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금속도재관으로 수복된 Abfraction lesion이 있는 치아에 가해지는 교합력의 응력 분포 분석

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Analysis of stress distribution of tooth restored with metal-ceramic crown covering abfraction lesion according to its finish line location under occlusal load

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Purpose: When the full veneer crown was treated in the tooth with abfraction lesion due to various causes, the prognosis of it may be compromised according to the location of the finish line, but there is few study about the location of its buccal finish line. The purpose of this study was to investigate the effect of location of the finish line of the full veneer crown on stress distribution of the tooth with abfraction lesion. **Materials and methods:** The two dimensional finite element model was developed to express tooth, surrounding tissue and full veneer crown. The stress distribution under eccentric 144 N occlusal load was analyzed using finite element analysis. The location of finish line was set just at the lower border of the lesion (Group 0), 1 mm (Group 1) and 2 mm (Group 2) below the lower border of the lesion. **Results:** In the Group 0, von Mises stress was concentrated at the finish line and the apex of the lesion. Also, the stress at the bucal finish line propagated to the lingual side. In the Group 1 and Group 2, stress distribution was similar each other. Stress was concentrated at the apex of lesion, but the stress at the buccal finish line did not propagate to the lingual side. That implied decrease of the possibility of horizontal crown fracture. **Conclusion:** Full veneer crown alleviated the stress concentrated at the apex of the abfraction lesion, when the finish line of full veneer crown was set below the lower border of abfraction lesion. *(J Korean Acad Prosthodont 2014;52:305-11)*

Key words: Abfraction; Metal-ceramic crown; Finish line; Stress distribution; Finite element analysis

Introduction

Grippo[1] named the unusual non caries cervical lesion (NCCL) as abfraction, derived from the Latin words ab (away) and fractio (breaking). He defined abfraction as the pathological loss of tooth substance caused by biomechanical loading forces.

Many researchers have suggested that tooth deformation could induce NCCL. Lee and Eakle[2] described tensile stress as the primary etiology of the cervical lesion. They also reported that lateral forces on tooth structure can cause bending of the tooth and two types of stress; compressive stress and tensile stress. Because both dentin and enamel have high compressive strength, little or no disruption of the crystalline structure results from compression. However tensile force may cause disruption of chemical bonds of the crystalline structures of enamel and

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dentin. Rees[3] examined the effect of varying position of an occlusal load on stress in the cervical region of a lower second premolar using a two-dimensional plane strain finite element model and he reported that the tensile and shear strains were concentrated in buccal cervical area of teeth during lateral force, and these stresses exceed the reported failure stresses for enamel. There is a gradually increasing body of evidence to suggest that the effects of occlusal loading contribute to the development of abfraction lesions.[4,5]

Grippo[6] suggested the reasons to treat these lesion and proposed composite resin as the first choice of treatment for abfraction lesion. He suggested that it decreases stress concentration. However, Francisconi[4] reported that occlusal loading increased the occurrence of marginal gaps in cervical restorations. When restorative treatment was considered in abfraction lesion, the clinician must consider the etiologic factor contributing to the lesion. If not, there is a risk that the restorative treatment will fail by means of the lesion's reappearing at a more apical level under the margins of the restorations, or by dislocation of the restoration.[4]

Due to the size of the defect or pulp vitality, in some case, the teeth with abfraction needs to be treated with full veneer crowns. When full veneer crowns were considered for the tooth with abfraction, the location of the buccal finish line of the full veneer crown might affect the prognosis of the prosthesis. However, there was no evidence based consensus about the location of the finish line. No study reported the change of stress distribution after the tooth with abfraction lesion was restored with full veneer crown.

The aims of this study were to investigate the effect of the full veneer crown on stress distribution of the tooth with abfraction lesion and whether the location of finish line of the full veneer crown affect the stress distribution or not.

The null hypothesis was established as following.

1. The full veneer crown does not affect the stress distribution of tooth with abfraction lesion.
2. The stress distribution is similar regardless of the location of finish line of full veneer crown.

Fig. 1. 2-dimensional normal tooth geometry.

Fig. 2. Abfraction finite element model.

Materials and methods

Tooth model base

A mandible including lower first premolar of human cadever were sectioned axially in the thickness of 10 mm using the low-speed diamond wheel saw (Isomet, Buehler Co., Lake Bluff, IL, USA). The 10 mm thick slice of the mandible body including the mandibular first premolar was radiographed by use of Micro computerized tomography system (Micro-CT, Skyscan-1072, Skyscan, Aartselaar, Belgium). Series of Micro-CT images were reconstructed to a 3-dimensional image by use of Bionix 3.0 (CANTIBio, Inc., Suwon, Korea). Central buccolingual image (Fig. 1) was selected to develop a 2-demensional finite element model (Fig. 2). The 2-dimensional geometry of tooth and alveolar bone were attained from this image.

Tooth with abfraction lesion

The abfraction lesion is clinically found as a wedge-shaped defect, usually observed below the CEJ (Cemento-Enamel Junction) of a tooth. In the 2-dimensional finite element model, abfraction lesion is represented as a wedge-shaped defect, of which the dimension is 2 mm vertically and 3 mm horizontally (Fig. 3). The abfraction lesion is clin-

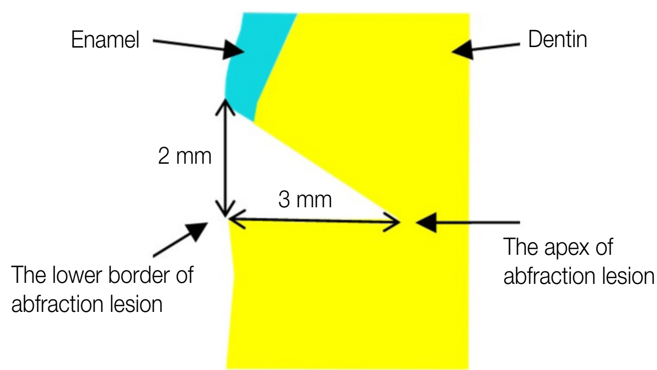

Fig. 3. Dimension of wedge-shaped defect.

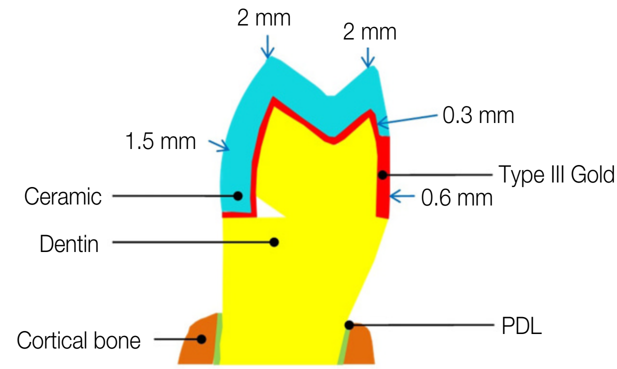

Fig. 4. Minimum recommended dimensions for a metal-ceramic restoration.

ically found as the equilateral triangle shaped defect. However, the lesion is replaced with the right triangle-shaped defect to simplify the relationship of the lower border of defect and the finish line of metal-ceramic crown finish line.

Metal-ceramic crown-restored

The first premolar was prepared according to the conventional method[7] (Fig. 4). The buccal finish line was 1.5 mm shoulder, and the location of the finish line was set just at the lower border of the wedge-shaped defect (Group 0, Fig. 4), 1 mm below the lower border of the wedge-shaped defect (Group 1), and 2 mm below the lower border of the wedge-shaped defect (Group 2). The defect was assumed to be empty.

Material properties and boundary conditions applied

The finite element model was developed on the basis of the 2-dimensional geometry using Hypermesh 7.0 (Altair engineering, Inc., Tokyo, Japan). The alveolar bone and tooth were of 3 dimensions. Rubin *et al.*[8] reported that one would not expect noticeable differences in results with or without the pulp. Therefore, the pulp was assumed as a part of the dentin in our study. The physical property of tooth and surrounding bone was adapted to 2 dimensional finite element model such as Table 1.

The enamel was modeled as an anisotropic material as described by Rees and Jacobsen[9] with a principal elastic modulus EX = 80 GPa and EY = EZ =20 GPa. The principle elastic modulus direction EX was rotated through 180° in 10° increments to model the radial distribution of the enamel prisms that is thought to give rise to its anisotrophic properties. Dentine was modeled as isotropic and

Table 1. Material properties used in the finite element analysis

Materials	Young's Modulus (MPa)	Poisson's ratio	Reference
Enamel	80,000	0.30	Rees[3]
Dentin	15,000	0.31	Rees[3]
PDL	50	0.49	Rees and Jacobsen[14]
Cortical bone	13,800	0.26	Vincent[15]
Cancellous bone	345	0.30	Rees[3]
Type III gold	80,000	0.33	Lewinstein[16]
Ceramic	68,900	0.28	Lewinstein[16]

homogenous material.[10,11] The occlusal load was applied at the buccal cusp of the mandibular first premolar. The amount and angle of occlusal load was 144 N and 45° respectively (Fig. 2). The inferior border of the alveolar bone was rigidly fixed in the X and Y directions. Material properties and boundary condition was applied to each model identically. The ANSYS solver (ANSYS, Inc., Pennsylvania, PA, USA) was employed to perform stress analysis. Von Mises stress was used to compare the stress distribution at the finite element models.

Results

Tooth with abfraction lesion

Fig. 5 represent von Mises stress distribution of 1st premolar with the wedge-shaped defect and surrounding alveolar bone on occlusal load. In the buccal cervical area, the stress level at the apex of the wedge-shaped defect is highest.

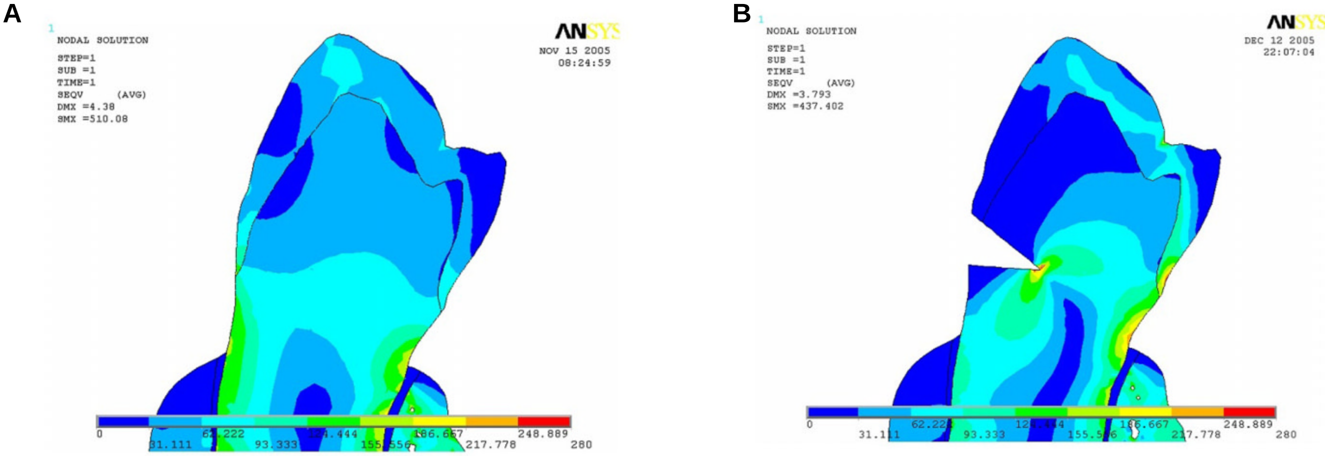

Fig. 5. von Mises stress distribution of normal tooth and the tooth with abfraction lesion. (A) Normal tooth, (B) Tooth with abfraction lesion.

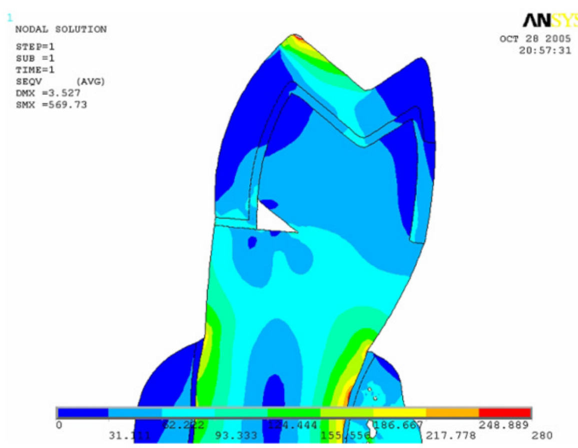

Fig. 6. von Mises stress distribution in the case that the finish line of metal-ceramic crown is set just at the lower border of wedge-shaped defect.

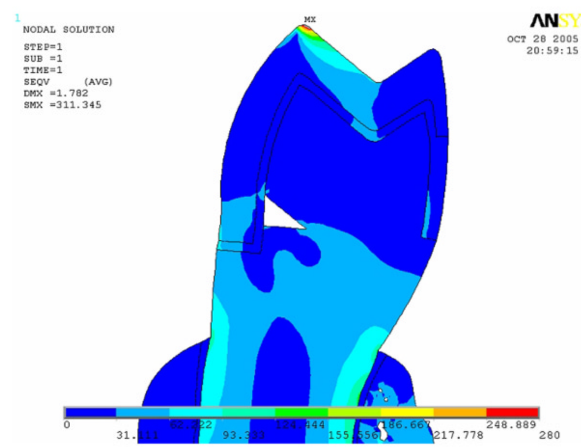

Fig. 7. von Mises stress distribution in the case that the finish line of metal-ceramic crown is set 1 mm below the lower border of wedge-shaped defect.

Metal-ceramic crown restored

Group 0

The finish line of the metal-ceramic crown is set just at the lower border of the wedge-shaped defect (Fig. 6). The stress level at the apex of the abfraction lesion was lower than that at abfraction model (Fig. 5B). However, the stress is concentrated at the apex of the wedge-shaped defect. The stress at the buccal finish line propagated from the lower border of the wedge-shaped defect to the lingual side.

Group 1

The finish line of the metal-ceramic crown is set at 1mm below the lower border of the wedge-shaped defect (Fig. 7). The stress level at the apex of the abfraction lesion was lower than that of Group 0 (Fig. 6). The stress at the buccal finish line does not propagate to the lingual aspect of tooth.

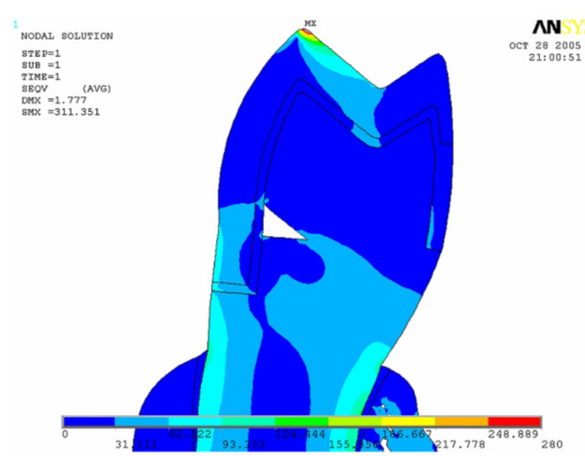

Fig. 8. von Mises stress distribution in the case that the finish line of metal-ceramic crown is set 2 mm below the lower border of wedge-shaped defect.

Group 2

The finish line of the metal-ceramic crown is set at 2 mm below the lower border of the wedge-shaped defect (Fig. 8). The stress distribution pattern is similar to Group 1 (Fig. 7).

Discussion

The present study was attempted to investigate the effect of the location of the finish line of the full veneer crown on stress distribution of the tooth with abfraction lesion. As the oblique occlusal load is applied at the buccal functional cusp of the lower 1st premolar, von Mises stress at the buccal CEJ area is higher than that at the lingual CEJ (Fig. 5). These findings are consistent with other studies.[3,12] Abfraction lesion is commonly found at the buccal side. The buccal cervical area is tensile, whereas the lingual side is compressive. Therefore, the cervical enamel at buccal side is the most vulnerable area to the lateral force in the lower premolar. Ree[3] also reported similar stress distribution pattern.

Stress distribution of the premolar with abfraction lesion is different from that of normal tooth on occlusal load as shown in Fig. 5A. Much stress of occlusal load is concentrated on the apex of the abfraction lesion, which acts as the weak point of the tooth. Since the apex of lesion is points of stress concentration, it could cause pulp involvement through microfracture or ultimately induce complete tooth fracture.[6] This result corresponds with the earlier studies.[4,5] Francisconi *et al.*[4] reported that occlusal loading increased the occurrence of marginal gaps in cervical restorations composed of composite in wedge-shaped defects. Ichim *et al.*[5] investigated the influence of occlusal loading on the mechanical response of cervical glass ionomer restoration using 3-dimensional finite element study, the tensile stresses in the cervical margin of the restoration exceeded the ultimate materials and bond strength.

In some cases, due to the size of the defect or pulp vitality, the tooth needs to be restored with full veneer crown instead of a composite resin restoration. Additionally, abutment for the bridge and endodontically-treated tooth are considered to be indication of full veneer crown. In that case, the buccal margins of full veneer crowns are to be determined, but there is few study about that. In our study, the effect of the location of the buccal finish line of the full veneer crown on stress distribution was examined.

When the finish line of metal-ceramic crown was set just at the lower border of the wedge defect (Group 0), stress level at the apex of the abfraction lesion decreases than that at Fig. 5B. However, the stress was concentrated at the apex of the wedge-shaped defect. The stress propagated from the finish line of the metal-ceramic crown, via the lower border of the wedge-shaped defect and the apex of the wedge-shaped defect continuing to the lingual side. The possibility of crown fracture seems to be still high.

When the finish line is set 1 mm or 2 mm below the lower border of lesion (Group 1, 2), the stress was also concentrated at the apex of the abfraction lesion, but the stress at the apex of the abfraction lesion was lower than that of Group 0. In addition, the stress did not propagate from the buccal finish line to the lingual finish line. Therefore, the possibility of tooth fracture cannot be as high as in the case of Group 0. It is a role such as ferrule that the finish line of metal-ceramic crown is set 1 mm below the lower border of wedge defect.[13]

In this study, the finish line of metal-ceramic crown needs to be below the lower border of the lesion to decrease the possibility of horizontal tooth fracture.

Further studies about the relationship of the finish line of crown and the lower border of abfraction lesion are necessary in the other method such as strain gauge method.

Conclusion

This study aimed to analyze the stress distribution of a normal tooth, tooth with abfraction lesion, and metal-ceramic crown-restored tooth with abfraction lesion under occlusal load. Within the limitation of the study design, the following conclusions may be;

Full veneer crown alleviated the stress concentrated at the apex of the abfraction lesion, when the finish line of full veneer crown was set below the lower border of the abfraction lesion due to the favorable stress distribution.

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금속도재관으로 수복된 Abfraction lesion이 있는 치아에 가해지는 교합력의 응력 분포 분석

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목적: 다양한 원인으로 발생된 Abfraction 병소가 있는 치아를 금속도재관으로 수복 할 경우, 변연의 위치에 따라 예후가 다양해질 수 있다. 수복물의 장기적 성공을 검증하기 위해서는 응력분포의 분석이 필요하지만 금속도재관이 abfraction 병소의 적응증인 경우 금속도재관이 응력 분포에 미치는 영향을 밝히는 연구는 아직 없다. 본 연구의 목적은 abfraction 병소가 있는 치아를 수복하는 금속도재관이 바람직한 응력 분포를 나타낼 수 있는 조건을 알아 보고자 함이다.

재료 및 방법: 치아, 주위 조직과 금속 도재관의 외형을 반영한 2차원 유한 요소모델을 제작하고 144 N의 편심 교합력 하에서의 응력분포를 유한요소 분석법으로 분석하였다. 금속 도재관의 변연 위치를 쐐기모양의 결손부의 하연에(Group 0), 그리고 결손부의 하연보다 1 mm 하방(Group 1)과 2 mm 하방(Group2)에 위치시켰다.

결과: Group 0에서 von Mises stress는 금속 도재관의 변연과 결손부의 첨부에 집중 되었고 협측 변연의 응력은 설측 부위로 분포되었다. Group 1과 Group 2에서의 응력분포양상은 비슷하게 나타났다. 응력은 결손부의 첨부에 집중되지만 협측과 설측의 응력띠는 서로 분리된 양상으로 나타났다.

결론: 금속도재관의 변연을 Abfraction 병소의 하연에 설정할 경우, 금속도재관은 Abfraction 병소의 첨부에 응력을 집중시킨다. *(대한치과보철학회지 2014;52:305-11)*

주요단어: Abfraction; 금속 도재관; 변연; 응력분포; 유한 요소 분석법

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