RADIOPACITY OF CAD/CAM CERAMICS

Jong-Hyeok Lee, Han-Seuk Choi, Chung-Moon Um

Dept. of Conservative Dentistry, College of Dentistry, Seoul National University

국문초록

CAD/CAM용 도재의 방사선 불투과성에 관한 연구

서울대학교 치과대학 치과보존학교실

이종혁 · 최한석 · 엄정문

목 적

치과용 수복재료의 방사선 불투과성은 매우 다양하다. 따라서 다양한 수복재료의 방사선 불투과성을 인지하여 치질과 비교하면 이차우식의 진단에 도움이 될 수 있다. 도재의 방사선 불투과성에따라 적절한 luting cement의 선택이 가능해진다. 수복재료의 방사선 불투과성은 알루미늄 step wedge의 후경과 방사선 불투과성과의 상관관계 의해 측정된다.

본 연구의 목적은 CAD/CAM용 도재와 이들의 접착에 쓰이는 접착재료의 방사선 불투과성을 조사해 적절한 재료의 선택과 이차우식 진단의 효율결정에 도움이 되게 하는데 있다.

방 법

본 실험에서는 CAD/CAM용 도재인 Vita MarkII, Dicor MGC와 이의 접착에 사용되는 Z-100, 그리고 luting cement인 Duo cement, Scotchbond resin cement를 사용해 방사선 불투과성을 측정하였다.

시편 제작을 위해 도재를 저속절단기로 두께 2mm, 3mm로 절단하였으며 Z-100과 cement시편은 두께 2mm와 3mm, 직경 7.0mm의 금속 주형을 제작한 후 재료를 양쪽 면에 유리판을 대고 조임쇠로 압접하였으며 광조사기를 사용하여 각 재료마다 두 가지 두께로 10개씩 100개의 시편을 제작하였다. 치질의 시편을 얻기 위해 교정 목적으로 최근에 발거된 정상적인 상악 소구치를 저속 절단기를 사용하여 협설측 교두정을 기준 삼아 2mm, 3mm 두께로 절단하였으며 방사선 불투과성의 기준을 위해 12개의 step으로 구성된 12mm두께의 aluminum step wedge를 사용하였다. Kodak E-Speed occlusal film에 aluminum step wedge와 시편들을 위치시킨 후 70kVp, 7mA, 2.16mmaluminum filtration으로 고정된 dental X-ray unit을 사용하여 target과 film 사이의 거리는 25cm, 노출시간은 0.2초로 하여 방사선 촬영을 한 다음, 현상된 방사선 사진상에 나타난 방사선 불투과성을 X-rite 301 densitometer를 이용하여 측정한 값들의 평균을 냈다. 얻어진

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결과는 one-way ANOVA Duncan test($P<0.01$)로 검증하였다.

결 론

1. Dicor MGC의 방사선 불투과성은 법랑질보다 약간 높게 나타났다.($P<0.01$)
2. Vita Mark II는 상아질보다 낮은 방사선 불투과성을 보였다.($P<0.01$)
3. Z-100과 Luting cement들의 방사선 불투과성은 법랑질보다 높았다. Duo cement가 방사선 불투과성이 가장 높았고 그 다음이 Z-100, 그리고 Scotchbond resin cement 순이었다.
4. Z-100과 2종류의 방사선 불투과성 luting cement들은 Vita Mark II와 같이 사용하면 2차우식 진단에 도움이 된다.

주요어 : 방사선 불투과성, CAD/CAM

I. Introduction

The demand for esthetic tooth-colored materials has increased. As a result, many new materials have been developed. In case of anterior restorations, conventional composite resin has been accepted as a proper material due to its long life span and reasonable proper esthetics. In case of posterior restorations, however, amalgam or gold restorations are still widely used because composites show weaknesses such as abrasion, fracture, recurrent caries, etc. The esthetic demand and the concern over the possible harm of the mercury have increased the demand for ceramic materials.

Ceramic use in the dental field began in 1780 in France. However, ceramic as restorative material in massive scale began only after the development of the ceramics which had similar coefficient of thermal expansion to the dental alloys in 1962 by Weinstein, Katz & Weinstein in the USA.[1] Despite of good esthetics, problems have still existed : the attrition of the opposite tooth material due to the ceramics, discrepancy of the coefficient of thermal expansion between the metal and the ceramics, and cracks between the opaque ceramics and metal oxides which have been produced for the cementation.

Recently, many ceramics have been developed as an answer to the following demand : high esthetic quality similar to the natural tooth, high compression strength, radiopacity, and stability in the oral environment. An all-ceramic restoration is now considered to be esthetically much better than a PFM restoration. However, the brittleness and the weak fracture resistance of ceramics have increased the interest on its life span. A lot of research has been done for its improvement.

A variety of cementing medium has been studied for ceramic restoration. In 1994, Scherrer & others[2] reported that the fracture resistance of ceramics was raised over the degree of 75% when resin cement was used rather than ZPC - the conventional luting cement. In 1991, it was introduced the cementing technique of fine hybrid composite which is highly filled, viscous, and abrasion resistant. When the working end of the ultrasonic device was applied on the occlusal surface, the seating of inlay body was complete.[3]

In early days, ceramic inlay or onlay was made a part of conventional feldspartic porcelain using platinum foil matrix. In recent days, however, they are produced on the refractory die, with glass ceramic, or apatite ceramic. Also they are produced by injection molding ceramic, using lost wax process.

Cerec system was first developed in 1980 by Mörmann & Brandestini in Switzerland. It was clinically used since 1986, when Vita-Cerec MK I porcelain block was made.

The effort to improve these materials was made since 1987. Dicor MGC Cerec block and adhesive material were developed as a result. Vita MK II and Vita-Cerec Duo cement were introduced, also. Researchers examined the abrasiveness of Vita-Cerec fine porcelain and Cerec-Dicor MGC using a chemo-thermo-mechanical test. Following the test, the surface of the Dicor MGC was slightly roughened whereas the Vita-Cerec MK II fine porcelain had a smooth surface and was comparable to enamel in its abrasiveness.[3] With the increasing use of these ceramic materials, the interest in recurrent caries related to ceramic use also has increased. To diagnose recurrent caries radiographically, restorative material must have an reasonable level of radiopacity.[4-18] Generally aluminum is used as a standard reference for radiopacity of dental materials. According to the ISO specification No.4049[19], if the manufacturer claims a material is radiopaque, the radiopacity of the material must be greater than that of the same thickness of aluminum.

It was reported that MGC Dicor glass ceramic is more radiopaque than Vita Mark II porcelain so the same luting cement cannot be used for both products.[20] Goshima & Goshima (1990) reported that radiopacity equivalent to that of enamel is optimum for diagnosis of recurrent caries because higher radiopacity makes the image of recurrent caries, marginal defect, or porosity too unclear to confirm.

The purpose of this study was measure the radiopacities of these new ceramic materials and compare them with those of tooth enamel, dentin, two resin cements and Z-100 composite resin.

II. Materials & Methods

Specimens which had sizes of 8.0×8.0mm with a thickness of 2mm and 3mm were cut from blocks of two ceramic materials (Dicor MGC, L.D. Caulk Division, Dentsply International Inc., Miliford, DE, USA; Vita Mark II, VITA Zahnfabrik, H. Rauter GmbH & Co. KG, Bad Säkingen, Germany). They were cut by low-speed cutting machine with diamond blade.

Z-100 composite (3M Dental products, St. Paul, MN, USA) and cements (Duo cement, Vita Zahnfabrik; Scotchbond resin cements, 3M) were manipulated following manufacturers directions. They were condensed into metal molds which had diameter of 7.0mm and depth of 2.0mm and 3.0mm under pressure from both sides, and light-cured with Visilux II (3M., U.S.A.). They were made 10 each, 100 total.

For tooth specimens, maxillary bicuspids, which had been recently extracted for orthodontic treatment, were cut with low-speed cutting machine using a diamond blade. They were cut to be 2.0mm and 3.0mm thickness with basis of buccal & lingual cusp tips as reference points. Also, aluminum step wedge with 12 steps was made with the thickness of 11.92mm.

Specimens were radiographed using E-speed occlusal film[22](Eastman Kodak co.,Rochester, New York 14650, USA), with a dental x-ray unit(Siemens, Aktiengesellschaft Wittelsbacherplatz, M nchen, Germany) with specification of 70kVp, 7mA, and 2.16mm aluminum filtration. Distance between the target and the film was 25Cmm. An exposure time was 0.2 seconds. After the radiopacity from the radiographs were measured, data was obtained with densitometer(X-rite *301*, X-Rite com-ANOVA. The statistical analysis showed that there were significant differences between all materials(P0.01).

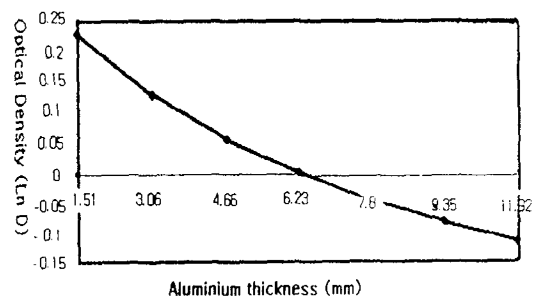

Fig.1 Standard curve for the optical density of the aluminium step wedge

pany, USA). Data analysis was completed using an analysis of variance and Duncan test at the 1% level. It indicated that there were *significant differences between materials.*

III. Data and Results

Standard curve(Fig.1) Ln D =0.5008-0.1048X(D : Densitometer readings, X : Al thick-

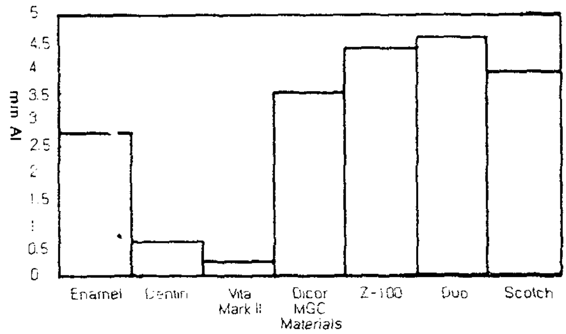

Fig. 2 Radiopacity of materials used in comparison with Enamel and Dentin

Table 1. Material

Material	Bat. No.
Dicor MGC	51691(Caulk/Dentsply)
Vita Mark II	4394(Vita Zanhfabrik)
Z-100	19941129 (3M)
Duo cement	Dk002(Vita Zahnfabrik)
Scotchbond resin cement	19961014 (3M)

Table 2. Radiodensities of Materials

Material	Densitometer readings		Equivalent thickness of Al(mm)	
	2 mm	3 mm	2 mm	3 mm
Dicor MGC	1.26± 0.007	1.14± 0.006	2.57	3.53
Vita Mark II	1.73± 0.006	1.61± 0.01	—	0.23
Z-100	1.19± 0.009	1.05± 0.008	3.12	4.31
Duo cement	1.16± 0.007	1.03± 0.006	3.36	4.50
Scotchbond resin cement	1.21± 0.009	1.09± 0.01	2.96	3.96
Enamel	1.35± 0.004	1.24± 0.006	1.92	2.73
Dentin	1.54± 0.006	1.40± 0.005	0.66	1.57

($P<0.01$)

ness) was obtained from the correlation between thickness and optical density, which was measured by densitometer. Optical density of each specimen was converted to the equivalent thickness of aluminum using the standard curve that was prepared. The data were analyzed statistically by Duncan test of one way ANOVA. The statistical analysis showed that there were significant differences between all materials(P0.01).

Materials with higher radiopacity than aluminum were Dicor MGC block, Z-100, Duo cement, and Scotchbond resin cement, while Vita Mark II showed the lower value(Fig.2). In 3mm samples, thickness of Dicor MGC block was equivalent radiopacity to 3.6mm of aluminum, which somewhat exceeds enamel. Vita Mark II showed equivalent radiopacing to 0.3mm, which has even lower than dentin.

Ⅳ. Discussion

Radiography plays a great role in the evaluation of the teeth and restorative materials. Studies before the mid-80 hypothesize that the more difference in radiopacity between restorative material and tooth, the better the diagnosis of recurrent caries or marginal defect could be made.

Kulid[22](1976) reported that the use of radiopaque composite resin helps the diagnosis of recurrent caries. Abou-Table, Tidy & Combe(1979)[4] measured the radiopacity of 18 different composite resins, and reported that they should not have radiopacity less than dentin for restorative use.

However, the degree of radiopacity has limited clinical significance. Dijken, Wing & Ruyter[8](1989) reported that when composites are applied to class II cavities, the X-rays must pass through two layers of tooth structure, buccal and lingual segments, which are contiguous with the cavity preparation, before reaching the film. These two layers of tooth structure partially mask the composite. If the composite is to be made radiopaque to facilitate the detection of enamel decay or marginal defects in Class II cavities, the material must have a radiopacity not less than that of the enamel. Goshima & Goshima[21](1990) reported that radiopacity equivalent to that of enamel is optimum for recurrent caries diagnosis because too much higher radiopacity makes the image of recurrent caries, marginal defect, or porosity invalid.

Tveit and Espelid[24](1986) reported composites that produced slightly higher radiopacity than that of enamel are favorable for recurrent caries diagnosis. Omer, Wilson & Watts[25] (1986) reported that composites remarkably exceeding the radiopacity of enamel are good for diagnosis. However, excessive radiopacity, such as one of amalgam, can be a difficulty in recurrent caries diagnosis.

It has been a long time that ceramic inlay was used in dental field.[26-29] Yet, its use has been quite limited due to the difficulty in acquiring good margin, attrition of opposite teeth, dissolution of cement, etc.

Recently, development of physical properties and skills has been made, and it became possible that ceramic inlay itself bonds to the tooth material with resin cement, thanks to the use of etching and bonding agents.[18] Moreover, newly developed ceramics are not as hard as conventional ones so that the opposite teeth attrition can be minimized.

It was reported that Cerec Dicor MGC inlay had a good suitability as gold, composites, or porcelain indirect inlay.[3] Goshima & Goshima [21](1990) and Curtis, Farman & Frauhofer[7] (1990) reported that radiopacity is determined by the X-ray absorption of the restorative material. In turn, x-ray absorption is determined by the constituents of the material, thickness of the restoration, and amount of the piled tooth material. But Sewerin[30](1980) reported that restorative material must not have less radiopacity than enamel in a class II cavity. According to these studies, the optimal radiopacity of posterior restorative material seems to be slightly higher than that of enamel. El-Mowafy, Brown & McComb[26](1991) reported that Dicor MGC has higher radiopacity than enamel, while Vita Mark II has lower radiopacity than dentin. It was reported that Dicor MGC is much more radiopaque than Vita Mark II that the same luting cement cannot be used. Cook[31](1981) tested a number of assumed factors having influence on radiopacity : radiation generation methods, film types, kVp, amount of radiation absorption. He reported that kVp had a great influence on the radiopacity.

Radiopacity of dental materials are presented as the equivalent thickness of aluminum (mmAl), and the equation Ln D=0.5008-0.1048X (D : Densitometer readings, X : Al thickness) was obtained using the correlation between thickness and optical density of aluminum step wedge measured using densitometer.

A linear or near-linear standard curve was obtained when Ln D was plotted against aluminum thickness. This linear relationship could be explained by applying Lamberts equation : $I = Io \times e^{-\mu x}$ in which I is the intensity of radiation passing through, Io is the intensity of radiation emitted from the X-ray tube, e is the base of natural logarithms, μ is the linear absorption coefficient of the material through which the beam passes, and x is the thickness of the material. In the case of the aluminum step wedge, x is the only variable in the experimental setup, and the relationship between x and I in equation may be transformed to $\log I \propto -x$; that is the logarithm of the intensity of transmitted X-rays is inversely proportional to the thickness of the aluminum step wedge. Changes in the exposure time had no discernible effect on the interpolated aluminum values for the materials.

Radiodensity of a dental restorative material has to be compared with that of enamel, dentin, and other restorative materials for analysis.

The thickness of a material itself is not more important than the molecule structure. However, it still has a great influence on the radiodensity. It is especially important when the image of a material with low radiopacity is overlapped on the image of enamel.

Various radiopacity values are reported from a number of other tests, because of a number of factors such as, film speed, exposure time, voltage, and film development. However, order of radiopacity of the materials remained constant.

In this test, dental x-ray unit was fitted to 70kVp, 7mA, and 2.16mm aluminum filtration. Distance between the target and the film was 25cm. Exposure time was 0.2 seconds.

All materials except Vita Mark II appeared effective in recurrent caries diagnosis because they showed a radiopacity exceeding enamel. Especially, Dicor MGC block can be accepted as an effective posterior restorative material for recurrent caries diagnosis because it showed the radiopacity very similar to enamel.

Materials prepared in two different thickness, 2 mm and 3 mm. Vita Cerec blocks could not be expressed as an equivalent thickness of aluminum in 2 mm samples because it is too radiolucent to be expressed as an equivalent thickness of aluminum. And, generally, the bucco-lingual dimension of inlay in Class II cavities are over than 3mm.

Cerec Vita block should be used with high radiopaque luting cement for recurrent caries diagnosis because of its low radiopacity. Z-100 composite, Duo and Scotchbond resin cement, are considered proper materials for ceramic inlay due to their radiopacity exceeding enamel.

In the future, a lot of clinical studies should be made for the effectiveness of diagnosis, about the methods and various factors having influence on radiopacity.

Ⅴ. Conclusion

This study examined if certain materials have an effective radiopacity for recurrent caries diagnosis. Materials tested were Dicor MGC block, Vita Cerec block being used in Cerec CAD-CAM system, and their luting cements, Duo and Scotchbond resin cement and a hybrid composite resin, Z-100. Radiopacity of each material was measured using a densitometer.

Findings and conclusion made are as follows ;

1. Dicor MGC block showed a radiopacity somewhat exceeding enamel.
2. Vita Cerec block showed a radiopacity lower than that of dentin.
3. Luting materials had radiopacity exceeding enamel, in decreasing order of Duo cement, Z-100, and Scotchbond resin cement.
4. Duo cement, Scotchbond resin cement and Z-100 are thought to be helpful in recurrent caries diagnosis when used with Vita Cerec block.

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논문사진 부도

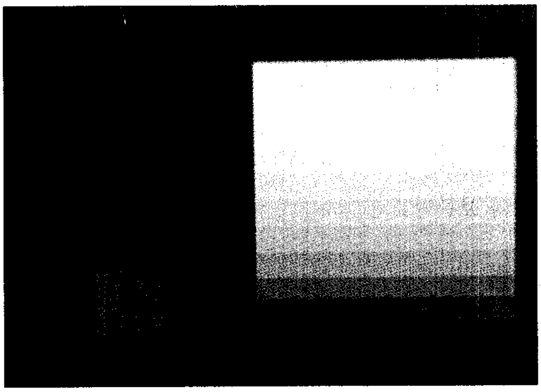

사진 1. Dicor MGC block

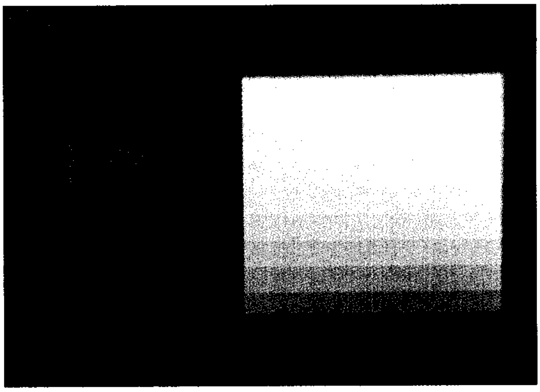

사진 2. Vita Mark II block

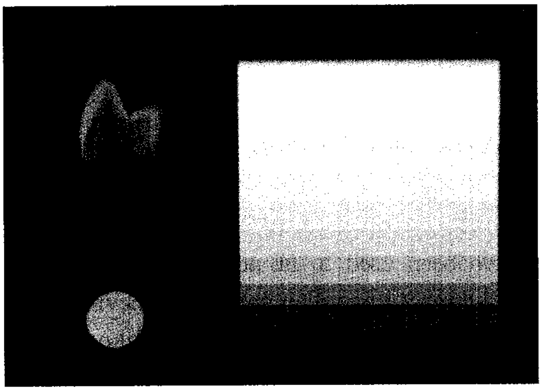

사진 3. Duo cement

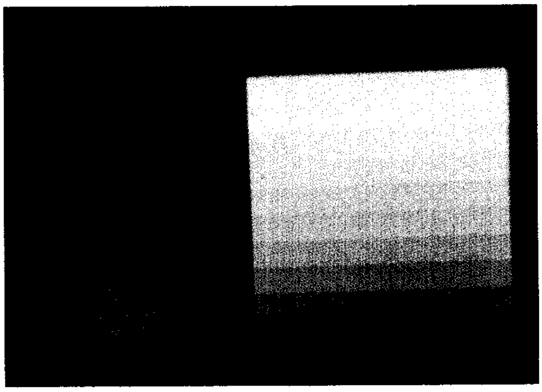

사진 4. Scotchbond resin cement

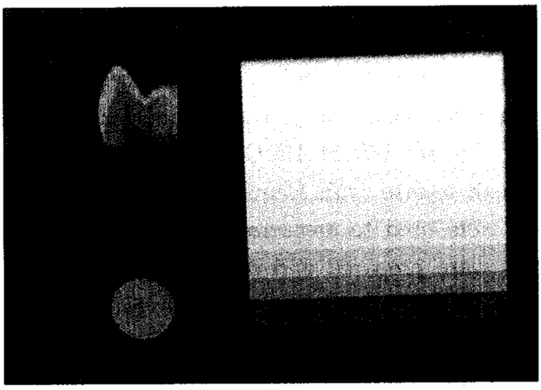

사진 5. Z-100