Comparison of cuspal deflection according to different placement techniques of composite resin

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Comparison of cuspal deflection according to different placement techniques of composite resin

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감사의 글

배움의 길은 가도 가도 끝이 없다는 진실이 본 논문을 작성하는 내내 제 머릿속을 떠나지 않았습니다. 이제 초라한 논문을 세상에 들어 낼 수 있도록 도와주신 분들께 감사의 마음을 전하려 합니다.

논문의 처음부터 끝까지 저를 믿어 주시고 연구하고 공부하는 자세를 밝혀주신 박성호 교수님, 부족한 실험을 논문으로 옮길 수 있도록 지도해 주신 박정원 교수님, 생체 재료학 교실 김광만 교수님께 감사를 드립니다.

보존과를 수련받은 것을 자랑스럽게 여길 수 있도록 이끌어 주신 이찬영 교수님, 이승종 교수님, 노병덕 교수님, 금기연 교수님, 김의성 교수님, 정일영 교수님 다시 한번 감사를 드립니다.

치과의사로서 살아 가야 할 도리를 일깨워 주시고 늘 베풀어 주시기만 하신 최용철 원장님께 감사를 드립니다.

수련 기간 동안 동고동락한 성곤 형, 상일, 용환, 재현, 혜영, 현준과 늘 고민을 함께 나누며 조언을 해준 방난심 선생과 조가영 선생, 도연, 선배로서의 위엄보다는 후배를 배려하는 마음을 보여 준 승호 형에게도 고마운 마음을 전합니다.

진료하면서 논문을 쓸 수 있도록 배려의 미덕을 보여준 재훈이 형, 승재 형, 형준에게 감사를 드립니다.

힘들 때 늘 그 자리에서 무거운 짐을 함께 해준 나의 소중한 친구 호진, 후배지만 의리있는 친구인 천기, 영범에게 고맙다는 말을 전하고 싶습니다.

마지막으로 저에게 아낌없는 헌신과 한결 같은 사랑으로 돌보아 주신 아버지, 어머니, 친동생보다 더 아껴 준 매형들과 누나들에게도 감사와 사랑의 마음을 전합니다.

2006년 7월

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Abstract

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The aim of this study was to investigate the cuspal deflection of the maxillary premolars during the composite resin filling according to 4 different techniques: bulk filling, horizontal incremental filling, oblique incremental filling, and indirect resin inlay with resin cement.

Caries-free human premolar teeth that had been extracted for the purpose of orthodontic treatment were collected. The buccolingual and mesiodistal widths of all the teeth were measured and recorded. Sixty teeth were selected and divided into 4 groups in a way that every 4 teeth of similar size were allotted to each group. The parallel-sided, tunnel-shped MOD cavities were prepared in a dimension of 3.5 mm buccolingually and 3 mm in depth from the occlusolingual margin. The cavities were flushed with copious water, dried completely and applied with AdheSE in comply with the manufacturer's directions for use.

In Group 1, a bulk filling of 0.15 g of Heliomolar was inserted and the specimens in Group 1 were light-cured with Curing Light XL3000 to the occlusal, mesial and distal surfaces for 60 seconds each. Group 2 had two horizontal fillings of 0.08 g and 0.07 g with each filling light-cured to the occlusal, mesial and distal surfaces for 60 seconds each. In Group 3, there were three oblique fillings of 0.05 g, each of which were light-cured to the occlusal, mesial and distal surfaces for 30 seconds each. In Group 4, 0.15 g of TESCERA was used to make a resin inlay and cemented with Duo-Link. Resin inlays were light cured to the occlusal, mesial and distal surfaces for 40 seconds each. Cuspal deflections were measured in the customized cuspal deflection measuring machine (CDMM) for 15 minutes from the initiation of light polymerization. Measurements of cuspal deflections were analyzed statistically using a one-way ANOVA test.

There was no statistically significant difference in cuspal deflection among Group 1 (14.52 ㎛ on average), Group 2 (15.03 ㎛) and Group 3 (13.44 ㎛) ($p>0.05$). Group 4 showed statistically significant reduction in cuspal deflection (5.64 ㎛) compared to other groups ($p<0.05$).

Under this experiment conditions, no direct composite filling method is superior to the other direct techniques in reducing the cuspal delfection. Resin inlays can help to reduce the cuspal deflection, compared to direct composite resin filling methods.

Keywords : cuspal deflection, bulk filling, incremental filling, resin inlay

Comparison of cuspal deflection according to different placement techniques of composite resin

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I. Introduction

Composite resin based materials have been used for the restoration of posteriors since 1969. As demand for aesthetics increases, composite resin for posterior restoration has evolved through improvement of their physical and chemical properties. Inherent polymerization shrinkage, however, remains the greatest challenge to overcome (Rees and Jacobsen, 1989). The polymerization shrinkage from 1-3% by volume (Bandyopadhyay, 1982; Goldman, 1983) can lead to clinical problems such as marginal gap formation, secondary dental caries, post-operative sensitivity (Bausch *et al*, 1982; Eick and Welch, 1986) and stresses in the material and the restored teeth (Bowen *et al,* 1983; Davison and De Gee, 1984).

The stresses associated with the polymerization shrinkage of composite resins restoring posterior teeth have been reported to result in cuspal deformation (Causton *et al*, 1985; Jensen & Chan, 1985; McCullock and Smith, 1986; Pearson and Hearty, 1987; Lutz *et al,* 1991). The previous literatures have shown that for the most of cases, the cuspal deflection occurs within first 15 minutes during the light curing and amounts from 6 to 46 μm (Causton *et al*, 1985; Jensen & Chan, 1985; McCullock and Smith, 1986; Suliman *et al*, 1993; Pearson and Hearty, 1987; Lutz *et al*, 1991; Segura and Donly, 1993).

The cuspal deflection of the tooth restored with composite resin can be affected by the size and shape of the cavity (Meredith and Setchell, 1997), the Young's modulus of the composite resin (Ausiello *et al*, 2001), the system of polymerization (Abbas *et al*, 1999), the bonding strength of the dentin bonding agents and the placement techniques. Among these, the placement techniques can be modulated by a clinician.

Many clinicians have suggested the incremental filling technique could minimize the cuspal deflection, compared to the bulk filling. Some researchers agreed that the cuspal deflection was reduced when cavities were restored with composite placed in multiple small increments (Jensen and Chan, 1985; Segura and Donly, 1993), whereas others failed to demonstrate the advantage of incremental filling over bulk filling (Crim and Chapman, 1986; Rees *et al*, 2004). They stated that there was no significant difference in reducing cuspal deflection between bulk filling and incremental filling techniques.

Even one study has indicated that incremental placement techniques produce higher polymerization shrinkage stresses than bulk filling (Versluis *et al*, 1996). They reported that inward deformation of the cavity walls decreases the size of the cavity during the filling process, which will effectively decreases the total amount of composite needed to fill the cavity and this leads to a higher-stressed tooth-composite structure.

There is still controversy over the effect of resin placement techniques on the cuspal deflection that is related to polymerization shrinkage stress on the tooth. Furthermore, the effect of resin inlay on the cuspal deflection has not previously been investigated.

The aim of this study was to compare cuspal deflections of the maxillary premolars according to the three different direct and one indirect filling techniques– bulk filling, horizontal filling, oblique filling and resin inlay, using the customized cuspal deflection measuring machine.

II. Material and method

1. Selection of teeth

Caries-free human premolar teeth that had been extracted for the purpose of orthodontic treatment were collected. The buccolingual width and mesiodistal width of all the teeth were measured and recorded. Sixty teeth were selected and distributed to 4 groups of 15 specimens in a way that every 4 teeth of similar size were allotted to each group, thereby standardizing the dimension of the tooth specimens used for the experiment (Table 1).

Table 1. Dimensions of the teeth used in this experiment

	Mean buccolingual dimension (mm)	Mean mesiodistal dimension (mm)
group 1 (n=15)	9.67±0.23	7.72±0.30
group 2 (n=15)	9.68±0.40	7.69±0.34
group 3 (n=15)	9.67±0.40	7.71±0.22
group 4 (n=15)	9.68±0.34	7.54±0.50

2. Preparation of modified MOD cavity

The tooth specimens were stored in saline solution from the time of extraction until cavity preparation. Before preparing the teeth, the outline of cavity was drawn with a lead pencil and then the parallel-sided MOD cavity without buccal or lingual extension was cut in a dimension of 3.5 mm buccolingually and 3 mm in depth from the occlusolingual carvosurface margin, using diamond coated burs in an air-turbine with water spray-cooling (Fig. 1). In order to verify this dimension, a prefabricated hexahedral resin block that was the same size of the cavity dimension was placed into the cavity and adjust the preparation until it fit into the prepared cavity.

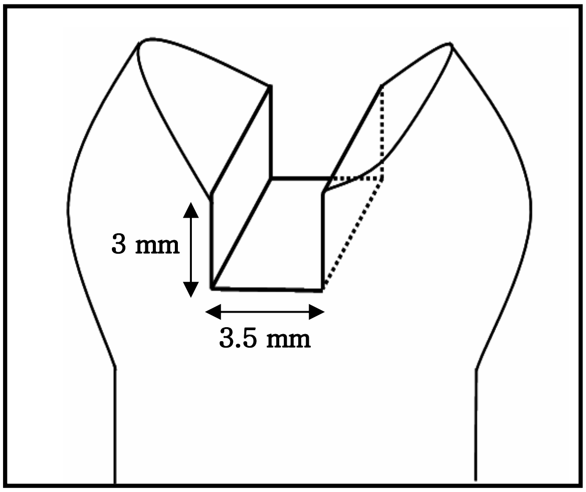

Fig. 1. Schematic representation of the parallel-sided, tunnel-shaped MOD cavity.

3. Polymerization and measurement of cuspal deflection

Each group was filled with following methods: bulk placement for group 1, horizontal placement of two layers for group 2, oblique placement of three layers for group 3 and resin inlay placement with composite resin-based cement for group 4 (Fig. 2).

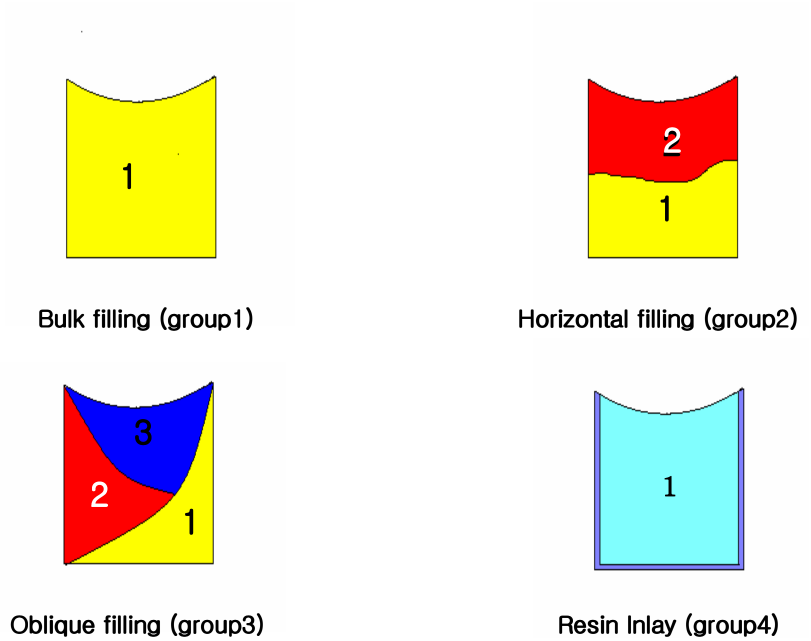

Fig. 2. Schematic diagrams of different placement techniques.

The cavities were flushed with copious water, dried completely and applied with AdheSE (Ivoclar Vivadent, Schaan, Liechtenstein) complying with the manufacturer's directions for use.

A total of 0.15 g of Heliomolar (Ivoclar Vivadent, Schaan, Liechtenstein) was used in the filling of the cavities in group 1, 2, and 3. In group 1 a bulk filling of 0.15 g was used, whereas group 2 had two separate fillings of 0.08 g and 0.07 g. In group 3, there were three fillings of 0.05 g each.

The amount of Heliomolar that was predetermined as above was weighed on the electronic balance and placed on the cavities. Afterwards, the specimen was positioned in the cuspal deflection measuring machine (CDMM R&B Inc., Daejon, Korea) (Fig. 3). To minimize any mobility of the tooth, a specimen stabilizer made of the putty impression material was used to sustain the specimen (Fig. 4). The CDMM was designed to detect the deflection of cusps during the polymerization through the two measuring crossheads contacting the buccal and lingual surfaces. The right side measuring crosshead was attached to the linear guide and the left side measuring crosshead could alter its position as the cusps moved. The sensor linked to the left measuring crosshead was not attached to other parts of the CDMM so that it was not influenced by frictional force. The positional change of the left measuring crosshead was transferred to the software that was connected to this machine. The software calculated the data and recorded the amount of cuspal deflection every 0.5 seconds for 15 minutes.

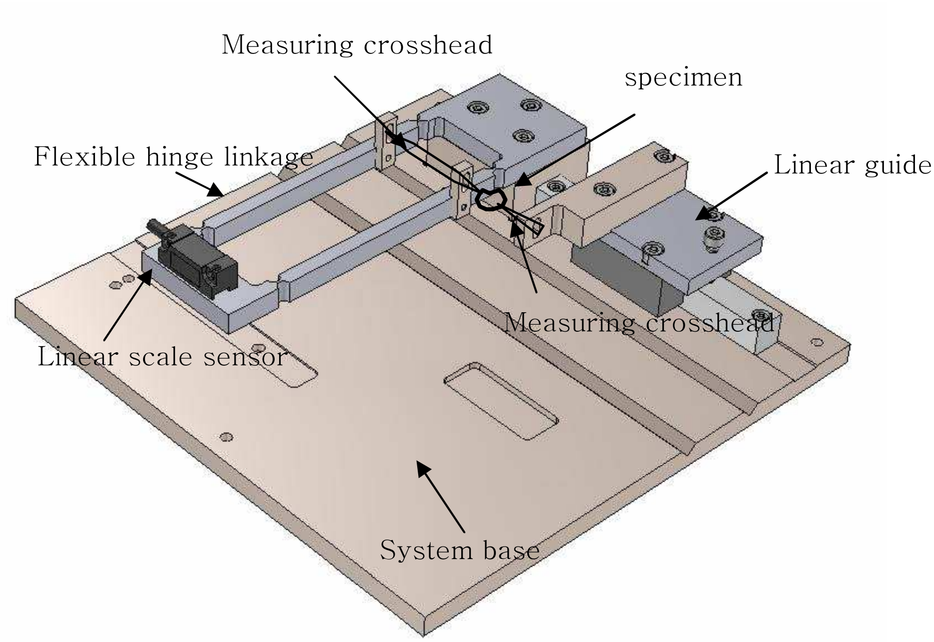

Fig. 3. Schematic drawing of the cuspal deflection measuring machine.

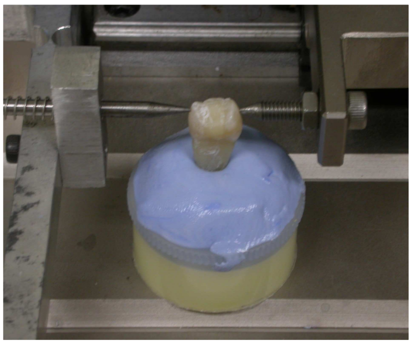

Fig. 4. Specimen placed in the CDMM.

Before light-curing the specimen, the initial distance sensed by two crossheads was set at a baseline value of 0. As light-curing with Curing Light XL3000 (3M, St. Paul, MN, USA) began, the CDMM measured and recorded the change in the cuspal deflection.

All the specimens in group 1 were light-cured to the occlual, mesial and distal surfaces for 60 seconds each, therefore 180 seconds in total. The tip of the curing light was kept within 5mm of the tooth specimen. After light-curing had been finished, the CDMM continued to measure until the time lapsed to 15 minutes from the start of polymerization.

Group 2 had two horizontal layers as shown in the figure 2, with each layer light-cured to the occlusal, mesial and distal surfaces for 60 seconds, 360 seconds in total. The cuspal deflection measurement by the CDMM continued while the second filling was being added on the top of the previous filling.

In the Group 3, the first layer was placed obliquely from the buccoocclusal carvosurface margin towards the linguopulpal line angle, not virtually touching the lingual wall. Then, the tooth was placed on the CDMM and light-cured to the occlusal, mesial and distal surfaces for 30 seconds each. Second layer was placed from the linguoocclusal carvosurface margin towards the middle of the first layer and was light-cured in the same way as the first layer. Finally, the third layer filled the occlusally concave portion, and underwent the same polymerization procedure. Just as in Group 2, the CDMM continued to measure while every subsequent layer was being added.

Resin inlays were made out of TESCERA (Bisco, Schaumburg, IL, USA) for group 4, according to the manufacturer's instructions and immersed in distilled water for 3 days before cementation. DUO-LINK (Bisco, Schaumburg, IL, USA) along with ONE-STEP (Bisco, Schaumburg, IL, USA) was used to cement resin inlays in accordance with the manufacturer's directions. When the resin inlay was placed into the cavity with the cement, the excess cement leaking out of the cavity was removed. Afterwards, the tooth was mounted on the CDMM and followed the same cuspal deflection measuring procedures as the previous groups with light-cured to the occlusal, mesial and distal surfaces for 40 seconds each.

The materials used and the curing times of each group is summarized in Table 2.

4. Statistical analysis

Measurements of the size of teeth and cuspal displacements were statistically analyzed using one-way ANOVA and Duncan's Multiple Range Test.

Table 2. Materials and curing time.

	composite resin	Bonding	resin filled (g)	Curing time (sec)
group 1 (bulk fillng)	Heliomolar	AdheSE	0.15	180 (180)
gorup 2 (horizontal filling)	Heliomolar	AdheSE	0.08 +0.07	180 +180 (360)
group 3 (oblique filling)	Heliomolar	AdheSE	0.05 +0.05 +0.05	90 +90 +90 (270)
group 4 (resin inlay)	TESCERA	ONE-STEP +DUO-LINK	0.15	120 (120)

* () in the curing time column indicates the total curing time.

III. Results

The mean value of final cuspal deflections of each group was calculated and compared (Table 3). The mean values of the cuspal deflections of group 1, 2, 3 and 4 were 14.40 ㎛, 14.68 ㎛, 13.26 ㎛ and 5.64 ㎛ respectively. There was no statistically significant difference in cuspal deflection among group 1, group 2 and group 3 ($p>0.05$). Group 4, however, showed a statistically significant reduction in cuspal movement compared to the other groups ($p<0.05$).

Table 3. Mean value of cuspal deflection (n=15).

	Mean (㎛)	SD
Group 1	14.40	1.89
Group 2	14.68	3.36
Group 3	13.26	1.94
Group 4	5.64	0.61

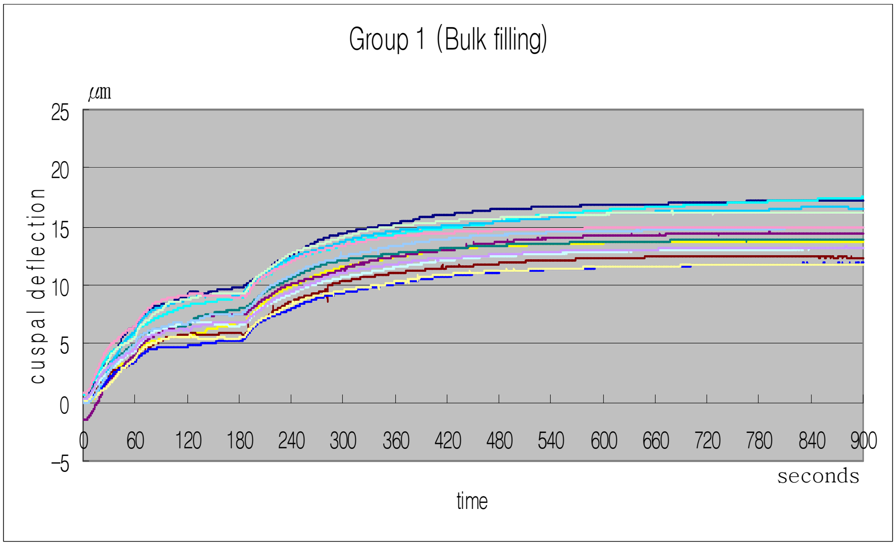

Fig. 5. Cuspal deflection of group 1.

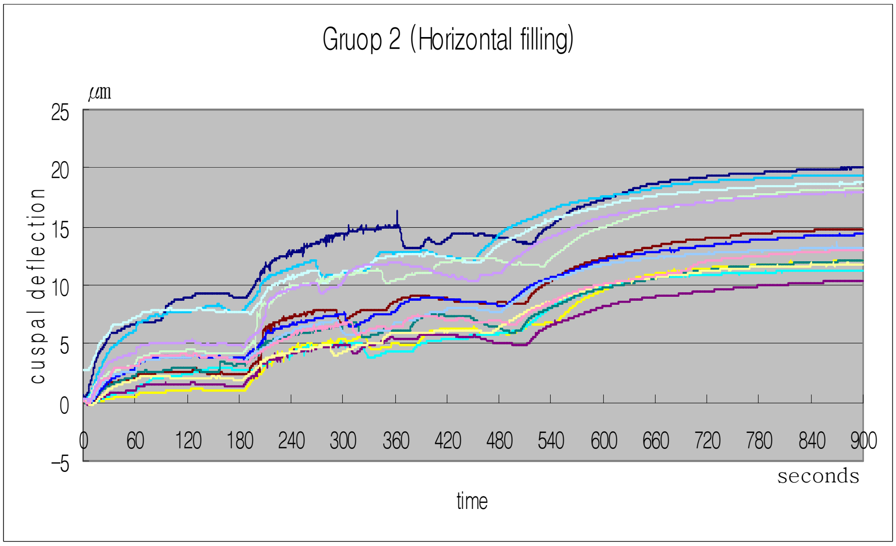

Fig. 6. Cuspal deflection of group 2.

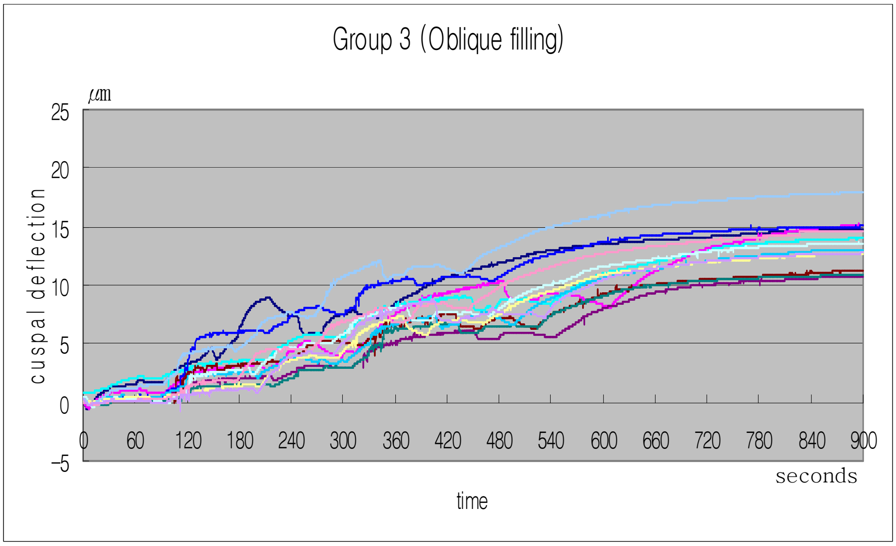

Fig. 7. Cuspal deflection of group 3.

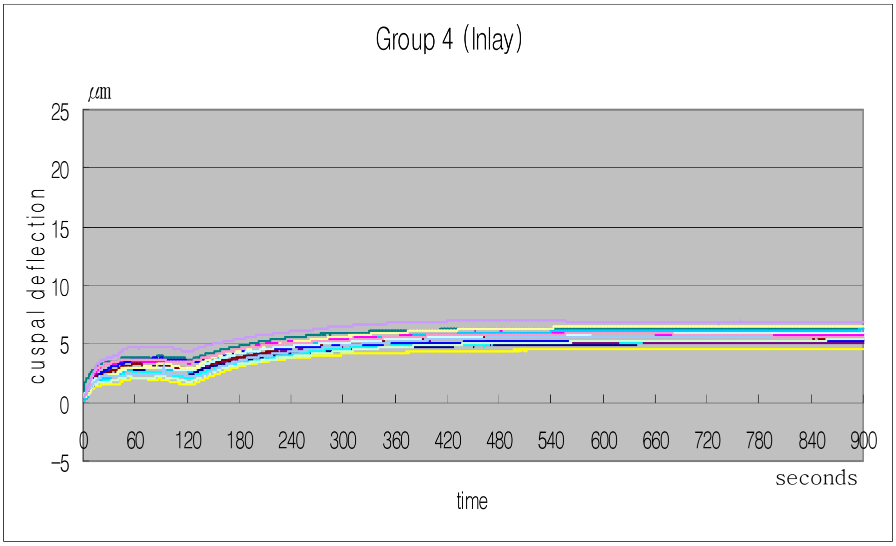

Fig. 8. Cuspal deflection of group 4.

The cuspal deflection of each group showed its own pattern over 15 minutes. Once light-curing was initiated, the cuspal deflection occurred very rapidly. This tendency continued approximately in the first 100second for group 1 and then the cuspal deflection reached a steady state at 7 ㎛ (Fig. 5 and 9). Immediately light-curing ceased at 180 sec, the cuspal deflection rate increased again until 550 sec and then arrived at the final plateau of 13.99 ㎛.

In the group 2, the first increment induced a rapid cuspal deflection to reach 3.53 ㎛ for the first 80 seconds and then maintained it in a steady state up until the first light-curing stopped at 180 sec (Fig. 6 and 9). For the next 80 seconds, the cuspal deflection showed a drastic increase up to 7.57 ㎛ while the second increment was being added onto the first layer. As the sencod light-curing started, the cuspal deflection slowed down so that it increased by about 1.2 ㎛ when the second light-curing ended at 500 sec. The cusps deflected so as rapidly to arrive at 14.11 ㎛ till 750 sec and then the cuspal deflection was maintained in the final steady state.

The first increment of the group 3 caused the cuspal deflection of 0.31 ㎛ for the first 90 seconds when the first light-curing was being performed (Fig. 7 and 9). And then the cuspal deflection repeated three times a pattern of drastic increase and slow rise up to 520 sec, reaching 8.90 ㎛. From then on, the cuspal deflection increased to 12.98 ㎛ again until 800 sec and then reached 13.26 ㎛ at 900 sec

Group 4 showed a similar pattern to the group 1. For the first 50 second, drastic cuspal deflection occurred (Fig. 8 and 9). Up until 130 sec, the cuspal deflection tended to be steady and even slightly decrease. Afterwards, it rapidly increased and reached 5.58 ㎛ at 500 sec.

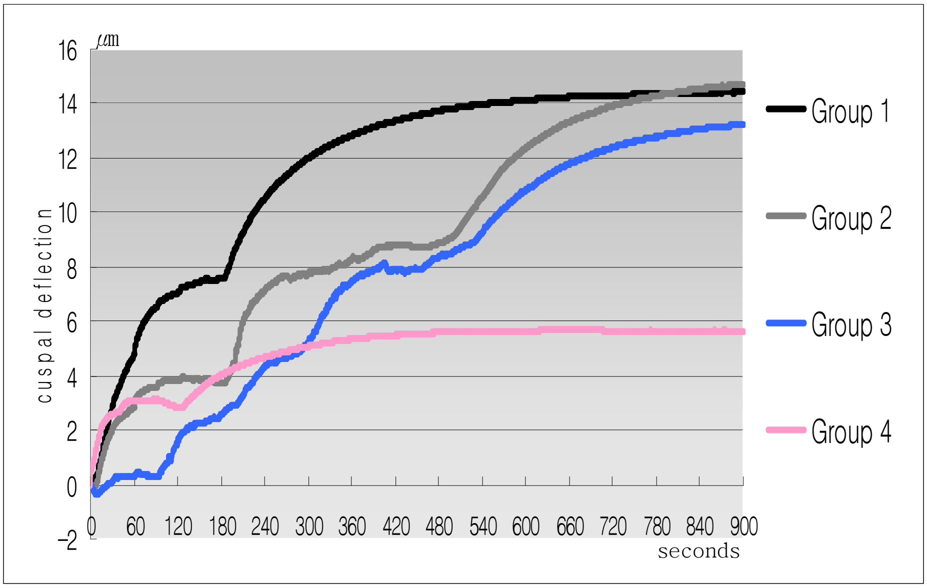

Fig. 9. Mean cuspal deflection of each group.

IV. Discussion

Polymerization shrinkage of composite resin is an unresolved weakness to the material and causes cuspal deflection when used in posteriors. The cuspal deflection can also lead to a number of clinical complications. This study focused on the relationship between composite resin placement techniques and the cuspal deflection.

The present experiment followed the same procedures of the previous study by Park *et al*, using the same composite resin, except the light-curing time. The cuspal deflection of bulk filling in this study was similar to 15.30㎛ reported by Park (Park *et al*, 2003). Thus we could confirm the validity of the CDMM used in both studies. The cuspal deflection of the other two direct techniques were also similar to the range of values of 6-15㎛ reported by McCullock (McCullock and Smith, 1986) and Rees (Rees and Jacobsen, 2004).

The cuspal deflection measuring time of this study was 15 minutes which was different from that of Park's study (Park *et al*, 2003). He experimented on the cuspal deflection of bulk filling of various materials for 10minutes that was enough time to reach a plateau. The present study, however, dealt with the horizontal and oblique layering techniques that contained application of more than one layers. Thus more time was needed to allow the final increment to polymerize and eventually reach its stable state, after it was added onto the previous one. In addition, previous literatures showed that the most of cuspal deflection took place within the first 15 minutes of polymerization (Causton *et al*, 1985; Jensen and Chan, 1985; McCullock and Smith, 1986; Suliman *et al*, 1993; Pearson and Hearty, 1987; Lutz *et al*, 1991; Segura and Donly, 1993).

The pattern of cuspal deflection demonstrated the very smooth curve, which may indicate the bonding strength of AdheSE and ONE-STEP were sufficient to overcome initial shrinkage stresses of the composite resin. If dentin bonding agent didn't overcome polymerization shrinkage of the composite resin, there should be some soaring spikes or intermittent appearance on the curve.

The cusps deflected inwards to the cavity drastically just as light-curing started but this tendency was offset by thermal expansion of the tooth structure and the composite resin. This thermal expansion supposedly was due to the temperature rise in the composite resin and tooth specimen which resulted from the heat from the curing light and exotherm of the composite resin (Shortall and Harrington, 1998). The reduction in cuspal deflection was more overt in group 4. Immediately the light curing ceased, the cuspal deflection increased drastically before the next light-curing because the heat source from irradiation disappeared.

This study didn't show statistically significant difference in cuspal deflection among bulk filling, horizontal filling and oblique filling. This result was consistent with that of Rees' experiment using the same composite resin (Rees and Jacosen, 2004). Rees reported that incremental filling technique was not superior to bulk filling technique in reduction of cuspal deflection. He stated that it might be that the total cuspal deflection was the result of the sum of polymerization shrinkages of all increments.

Even though each increment in horizontal and oblique filling had less volume than a single bulk filling, the first or second increment became more light-cured with subsequent light-curing and developed a higher modulus of elasticity. So in early stage of incremental techniques, the cuspal deflection was not so distinct owing to a lower C factor, thermal expansion of composite resin and tooth resistance to cuspal deflection. But in the later stage, the increased Young's modulus and highly polymerized early increments and subsequent increment polymerization, therefore, contributed to the total cuspal deflection.

On the contrary, Versluis (Versluis *et al*, 1996) reported in his finite element study that incremental fillings induced more cuspal deflection than a bulk filling. He explained that the total amount of composite material to fill a cavity turned out to be lower for an incremental filling technique than a single bulk filling, because the cusps moved towards the cavity as increments of composite resin light-cured, which lead to the less cavity dimension. In the present study, the same amount of composite resin was filled into all the cavities and this may lead to different results from those of Versluis.

Helimolar was selected for the reason that in the pilot study, its manipulation was superior to other types of posterior composite resins and it could barely cause interference to the CDMM when adding increments for incremental techniques. Helimolar was reported to have relatively low shrinkage compared to other posterior composite resins (Park *et al*, 2003). This low shrinkage stress may cause no statistical difference in cuspal deflection among three different direct filling techniques. Further study with other composite resin such as microhybrid type will be required.

Polymerization shrinkage in the resin inlay system was thought to take place only in the resin cement. Its total amount of polymerization shrinkage was less than that of direct composite restorations. That would be the reason why resin inlay caused less cuspal deflection than the direct filling techniques. Nonetheless, 5.64 ㎛ of the cuspal deflection in the group 4 was higher than expected, considering that significantly less amount of resin cement shrank. This may be due to extremely high C-factor in the resin cements when they were polymerized.

V. Conclusion

The purpose of the present study was to investigate the cuspal deflection of the maxillary premolars during the composite resin filling according to 4 different techniques – bulk filling, horizontal filling, oblique filling and indirect resin inlay with resin cement.

The conclusion was as follows:

Under this experiment conditions, none of direct composite filling methods is superior to the other direct techniques in reducing the cuspal deflection. Resin inlays can help to reduce the cuspal deflection, compared to direct composite resin filling techniques.

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국문요약

복합 레진의 충전방법에 따른 교두변위의 비교

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현 주 영

이 실험의 목적은 상악 소구치에서 복합레진을 4 가지 방법- bulk filling, horizontal filling, oblque filling, resin inlay-으로 수복하는 동안 나타나는 교두변위를 비교해 보는 것이었다.

교정 치료를 목적으로 발거된 치아중 치아 우식에 이환되지 않은 치아를 시편으로 선택했다. 선택된 치아의 근원심 폭경과 협설측 폭경을 측정하여 기록하였다. 크기가 비슷한 4 개의 치아를 각 군에 분배하는 방식으로 하여 각군당 15 개의 치아를 배정하여 총 60 개의 치아가 실험에 사용되었다. 협측 또는 설측으로 연장되지 않고 양측벽이 마주 보는 근원심 와동을 협설측으로 3.5 mm, 깊이는 3 mm가 되도록 형성하였다. 와동은 물로 충분히 세척하고 와동 건조후AdheSe를 제조자의 지시에 따라 적용하였다.

제 1군에서는 0.15 g의 Heliomolar를 bulk filling으로 와동을 충전하였다. 제 1군의 모든 시편은 Curin Light XL 3000을 이용하여 교합면, 근심면, 그리고 원심면에서 각각 60초씩 광중합하였다. 제 2군에서는 0.08 g과 0.07

g의 Heliomolar를 적층으로 충전하였으며 두층 모두 각각 교합면, 근심면, 원심면에서 60초씩 광중합하였다. 제 3 군에서는 0.05 g씩 세 층의 Heliomolar를 충전하고 세층 모두 교합면, 근심면, 원심면에서 각각 30초씩 광중합하였다. 제 4군에서는 0.15 g의 TESCERA로 레진 인레이를 제작하여 Duo-Link로 치아에 접착시키고 교합면, 근심면, 원심면에서 40초씩 광중합하였다. 광중합하는 동안 교두변위는 자체 제작한 교두 변위 측정 장치를 이용하여 광중합개시로부터 15분간 측정하였다. 측정값은 one-way ANOVA를 이용하여 통계 분석하였다.

제 1군 (14.52 ㎛), 2 군 (14.68 ㎛), 3 군 (13.44 ㎛) 간에는 교두 변위에 있어 통계적 유의한 차이가 없었다 ($P>0.05$). 제 4 군은 제 1, 2, 3군에 비하여 유의할 만한 감소된 교두 변위를 나타냈다 ($P<0.05$).

본 실험의 조건하에서는 복합 레진을 직접 충전하는 경우 어떤 충전법을 이용하더라도 교두 변위를 감소시키는데 효과적이지 못하며, 복합 레진의 간접 충전법이 교두 변위의 감소시키는데 도움을 줄 수 있을 것이다.

핵심되는 말: 교두 변위, bulk filling, Incremental filling, 레진 인레이