

Clinical Evaluation of High Density Posterior Composite

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ABSTRACT

고밀도 구치부 복합레진의 임상적 평가

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본 연구에서는 35개의 구치부 2급 와동에 고밀도 구치부 복합레진(Surefil, Caulk, U.S.A.)을 수복하였다. 단일 충전군은 18개 치아의 인접면 와동을 한꺼번에 충전한 후 광중합하였고 분할 충전군은 17개 치아의 인접면 와동을 두 층으로 나누어 충전 및 광중합하였다.

6개월 후의 임상검사 결과 다음과 같은 결론을 얻었다.

1. 기초검사에서 단일 충전군과 분할 충전군 모두 색상조화도(Color match)를 제외한 다른 검사 항목들에서 Alfa로 나타났다.
 2. 단일 충전군은 6개월 후 모든 검사(색상 조화도 제외)에서 인접면 접촉도(Proximal contact), 변연부 변색(Marginal discoloration), 술후 과민증(Postoperative sensitivity) 검사에서 소수의 치아가 Bravo, Charlie로 나타났으나 기초 검사와 3개월 후 검사 사이에 통계적으로 유의한 차이는 보이지 않았다.
 3. 분할 충전군은 6개월 후 시행된 모든 검사(색상 조화도 제외)에서 인접면 접촉도(Proximal contact), 술후 과민증(Postoperative sensitivity) 검사에서 소수의 치아가 Bravo, Charlie로 나타났으나 기초 검사와 6개월후 검사 사이에 통계적으로 유의한 차이는 보이지 않았다.
 4. 모든 검사항목에서 단일 충전군과 분할 충전군을 비교한 결과 통계적으로 유의한 차이는 보이지 않았다.
- 따라서 고밀도 구치부 복합레진(Surefil, Caulk, U.S.A.)은 색상 재현의 어려움을 제외하고는 여러 평가에서 우수하게 나타났으므로 본 연구 결과를 기준으로 보면 이전 복합레진의 단점이 보완되어 구치부 2급 와동에 적절하게 사용될 수 있다고 사료되며 단일 충전군과 분할 충전군 사이에 통계적으로 유의한 차이를 보이지 않으므로 시술 시간을 좀 더 단축시킬 수 있을 것으로 사료된다.

주요어 : 고밀도 구치부 복합레진, 2급와동, 단일 충전, 분할 충전

I. Introduction

For the last 150 years, dental amalgam was usually used as a filling material for Class II cavity. Research, however, has shown that the minute amounts of mercury vapor escaping from amalgam are in concentrations high enough to produce any detectable effect on the body¹⁾. Also, concern about the potential mercury biohazard to patients, operators and the environment has encouraged the profes-

sion to explore the viability of mercury-free materials as alternatives to dental amalgam.

Efforts have been made for the last 30 years to develop a composite resin originally introduced as a tooth-colored restoration in the anterior dentition into an alternative to amalgam in posterior teeth. Their introduction to dentistry by Rafael Bowen²⁾ in the mid-1960s opened the door for opportunities not even imagined at that time. But many dentists have a difficulty in filling Class II cavity with early posterior

composite. Because of the technique sensitivity of materials, tight proximal contact³⁾ and natural contour⁴⁾ couldn't be regained properly. Also, early composite resin was more susceptible to recurrent caries⁵⁾ and worn³⁾ more easily than amalgam. Therefore, indirect technique was explored, in which you make the restoration in a laboratory and cement it to teeth. However, in indirect technique, there were some disadvantages such as more visits, much more loss of tooth structure and higher prices patients should pay. Thus, it was still necessary to create a composite resin adequate to be used in direct technique.

Over the years, composite resins became substantially better. Many of the problems associated with the original formulations eventually were resolved. Unfortunately, however, the material's handling characteristics remained relatively unaltered. Only those operators who took the extra time required for placement and followed all of the detailed procedures associated with insertion and finishing experienced a high level of success. Also, composite resin could not actually serve as a replacement for amalgam until its handling characteristics were changed.

Recently, high density posterior composites have been introduced to solve many of these problems. Surefil(Caulk, U.S.A.), a urethane modified BIS-GMA resin system, used in this study was comprised of the synergistic linking of a unique inorganic filler system(interlocking particle technology). Surefil is a precisely engineered mixture of different-size particles which are made of patented fluoride-infused glasses. Interlocking action between the particles gives this restorative a feel and resistance similar to

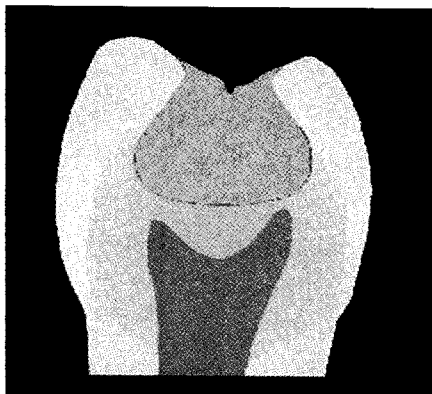
an amalgam during condensation. It also eliminates the slumping and rebounding of most composites when trying to establish contacts.

The objective of this study was to test the Surefil under clinical conditions by examining the clinical performance, such as color match, marginal discoloration, recurrent caries, marginal integrity, wear, proximal contact, fracture, postoperative sensitivity, gingival health.

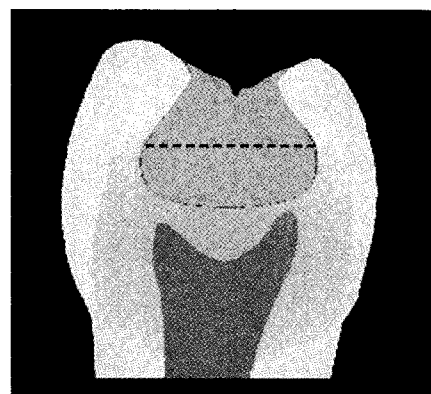
II . Materials and Methods

1. Materials

A total of 35 restorations of Surefil were made in Class II cavities. All patients included in the study, ranging from 20 to 60 years of age, were selected from the clinical pool available through the Dankook Dental School clinic. In class 2 cavities of 35 teeth of 30 patients were filled in two ways, one of which is total filling technique and the other is incremental filling technique. 18 of those teeth were filled in total filling technique and 17 of those were filled in incremental filling technique. They were bonded with Prime & Bond NT(Caulk, U.S.A.) which is one coating bonding agent. Patients who have vital class II defects including initial/secondary class II carious lesion, tooth fracture except full cuspal fracture and esthetic re-restoration on existent class II metallic restoration were selected. All teeth included in the study were in normal functional occlusion with at least one cusp in occlusal contact, and they all had a favorable response to a pulp tester, percussion, and



Total filling



Incremental filling

Fig. 1. Filling methods

palpation.

2. Methods

1) Preparations

Before initiating the procedure, a clinical examination, radiograph and photograph were taken. After appropriate isolation using rubber dam and gingival retraction cord, the cavity was prepared with a No. 245 Carbide bur at high speed. The occlusal aspects of the preparation were parallel with a butt joint at the cavosurface margin, and bevel may be used on the both buccal and lingual sides of proximal box except on the side of gingival wall. Gingival wall was positioned on the site of enamel, dentin and/or cementum, but was extended deeper than 2mm depth of gingiva. In deep cavities, hard-setting Ca(OH)₂(UltraBlend, Ultradent, U.S.A.) was applied

on the local area only close to the pulp and GI cement base was used.

2) Composite resin filling

After the conservative outline of preparations was kept very close to original contour using a Tofflemire retainer, a thin(.0015") metal matrix and wedge, a cavity cleanser(Bisco, U.S.A.) was then used to clean up the cavities. A 34% phosphoric acid solution was then applied to the enamel and dentin surfaces for 15 seconds, rinsed, and lightly air dried. Next, Prime & Bond NT was applied to the surface of the preparation with a fully saturated small brush. The bonding agent was air dispersed for 20 seconds from the time of application, photo-cured for 10 seconds.

After inserting into proximal box with a nonstick nylon amalgam carrier, the total filling group were inserted into proximal box with bulk, and the incre-

Table 1. United State of Public Health Service Criteria

Category	Rating	Characteristics
Color match	Alfa	The restoration appears to match the shade and translucency of adjacent tooth tissue.
	Bravo	Doesn't match the shade and translucency of adjacent tissues, but the mismatch is within the normal range of tooth shades.
	Charlie	Doesn't match the shade and translucency of adjacent tissues, and the mismatch is outside the normal range of tooth shades and translucency.
Marginal discoloration	Alfa	No visual evidence of marginal discoloration different from the color of the restorative material and from the color of the adjacent tooth structure.
	Bravo	Visual evidence of marginal discoloration at the junction of the tooth structure and the restoration, but the discoloration has not penetrated along the restoration in a pulpal direction.
	Charlie	Visual evidence of marginal discoloration at the junction of the tooth structure and the restoration, and the discoloration has penetrated along the restoration in a pulpal direction.
Recurrent caries	Alfa	No visual evidence of dark, deep discoloration adjacent to restoration.
	Bravo	Visual evidence of dark, deep discoloration adjacent to restoration. but it is not directly associated with cavosurface margins.
Marginal integrity	Alfa	Explorer doesn't catch when drawn across the surface of restoration. Toward the tooth, or, if explorer does catch, there is no visible crevice along the periphery of the restoration.
	Bravo	Explorer catches and there is visible evidence of a crevice, into which the explorer penetrates, indicating that the edge of the restoration doesn't adapt closely to the tooth structure. The dentin and/or the base is not exposed, and the restoration is no mobile.
	Charlie	Explorer penetrates an crevice defect that extends to DEJ.

mental filling group were inserted into proximal box with two increments. The material was cured for 40 seconds per application.

3) Finishing and Polishing

The composite was finished with diamond finishing burs. Final polishing was done with polishing points and pastes(Enhance, Caulk, U.S.A.).

3. Evaluation

Restorations were evaluated at the 1 week later as a baseline, and the recall was done at the 6 months later. Clinical photographs and impressions were taken at placement and at recall visits. Each restoration was impressed with a polyvinyl siloxane impression material(Aquasil, Dentsply) and then casted with a die stone to determine the extent of wear. In addition, radiographic records were made of each restoration to determine secondary caries and proximal contact.

Each restoration was directly evaluated by two clinicians using the United States Public Health

Service(USPHS) System(Table 1, 2). Devised by Cvar and Ryge⁶⁾ in the 1970s, this system used a direct evaluation method performed at chairside. The two clinicians who evaluated the restorations were never involved in the placement of any of the restorations. Records from two clinicians should be coincide more than 85% and when there is some points that don't, they should discuss and find an agreement.

Characteristics evaluated during the clinical study included color match, marginal discoloration, secondary caries, marginal integrity, wear, proximal contact, fracture, postoperative sensitivity, and gingival health. At the baseline and 6 month recalls, the results were recorded as Alfa, Bravo, and Charlie.

4. Statistical evaluation

Mann-Whitney U Test was used in detecting differences between filling methods(Total, Incremental) and Wilcoxon Signed Ranks Test was used to detect differences between recall times.

Table 2. United State Public Health Service Criteria.(2)

Category	Rating	Characteristics
wear	Alfa	The restoration is a continuation of existing anatomic form or is slightly flattened. It may be overcontoured. When the side of the explorer is placed tangentially across the restoration, it does not touch two opposing cavosurface line angles at the same time.
	Bravo	A surface concavity is evident. When the side of explorer is laced tangentially across the restoration, it touches two opposing cavosurface line angles at the same time, but the dentin or base is not exposed.
	Charlie	Loss of restoration substance so that a surface concavity is evident and the base and/or dentin is exposed.
Proximal contact	Alfa	The proximal contact is fully present.
	Bravo	The proximal contact is slightly present.
	Charlie	The proximal contact is missing
Fracture	Alfa	No bulk fracture is present.
	Bravo	Bulk fracture is evident.
Postoperative sensitivity	Alfa	There is no sensitivity.
	Bravo	Sensitivity is transient(passing within 4wks after placement)
	Charlie	Sensitivity is permanent.
Gingival health	Alfa	No clinical inflammation is present.
	Bravo	Clinical inflammation is present.

III. Results

At the baseline, color matching for Total filling group revealed four teeth with Alfa, eleven teeth with Bravo and three teeth with Charlie and color matching for Incremental filling group revealed two teeth with Alfa, thirteen teeth with Bravo, two teeth with Charlie. At the 6 Months recall, the results showed no change compared with those of baseline(Table 3).

At the marginal discoloration evaluation, all of restoration at the baseline were rated as Alfa and at the 6 months later, one tooth of Total filling group changed into Bravo and Incremental filling group showed no change(Table 4).

At the proximal contact evaluation, all of restorations at the baseline were rated as Alfa and at the 6

months later, two teeth of Total filling group and two teeth of Incremental filling group were rated as Bravo(Table 5). At the postoperative sensitivity evaluation, all of restorations at the baseline were rated as Alfa and at the 6 months later, Total filling group revealed two teeth with Bravo and one tooth with Charlie and Incremental filling group revealed two teeth with Bravo and two teeth with Charlie(Table 6).

Regardless of filling method, all of the restorations at the baseline and 6 months later were rated as Alfa for marginal integrity, wear, recurrent caries, fracture, and gingival health(Table 7).

There was no significant difference between the baseline and 6 months later. At the 6 months recall, there was no significant difference between the filling methods.

Table 3. Color match

	Baseline		6 Months	
	Total	Incre	Total	Incre
Alfa	4	2	4	2
Bravo	11	13	11	13
Charlie	3	2	3	2
Total	18	17	18	17

Table 4. Marginal discoloration

	Baseline		6 Months	
	Total	Incre	Total	Incre
Alfa	18	17	17	17
Bravo	0	0	1	0
Charlie	0	0	0	0
Total	18	17	18	17

Table 5. Proximal contact

	Baseline		6 Months	
	Total	Incre	Total	Incre
Alfa	18	17	16	15
Bravo	0	0	2	2
Charlie	0	0	0	0
Total	18	17	18	17

Table 6. Postoperative sensitivity

	Baseline		6 Months	
	Total	Incre	Total	Incre
Alfa	18	17	15	13
Bravo	0	0	2	2
Charlie	0	0	1	2
Total	18	17	18	17

Table 7. Wear, Recurrent caries, Fracture Marginal integrity, Gingival health

	Baseline		6 Months	
	Total	Incre	Total	Incre
Alfa	18	17	18	17
Bravo	0	0	0	0
Charlie	0	0	0	0
Total	18	17	18	17

IV. Discussion

Dental amalgam made of silver amalgam alloy and mercury has been favorably used for past 150 years⁷⁻⁹. Even the use of amalgam has been reduced, it has still many advantages such as durability, cheapness¹⁰, and easiness to fill cavities. Noxiousness of amalgam is not fully elucidated¹¹. It can be innocuous when an expert manipulates it skillfully¹². As growing interest in materials which don't contain mercury^{13,14}, researches of the use of composite resin for posterior tooth restoration actively started to proceed.

Direct esthetic restorative material was first introduced by Fletcher¹⁵ in 1871. It was widely used for anterior tooth restoration at the first time because of natural color and high esthetics. But low bio-compatibility due to pulpal stimulation retarded the development of that material. In mid 1940's, PMMA (poly methyl methacrylate) replaced silicate cement. It was easy to select color similar to natural teeth and easy to polish. But microleakage due to polymerization shrinkage irritates pulpal tissue. In 1962, Ray Bowen² created Bis-GMA macrofilled composite which overcame this problem. Bis-GMA is a synthetic material made from bispheno-A and glycidyl methacrylate. Composite resin composed of Bis-GMA has less polymerization shrinkage and better abrasion resistance than PMMA. Also, it is more resistant to tarnish and keeps own shape better than silicate cement, thus it has started to be used for restoration of anterior teeth. As growing interest in esthetics, composite resin was started to be used for restorations of posterior teeth.

But there were still many problems in former composite resin. One of them is that it is highly technique sensitive. There are many investigations showing different views about posterior composite resin filling¹⁷. When you fill cavities with composite resin, we need a matrix to make a good shape. Different with amalgam, it has flow and friable to change shape. Even you place a matrix in a right place, it is hard to make a good tooth shape, and tight contact with adjacent tooth. It is shown in many papers, that secondary caries can occur and spread faster in teeth restored with composite resin¹⁸. Marginal leakage due to polymerization shrinkage allows bacteria to

invade. As marginal deformation increases as time goes on, secondary caries increases^{18,19}. Also, Composite resin has higher ratio of recurrence of caries⁵ than amalgam because amalgam has sealing effect of corrosional product. When you use composite resin, you can overcome this problem using liner and base. Former composite resin has less resistance to abrasion so it was more easily abraded than amalgam²⁰. In 1994, Pink and his colleagues²¹ said that life of amalgam ranged 6 years to 11 years and composite resin ranged 5 to 6 years, over 80% of wear data for composite restorations were for relatively low stress applications. Opposite to this, in some papers, it was said that abrasion resistance of composite resin was almost equal to amalgam^{22,23}. Composite resin has 3 to 7% of polymerization shrinkage²⁴, and it diminishes adaptability to cavity walls, thus it makes marginal leakage²⁵ which results in postoperative sensitivity²⁶ and secondary caries²⁷.

Due to the problems shown above the former composite resin wasn't adequate to be used. Therefore, it was necessary to create a material which has these functions²⁸. Firstly, preparation of cavities should be conservative. Secondly, own shapes of teeth should be preserved, and has mechanical resistance. Thirdly, good adaptation to walls and sealing should be made. It should be bio-compatible and appropriately durable.

Surefil (Caulk, U.S.A.) used in this study overcame many problems of former composite resin. It is an urethane modified Bis-GMA resin system, and the filler components of Surefil restorative are consisted of a precise blend of barium fluoro alumino borosilicate glasses and fumed silica of distinct particle size distributions and morphologies. With an average filler particle size of 0.8 microns combined with a filler loading of about 82wt%. The most characteristic point of this composite resin is the Interlocking Particle Technology (IPT). When packed, the larger particles mechanically interlock with the smaller particles, and it makes a lattice form which resists deformation. Also, fluoride which prevents secondary caries is released. It can be light-cured 5mm in depth once, therefore reduces operation time.

Prime & Bond NT (Caulk, U.S.A.) was used to bond this high density posterior composite resin. Since it is just one coating bonding agent which con-

tains 100 times smaller filler than typical hybrid resin which can penetrate into dentinal tubules and microfilaments²⁹⁾, it can strengthen resin matrix and it is able to have superior adhesive strength to both enamel and dentin, and maintain thin film thickness.

In this research, high density posterior composite resin (Surefil, Caulk, U.S.A.) was used to evaluate if composite resin could substitute amalgam and resolve the problems which former resin had. We compared Total filling groups with Incremental filling groups in different evaluation times and filling methods. The method of test is applied by clinical evaluation methods, United State Public Health Service (USPHS) criteria, suggested by Cvar and Ryge⁶⁾ in 1971. This standard supplies a way of observing and recording the differences between filling methods and materials. And later, clinical photograph by Mahler³⁰⁾ and wear test by Leinfeild³¹⁾ and other tests are added to this criteria.

Baseline was taken 1 week after the treatment and following up test was taken 6 month after baseline. Sub-method of test is used by clinical photograph, x-rays, and impression model. Impression is taken by polyvinyl siloxane impression material, and wear test is taken to the stone cast, and second caries and proximal contact ratio is recorded by X-rays.

Since Surefil has only three colors(A2, B1, C2), it is harder to select adequate color than other posterior composite resins. Therefore, filling every tooth with Alfa was impossible at baseline. In Total filling group, four of eighteen teeth turned out to be Alfa, The other teeth were recoded as Bravo and Charlie. In Incremental filling groups, two of seventeen teeth were recorded as Alfa and others were Bravo and Charlie. But comparing test with 6 months from baseline, measured values have not been changed. In recurrent caries test, between baseline and test after 6 months, there was no difference and every value of measure showed as Alfa. It is thought that there may be some effect by fluoride continuously released during the first year, which is a characteristic of Surefil. At marginal discoloration test, in baseline every tooth was Alfa. And after 6 months, in Total filling group, one tooth was turned out to be Bravo, and there was no change in Incremental filling group. Marginal integrity, wear, and gingival healthy test was taken with clinical test and impression cast.

There was no change between baseline and a test after 6 months. They were all Alfa.

At proximal contact test, all teeth were Alfa in baseline, but in a test after 6 months, two teeth of each group showed up as Bravo, and the others were all Alfa. At postoperative sensitivity test, in baseline, all teeth were Alfa. In a test after 6 months, Total filling group had two Bravo teeth and one Charlie tooth. In Incremental filling group, there were two Bravo teeth and two Charlie teeth, and the rest of them were Alfa teeth. Bravo teeth got symptom free in 4 weeks and Charlie teeth were retreated again.

In statistical comparison with testing time, We used Wilcoxon Signed Ranks Test. There was no statistical significance between baseline and 6 month recall. In statistical comparison of filling methods done 6 months after baseline, We used Mann-Whitney U Test. There was no statistical significance between Total filling group and Incremental filling group.

In results of this research, there were some differences at values of number of teeth about Surefil. But since there was no significance at statistical comparison of filling methods and testing time, Surefil could be an appropriate material for posterior composite resin. But the testing time has not been so long, that it seems necessary to observe for a longer period.

V. Results

In this study, total 35 class II cavities in posterior teeth were filled with Surefil and Prime & Bond NT: proximal boxes of eighteen teeth were filled in a total mass and those of seventeen teeth were filled in 2 increments. Their clinical behavior was evaluated under the some standard based on the USPHS by 2 clinicians.

At baseline and 6 months recall, the results were as follows:

1. At baseline, all of the restorations were rated as Alfa except color matching.
2. At the end of 6 months recall, a few teeth of Total filling group(except color matching item) were rated as Bravo or Charlie for proximal contact, marginal discoloration and postoperative sensitivity. But there was no statistical difference between baseline and 6 months recall.

3. At the end of 6 months recall, a few teeth of Incremental restoration group (except color matching item) were rated as Bravo or Charlie for proximal contact and postoperative sensitivity. But there was no statistical difference between baseline and 6 months recall.
4. At the end of 6 months recall, there was no statistical difference between Total filling and Incremental groups.

Because the High density posterior composite (Surefil, Caulk, U.S.A.) in all criteria except color match was superiorly evaluated, it may be possible to use this as a Class II restorative material. It could be concluded that we might be able to spare operating time from the fact of no difference between Total filling and Incremental groups.

Reference

1. Bergman M : Side effect of amalgam and its alternatives: local, systemic and environmental. *Intern Dent J* 40:4-10, 1990.
2. Properties of a silica-reinforced direct polymer for dental restorations. *JADA* 66:72, 1963.
3. Rykke M : Dental materials for posterior restorations. *Endod Dent Traumatol* 8:139-148, 1992.
4. Boksman L, Jordan RE : Posterior composite restorations. In: *Esthetic composite bonding*, edited by Jordan R. E. BC Decker Inc., 1986.
5. Lezel H., Van 't Hof MA. : A controlled clinical study of amalgam restoration: Survivals, failures, and causes of failures. *Dent mater* 5:115-121, 1989.
6. Cvar JF., Ryge G : Criteria for clinical evaluation of dental restorative materials. United State Public Health Service publication 790. US Government Printing Office, San Francisco, 244, 1971.
7. Dawson AS, Smales RJ : Restoration longevity in an Australian Defense Force population. *Aust Dent J* 37:196-200, 1992.
8. Klausner LH, Green TG, Charbeneau GT : Placement and replacement of amalgam restorations: A challenge for the profession. *Oper Dent* 12:105-111, 1987.
9. Robbins W, Summitt JB : Longevity of complex amalgam restorations. *Oper Dent* 13:54-57, 1988.
10. Peter Williams : Goodbye amalgam, Hello alternatives?. *Dent Mater* 62:139-144, 1996.
11. Mackert J.R, Berglund A : Mercury exposure from dental amalgam fillings: absorbed dose and the potential for adverse health effects. *Crit Rev Oral Biol Med* 8:410-436, 1997.
12. Eley BM., Cox SW : The release, absorption, and possible health effects of mercury from dental amalgam: A review of recent findings. *Br Dent J* 175:355-362, 1993.
13. Bryant RW : Direct posterior composite resin restorations: A review. 1. Factors influencing case selection. *Aust Dent J* 37:81-87, 1992.
14. Bonner P : Advances in dental materials: An exclusive interview with Dr. Karl Leinfelder. *Dent Today* 5:32-34, 1994.
15. Fletcher T : New plastic filling. *Br J Dent Sci* 14:514-516, 1897.
16. Willems G, Lambrechts P, Braem M, Vanherle G : Three-year follow up of five posterior composite: In vivo wear. *J Dent* 21:74-78, 1993.
17. Letzel H : Survival rates and reasons for failure of posterior composite restorations in multicentre clinical trial. *J Dent* 17:S10-S17, 1989.
18. Barnes DM, Hoston AM, Strassler HE, Shires PJ : Evaluation of clinical performance of twelve posterior composite resins with a standardized placement technique. *J Esthet Dent* 2:36-43, 1990.
19. Dicknison GL, Gerbo LR, Leinfelder KF : Clinical evaluation of a highly wear resistant composite. *Am J Dent* 6:85-87, 1993.
20. Gary D, Derkson, Alan S : Clinical evaluation of composite resin and amalgam posterior restorations: Three year results. *J Canad Dent* 6:478-481, 1984.
21. Pink FE, Mindan NJ, Simmonds S : Decisions of practitioners regarding placement of amalgam and composite restorations in general practice settings. *Oper Dent* 19:127-132., 1994.
22. Feller RP, Ricks CL, Matthews G, Santucci EA : Three-year clinical evaluation of composite formulations for posterior teeth. *J Prosthet Dent*. 57:544-550, 1987.
23. Norman RD, Wright RJ : A 5-year study comparing a posterior composite resin and an amalgam. *J Prosthet Dent* 64:523-9, 1990.
24. Feilzer AJ, de Gee AJ : Curing contraction of composites and glass-ionomer cements. *J prosthet Dent* 59:297-300, 1988.
25. Davidson CL, de Gee AJ, Feilder A : The competition between the composite dentin bond strength and the polymerization contraction stress. *J Dent res* 63:1396-1399, 1984.
26. Torstensen B, Brannstrom M : Contraction gap under composite resin restoration: Effect of hygroscopic expansion and thermal stress. *Oper Dent* 13:24-31, 1988.
27. Brannstrom M : Communication between the oral cavity and the dental pulp associated with restorative treatment. *Oper Dent* 9:57-68, 1984.
28. Newman SM : Amalgam alternatives: What can complete?. *JADA* 122:67-71, 1991.
29. Ferrari M, Monnoci F, Kugel G, Fracklin GG : Standardized microscopic evaluation of the bonding mechanism of NRC/Prime & Bond NT. *Am J Dent* 12:77-83, 1999.
30. Mhaler DB, Terkla LG, Van Eysden J, Reisbick MH : Marginal fracture vs mechanical properties of amalgam. *J Dent Res* 49:1452-1457, 1970.
31. Leinfelder KF, Taylor DF, Brakmeier WW, Goldberg AJ : Quantitative wear measurement of posterior composite resins. *Dent Mater* 2:198-201, 1986.