer system have enhanced the physical properties and wide application in restorative dentistry.[1-10] Fabrication of fixed partial dentures without metal substructures offers the optical advantage of more natural light dynamics and decreases the potential biologic incompatibility.[4-6] Clinical obser-

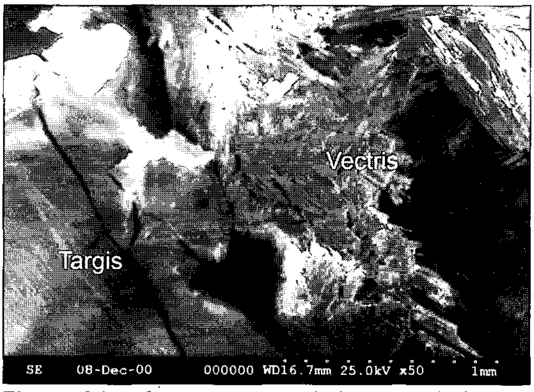

**Fig. 3a.** SEM observation revealed two-mode failure. Cracked Targis and exposed Vectris was appeared.

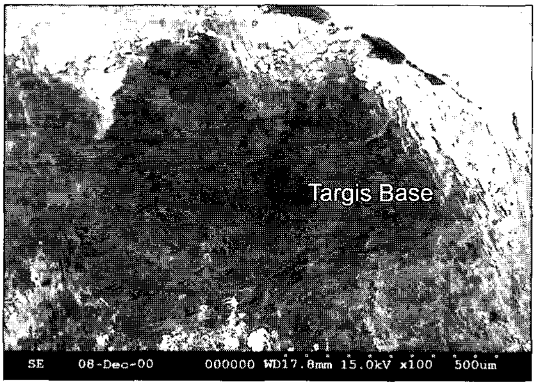

**Fig. 3c.** Adhesive failure between Targis Base and Targis Dentin layer.

vations over 4-year periods have shown that FRC/Ceromer restorations had equal longevity to ceramic restorations.[26] In addition to aesthetics, the marginal accuracy and fracture strength are one of the most important criteria to ensure clinical sucess. The aim of this study was to evaluate the influence of three different convergence angle on marginal accuracy and fracture strength of FRC/Ceromer crown.

The marginal discrepancy of the restoration is believed to be closely associated with the development of secondary disease such as caries and periodontitis.[18] The marginal accuracy is significantly influenced by the preparation design, the distortion of master die, impression, characteristics of material and fabrication method, measurement method of the gap and cement etc.[13-15,17,19,20] The marginal gap inevitably is produced during dental restoration setting due to cement film thickness and dimensional change.[23]

Many methods to examine the marginal accuracy were introduced. In previous literature, measurement of embedded and sectioned specimens, direct visualization of specimen or replica and laser videography measurement were used.[27] Groten et al.[28] reported that small numbers site of measurement in current in vitro studies are not appropriate for precision. Moreover, they insisted approximately[50] measurement per crown regardless of whether the measurement sites are required for clinically relevant information about gap size. The measurement method used in this study was direct visualization by stereomicroscope (¡¿40) and reading 48 points per crown. In observation procedure, we used mounting jig for 8 side fixations for preventing parallax error.

The cement film thickness was equally controlled by use of low viscosity dual cure resin cement, rounded shoulder margin configuration, internal relief with 50§> $Al_2O_3$ sandblast and constant loading (10 N) on all test specimens. The results of this study described the difference of prior to and after cementation gap. Increasing marginal gap after cementation was considered inevitable phenomenon. The result of this study had similar pattern to previous studies.[13,19] The difference of the marginal gap among the groups after cementation were not statistically significant, but the 15° convergence angle groups had the smallest amount of marginal gap increasing during cementation. It was supposed that large convergence angle might permit residual cement to escape easily.

In general, the marginal discrepancies at each marginal location are influenced by effect of fabrication method and technician¡¯s skill. Since, *firing shrinkage is a function of the porcelain* bulk, it is possible that the larger marginal discrepancy seen at the lingual margin could be related to the greater bulk of porcelain.[17] However, the FRC/Ceromer crown was fabricated with different methods to porcelain. The Vectris substructure was ground up to 1mm above from the margins and the Targis were built incrementally with instruments. Moreover, polymerization shrinkage was less than 2 %. Thus, there were no significant differences in the marginal discrepancies among the site of examination. The mean marginal discrepancy of FRC/Ceromer crown in this study was approximately 71§>. Although, few studies that designed same manner compared to this study, the margin quality of FRC/Ceromer was superior to all-ceramic crown and considered clinically acceptable.

The fracture strength of a clinical crown is influenced by several factors, such as shape of the preparation, material, wall thickness of crown, the way of luting, loading condition, thermocycling and cyclic loading and elastic modulus of supporting die. Campbell[29] found that the fracture strength of all-ceramic crown is dependent on the modulus of elasticity of the supporting materials. Scharrer et al.[21] concluded that the higher elastic modulus of supporting die, the fracture strength increased. In this study, the FRC was acted as substructure of the crown. The elastic modulus of Vectris¡ fSingle ¡ fiwas approximately 21GPa, similar to that of dentin (12GPa) and the elastic modulus of supporting metal die was more than 100GPa.[8,9] If the supporting model were a natural teeth, the fracture strength of crown might be lower.

Rinke et al.[14] reported that the fracture strength of the 90 ¡ ˚load direction was greater that of the non-axially load direction. In this study, we tested the samples with inclined load to simulate the average inter-incisal angle. The loading jig was made similar to mandibular incisor.

Dong et al.[30] and Doyle et al.[24,25] reported that larger the occlusal convergence angle of the abutment increased the fracture strength of all-ceramic crown in vitro. It might be caused by the fact larger convergence angle would have greater axial restoration thickness and decreased seating pressure. Contrary to the results of the ceramic restoration, the result of this study suggested that the mean fracture strength of the FRC/Ceromer crowns followed in descending order: 6 ¡,˚10 ¡,˚15 ¡ group. The difference among the groups might be attributed to the area of Vectris coverage. Fifteen degree angle group had the largest Targis area and the smallest fracture strength.

The Break force determination was set at a 10% loss of maximum force in this study. Decreasing the % level of setting manual (break detector level) could decrease the value of fracture strength. The Guideline of the setting range in UTM software was not established material characteristic.

In the literature, the maximum bite force was known to have wide variation ranged 200 N to 3500 N. The mean bite force in adult was about 400 to 800 N at molar region, about 300 N at premolar and 200 N at anterior region.[31] In the limitation of this in vitro study, FRC/Ceromer crown could withstand load up to 900 N before fracture occurring. This fracture resistance is considered adequate for bite force exerted on natural dentition.

SEM, mode of fracture - two-phase fracture[14,16] : Targis veneer crack initiation followed by catastrophic failure. Targis layer initially was cracked and chipped (Fig. 3a). And then, Vectris¡ fSingle ¡ fi layer was exposed. In some cases, adhesive failure between Targis base layer and Targis dentin layer was developed. In this case, bonding of Targis link and Vectris was so high not to show failure between Targis and Vectris.

One of the problems of margin gap evaluation in this study was the use of metal die. The metal die abutment gave neither real information about hard tissue of the teeth nor about luting material relation to the dentin because actually cemented natural teeth could afford a better marginal adaptation because of the stable adhesive bonding.[13] However, non-axial loading would produce fracture of neck portion in natural teeth. Using natural teeth could also cause non-homogeneous bonding and irregular fracture pattern due to variation in specimens. Thus, we used metal die for standardizing the study results.

Another problem was that we didn ¡ ̄apply artificially aging process, such as thermocycling and mechanical loading(TCML). Behr et al.[4,5] and Krejici et al.[32] reported a significant negative effect of TCML on the margin integrity. However, Strub et al.[13] reported a no significant influence of aging in the chewing stimulator on the marginal fit. It might be concluded including two clinical important aspects of failure: static chemical and cyclic mechanical fatigue phenomena, degradation of luting agents under the conditions of the oral cavity would be better.

Despite the limitations of our study, the results emphasize the design of preparation should have some convergent angle. Further investigations to determine the mostly appropriate convergence angle for FRC/Crown and the effect of chemical, mechanical aging should follow.

## CONCLUSIONS

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

1. The mean marginal gap prior to cementation was in clinically acceptable level. It showed increasing pattern with the convergence angle of preparation.
2. The mean marginal gap increased significantly after cementation. The increasing amount during cementation was the largest in the 6° group.
3. The crowns on 6° convergence angle had a significantly higher fracture strength than the crowns on 15° angle. Mean fracture strength was higher than all-ceramic crowns and could endure normal biting force.
4. Fracture pattern was two-mode failure. Ceromer crack was followed by adhesive failure between FRC and ceromer layer.

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