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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감사의 글

이 논문이 완성되도록 끊임없는 지도와 격려를 보내주신 심준성 교수님께 진심으로 감사드리며, 귀중한 조언과 심사에 도움을 주신 이근우 교수님, 김광만 교수님, 노병덕 교수님, 김한성 교수님께도 깊은 감사를 드립니다. 따뜻한 관심과 조언으로 항상 지켜봐 주신 이호용 교수님, 정문규 교수님, 한동후 교수님, 황선홍 교수님, 배은경 교수님, 이재훈 선생님께도 감사를 드립니다.

본 연구를 위한 실험에 많은 도움을 주신 의용공학부 전산의용 생체공학연구실의 우대곤 선생님께 깊은 감사의 뜻을 전합니다.

곁에서 항상 지켜보며 힘이 되어 준 우진형, 수형, 영아, 민옥, 승진 동기들과 보철과 의국원들에게도 감사의 마음을 전합니다.

끝으로 현재 저의 모습이 되도록 전적인 희생을 감수하시고 지금은 천국에서 저희 식구들을 지켜 주시는 자랑스러운 윤덕근 집사님, 봉사와 희생으로 저희 형제를 길러 주신 어머니와 함께 어려운 시절을 보내며 미래의 영광을 꿈꾸던 형에게 진심으로 감사드리며 저의 조그만 기쁨을 함께 나누고 싶습니다.

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Abstract

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Many studies have showed that occlusal force was concentrated at the apex of abfraction lesion and the lesion could cause enlargement of the lesion, pulp involvement and ultimately tooth fracture if not treated. The choice of treatment for the abfraction lesion was known as composite resin restoration. Full veneer crown was recommended when the abfraction lesion occurred both facial and lingual surfaces or circumferentially. Also, full veneer crown was clinically indicated in the case of endodontically-treated tooth and abutment for bridge.

An analysis of stress distribution was needed to verify the future success of restoration. However, no study showed the effect of the full veneer crown on stress distribution when full veneer crown was the indication of restoration for abfraction lesion.

The purpose of this study was to discover the condition that was absolute to favorable stress distribution at the indication of full veneer crown. The two-dimensional finite element model was developed to express tooth, surrounding tissue and full veneer crown. The stress distribution under occlusal force was analyzed using finite element analysis. The condition includes the buccal finish line of full veneer crown and restoration of wedge-shaped defect. The location of finish line was set just at the lower border of the lesion(experiment 0), 1㎜(experiment 1) and 2㎜(experiment 2) blow the lower border of the lesion. Additionally, the stress distribution was analyzed according to existence of restoration for the lesion.

In the experiment 0, von Mises stress was concentrated at the finish line and the apex of the lesion. Also, the stress band crossed the long axis of the tooth. That meant high possibility of horizontal crown fracture. In the experiment 1 and the experiment 2, stress distribution was similar each other. Stress was concentrated at the apex of lesion, but the buccal stress band and the lingual stress band was separate. That implied decrease of the possibility of horizontal crown fracture. When the tooth with abfraction lesion was restored with full veneer crown after the defect was restored with composite resin, the stress distribution was favorable.

In this study, the finish line of metal-ceramic crown should be set minimally below the lower border of abfraction lesion to prevent horizontal crown fracture. Also, It was recommendable that the wedge-shaped defect was restored with composite resin if though the tooth with the abfraction lesion was restored with full veneer crown.

Keyword : Abfraction, metal-ceramic crown, Finish line, Stress distribution, Finite element analysis

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Ⅰ. Introduction

A. Traditional concept

Non-carious loss of tooth structures is usually observed at cervical area. This loss causes clinically unesthetic results and hypersensitivity to patient. Since it is difficult for clinician to treat the lesion, the lesion is challenge to clinician. Non-carious loss of tooth structure at cervical area had been named as non-carious cervical lesion(NCL, NCCL), which was traditionally explained using concept of erosion, abrasion. The definition of each concept is as following(Levitch, 1994).

Erosion is chemically induced loss of tooth substance, mainly through acid dissolution. Two origins of acid can be divided into extrinsic and intrinsic; extrinsic origin includes diet (e.g. citrus fruits, carbonated soft drinks) and air pollution from some industrial chemical plants and, regurgitation of gastric acids is an example of intrinsic origin. *Abrasion* is pathologic wear of tooth substance through biomechanical frictional process such as improper or excessive tooth brushing, noxious oral habits, that is, biting a pipe stem and fingernails, holding nails between the teeth, and opening bobby pins.

Many clinicians had clinically observed unusual features which was not explained through traditional concepts. The shape of the lesion was wedge-shaped with sharp line angle, the size was deep cervical V-shaped lesions alone, or multiple notches, the loci was only one tooth in a quadrant of the dentition, CEJ or beneath the margin of a prosthetic crown and the lesion was prevalently examined at the maxillary premolar. So, another concept of non-carious cervical lesion was needed.

B. Histological background

Many clinicians have struggled to explain the unusual lesion. Zsigmondy(1894) was known to be the first author to describe as “the loss of dental hard tissue in the cervical region of the tooth is a common clinical occurrence and it as wedge shaped defects affecting the labial surfaces of anterior teeth”(Rees, 2003). Black(1914) analyzed theories on the etiology of dental erosion, but didn’t induce the definite results(Lambert, 1994). Ferrier(1931) referred to etiology of cervical erosion as mystery on the basis of his clinical observation. Since the cervical lesion had been considered only as erosion, it could not be explained clearly.

Kornfeld(1932) observed the wear facets were related to labial cervical erosion. Many researcher began to realize that tooth deformation could induce NCCL. Körber(1962) found elastic deformation at the cervical region was generated by horizontal force. Lehman and Meyer(1966) proved stress to be a etiology of non-carious cervical lesion through photoelastic experimental study. Spranger and Haim(1969) found that the teeth under cyclic load underwent flexural deformation. Hood(1972) discovered that teeth could be bended by lateral occlusal forces which was generated during mastication and bruxism. Spranger, Weber, and Kung(1973) traced past clinical finding and experimental results and proposed the biodynamics that explained the generation of the lesion. McCoy(1982) described that the sufficient stress level could generate the NCCL whether static or cyclic load. Lee and Eakle(1984) described tensile stress as the primary etiology of the cervical lesion. Many clinical finding and experiment revealed that tooth deformation by stress could be a cause of NCCL and established a theory on the unusual NCCL.

C. Generation of new term and theory

Grippo(1991) named the unusual NCCL abfraction, derived from the Latin words *ab*(away) and *fractio*(breaking). He defined abfraction as the pathological loss of hard tissue tooth substance caused by biomechanical loading forces. Burke, Whitehead, and McCaughey(1995) discriminated abfraction from erosion and abrasion as following: lesions occur in teeth subjected to lateral load, yet, adjacent teeth not subject to these forces remain unaffected. Rarely seen on the lingual aspects of teeth, this may occur subgingivally, which would not happen with lesions due to erosion or abrasion. The genesis of abfraction could be explained on the basis on tooth-flexure theory that as the tooth flexes, the tensile stresses generated may cause disruption of the bonds between hydoxyapatite crystals, leading to cracks in the enamel and eventual loss of enamel and the underlying dentin.

D. Treatment modality for the abfraction lesion

Grippo(1992) suggested reasons to treat the lesion and proposed composite resin as the first choice of treatment for NCCL. In addition, he indicated full crowns covering abfraction lesion when it occurred both facial and lingual surfaces, or even circumferentially. Endontically-treated tooth and abutment of bridge are clinically indication of full veneer crown. The stress analysis is needed to estimate the long-term success of the restoration. The successful restoration shows the favorable stress distribution. No study reported the change of stress distribution after the tooth with abfraction lesion was restored with full veneer crown.

E. The purpose of this study

The purpose of this study is 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 and the restoration of the wedge-shaped defect affect the stress distribution or not. There is a gradually increasing body of evidence to suggest that the effects of occlusal loading contribute to the development of abfraction lesions. This evidence comes from various types of stress and strain analysis including strain gauge studies(Nohl, 1999; Chen, 1999; Nohl, 2000), photoelastic stress analysis(Lukas, 1973; Klähn, 1974) and finite element stress analysis(Khera, 1988; Goel, 1990; Goel, 1991; Spears, 1997; Rees, 1997; Rees, 2000). Finite element analysis is superior to the clinical study in that a parameter is readily adjustable under same condition and has been used at many studies about abfraction lesion. This study adopts finite element analysis.

Since the precision of finite element analysis is dependent on exact representation of clinical status, modeling is very important. The geometry of tooth (enamel, dentin, pulp) and alveolar bone (cortical bone, cancellous bone) is needed to make finite element model. Trabecular pattern of cancellous bone is composed of very complex architecture because it adapts itself to the stress environment. Micro computerized tomography (Micro-CT) is most available to present geometry of tooth and alveolar bone, especially cancellous bone.

F. Hypothesis

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.

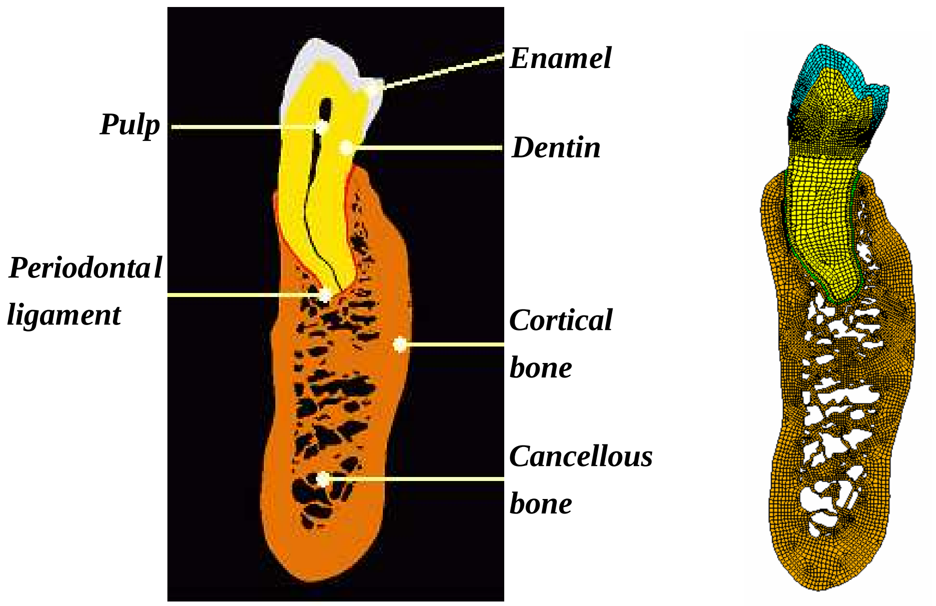
3. Whether the defect is restored with composite resin or not, the stress distribution is not various.

Ⅱ. Material and method

A. Development of finite element models

1. Tooth model base

To develop the FEM model based upon actual geometric dimensions, a human mandible with its tooth present was necessary. Mandibular first premolar and mandible body of human cadever were sectioned axially and in the thickness of 10㎜ using the low-speed diamond wheel saw (Isomet, Buehler Co., Lake Bluff, Illinois, U. S. A). The 10㎜ 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, Belgium). Series of Micro-CT images were reconstructed to a 3-dimensional image by use of Bionix 3.0 (CANTIBio, Inc., Suwon, Korea). Central bucco-lingual image was selected to develop a 2-demensional FEM model. The 2-dimensional geometry of tooth and alveolar bone were attained from this image (Figure 1-(a)). Buccal bone plate of mandible was resorbed, and the buccal cortical bone was added by use of graphical technology.



(a) (b)

Figure 1. (a)2-dimensional normal tooth geometry and (b)finite element model.

2. 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㎜ vertically and 3㎜ horizontally (Figure 2). The abfraction lesion is clinically 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.

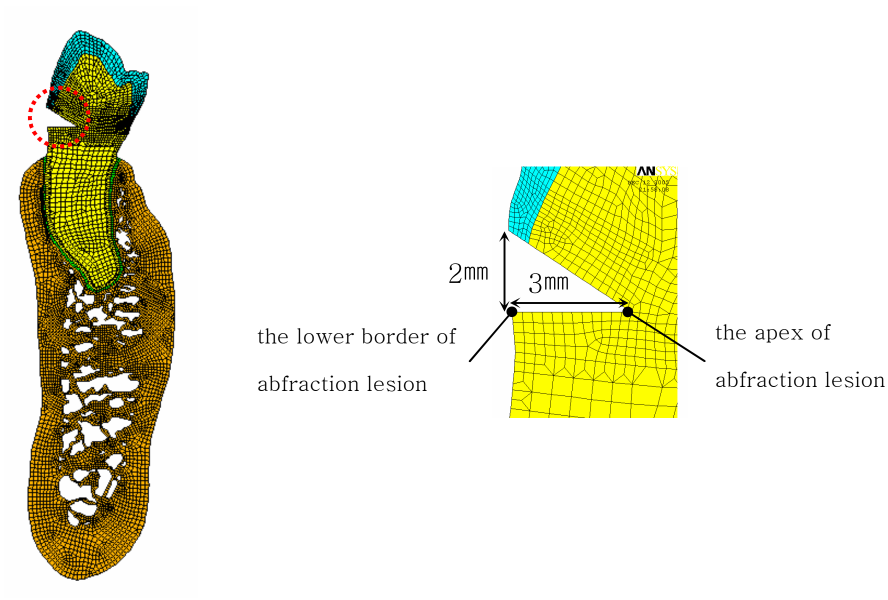


Figure 2. Abfraction model and dimension of wedge-shaped defect.

3. Metal-ceramic crown-restored, defect left

The full veneer metal-ceramic crown is the restoration which veneers occlusal and axial surfaces of the tooth. The reduction of tooth is necessary for restoration and longevity, which demands an adequate dimension. The first premolar was prepared 2㎜ deep at the buccal cusp, 2 ㎜ deep at the lingual cusp, 1.5 ㎜ deep at the buccal surface(Figure 3; Rosenstiel, 2001). The buccal finish line was 1.5 ㎜ shoulder, and the location of the finish line was set just at the lower border of the wedge-shaped defect (experiment 0, Figure 4-(b)), 1㎜ below the lower border of the wedge-shaped defect (experiment 1, Figure 4-(c)), and 2㎜ below the lower border of the wedge-shaped defect (experiment 2, Figure 4-(d)). The defect was assumed to be empty.

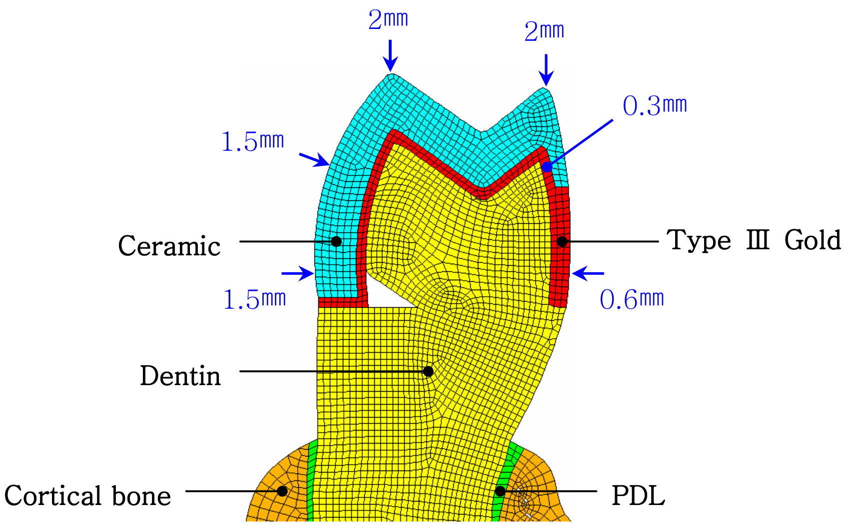
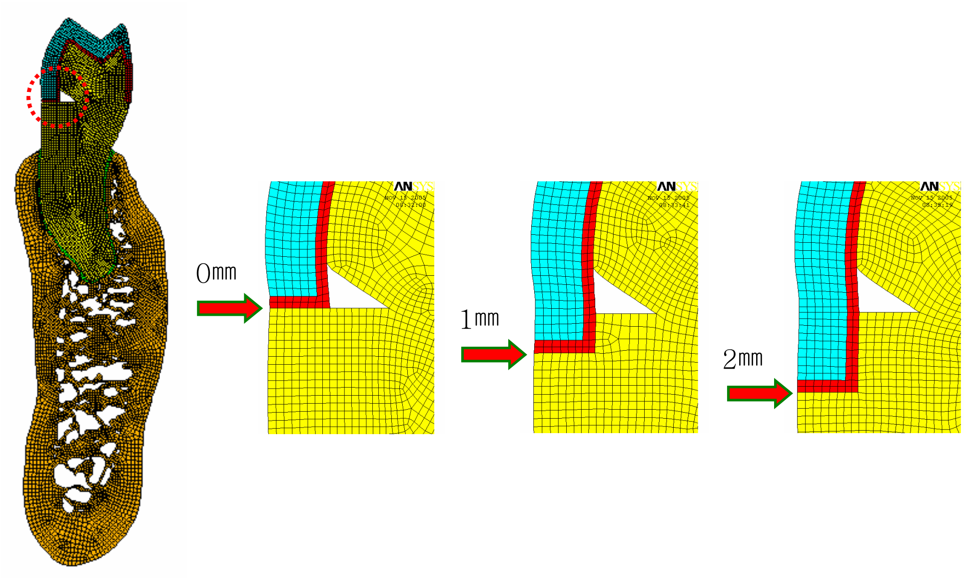


Figure 3. Minimum recommended dimensions for a metal-ceramic restoration.



(a) (b) experiment 0 (c) experiment 1 (d) experiment 2

Figure 4. (a) Metal-ceramic crown-restored tooth model and (b,c,d) location of metal-ceramic crown finish line.

4. Metal-ceramic crown-restored, composite resin filled

The metal-ceramic crown was modeled such as chapter 3 after the wedge-shaped defect was restored with the composite resin (Figure 5). The bonding between the dentin and the composite resin was assumed to be complete.

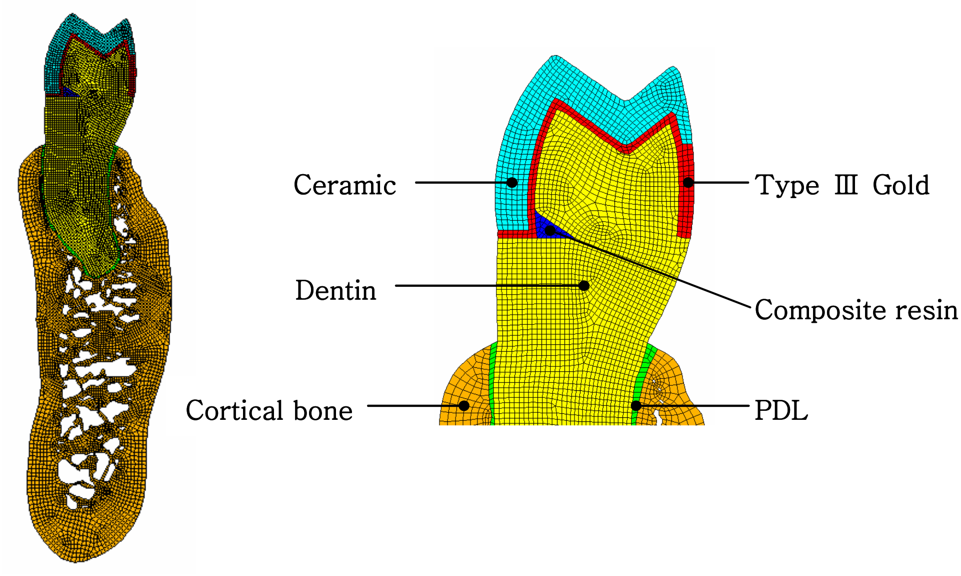


Figure 5. Composite resin and metal-ceramic crown-restored tooth model.

5. 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.). The alveolar bone and tooth were of 3 dimensions. The following assumptions were necessary to analyze the 3-dimensional model in a 2 dimensional model.

Assumption 1. A middle image of axial Micro-CT images was used for the geometry of tooth (enamel, dentin), periodontal ligament and alveolar bone(cortical bone, cancellous bone).

Assumption 2. The used plane elements used were assumed as a state of plane strain.

Assumption 3. The bottom of the mandible was assumed to be bound.

The enamel was modeled as an anisotropic material as described by Rees and Jacobsen(1995) with a principal elastic modulus E_X =80GPa and $E_Y = E_Z$ =20GPa. The principle elastic modulus direction E_X 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 an isotropic and homogenous material because their anisotropy belongs to a microscopic scale whereas the tooth model is macroscopic (Darendeliler et al.,1998; Versluis et al., 1996). The pulp is assumed as a part of the dentin based on the finding by Chon et al.(2005) where the 2-dimensional FEM excluding the pulp represented a similar result to the 3-dimensional FEM. The physical property of tooth and surrounding bone was adapted to 2 dimensional finite element model such as Table 1. The occlusal load was applied at the buccal cusp of the mandibular first premolar. The amount and angle of occlusal load was 144N and 45° respectively (Figure 6). The inferior border of the alveolar bone was rigidly fixed in the X and Y directions.

Figure 6. Occlusal force condition.

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 and Jacobsen(1993)
Dentin	15,000	0.31	Rees and Jacobsen(1993)
PDL	50	0.49	Rees and Jacobsen(1997)
Cortical bone	13,800	0.26	Vincent(1992)
Cancellous bone	345	0.30	Wilson(1991)
Type Ⅲ gold	80,000	0.33	Lewinstein(1995)
Ceramic	68,900	0.28	Lewinstein(1995)
Composite resin	7,000	0.2	Craig(1989)

B. Two-dimensional finite element analysis

Material properties and boundary condition was applied to each model identically. The ANSYS (ANSYS, Inc.) solver was employed to perform stress analysis. Von Mises stress was used to compare the stress distribution at the finite element models.

Ⅲ. Results

1. Tooth model base

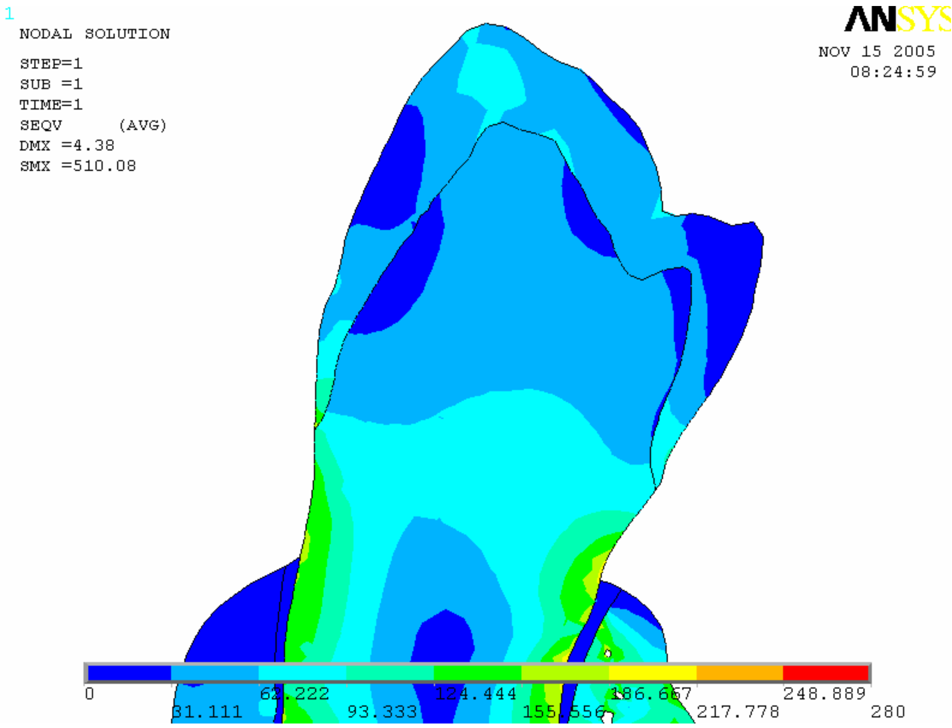


Figure 7. von Mises stress distribution of the normal tooth.

Figure 7 represents von Mises stress distribution of normal 1st premolar and surrounding alveolar bone on occlusal load. The cervical area of premolar is of the higher stress level than the other area else. Especially, the stress level of buccal CEJ area is higher than that of lingual CEJ area.

2. Tooth with abfraction lesion

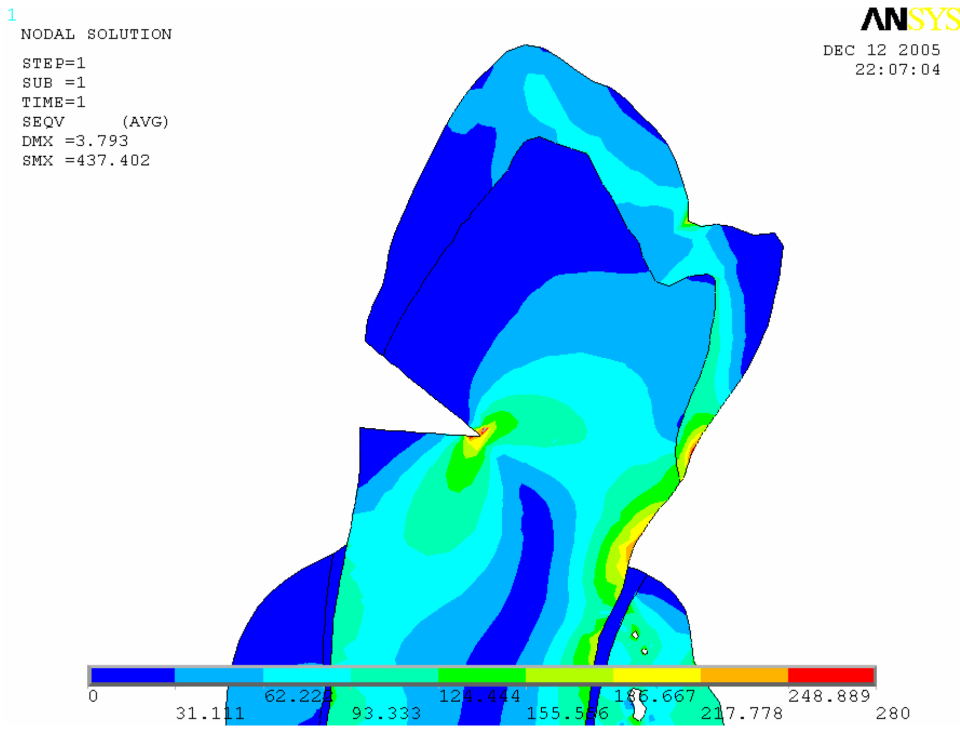


Figure 8. von Mises stress distribution of the tooth with abfraction lesion.

Figure 8 represents von Mises stress distribution of 1st premolar with the wedge-shaped defect and surrounding alveolar bone on occlusal load. At the cervical area of the lingual side, the stress level shows similar result such as the environment of a normal tooth. However, at the buccal cervical area, the stress level at the apex of the wedge-shaped defect is highest.

3. Metal-ceramic crown-restored, defect left

3.1 Experiment 0

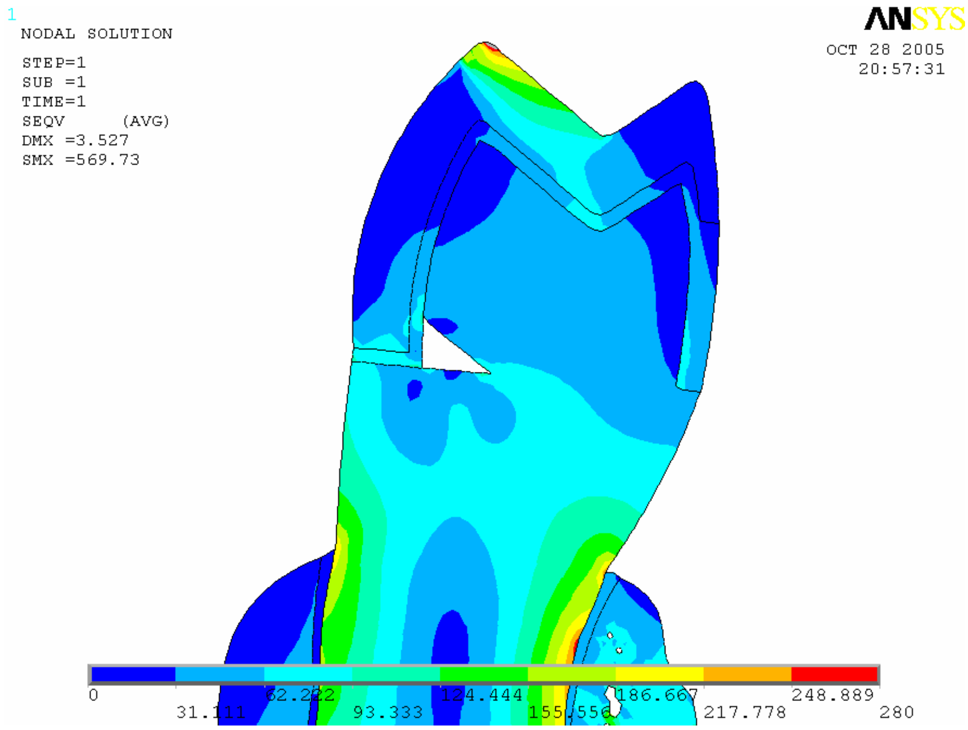


Figure 9. von Mises stress distribution in the case that the finish line of metal-ceramic crown is set just at the lower border of wedge-shaped defect.

Figure 9 represents von Mises stress distribution of the metal-ceramic crown-restored 1st premolar with abfraction lesion and surrounding alveolar bone on occlusal load. The finish line of the metal-ceramic crown is set just at the lower border of the wedge-shaped defect. The stress level at the apex of the abfraction lesion decreases than that at abfraction model (chapter 3.2). However, the stress is concentrated at the apex of the wedge-shaped defect. The stress band ( ) distributes from the lower border of the wedge-shaped defect, the finish line of the metal-ceramic crown and the apex of the wedge-shaped defect continuing to the lingual side.

3.2 Experiment 1

Figure 10 represents von Mises stress distribution of the metal-ceramic crown-restored 1^{st} premolar with abfraction lesion and surrounding alveolar bone on occlusal load. The finish line of the metal-ceramic crown is set at 1mm below the lower border of the wedge-shaped defect. The stress level at the apex of the abfraction lesion decreases than experiment 0. The stress band ( ) distributes at the buccal aspect of the metal-ceramic crown and 1^{st} premolar, whereas the lingual aspect of the 1^{st} premolar is independent. That is, the finish line of metal-ceramic crown does not link the stress on both buccal and lingual stress band.

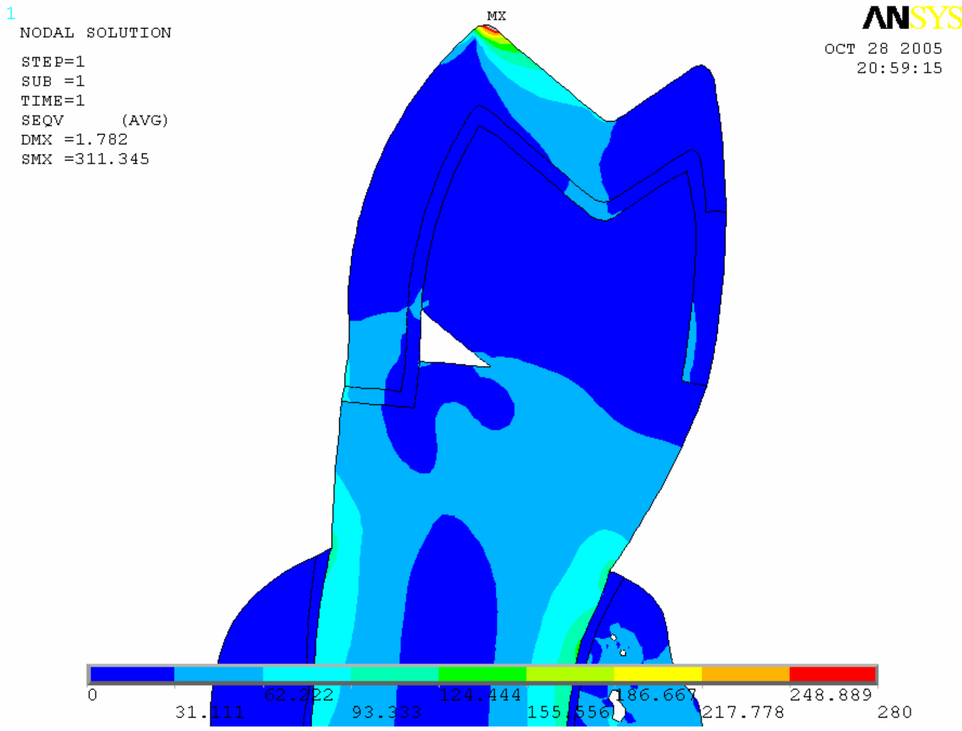


Figure 10. von Mises stress distribution in the case that the finish line of metal-ceramic crown is set 1㎜ below the lower border of wedge-shaped defect.

3.3 Experiment 2

Figure 11 represents von Mises stress distribution of the metal-ceramic crown-restored 1st premolar with abfraction lesion and surrounding alveolar bone on occlusal load. The finish line of the metal-ceramic crown is set at 2mm below the lower border of the wedge-shaped defect. The stress distribution pattern is similar to experiment 1.

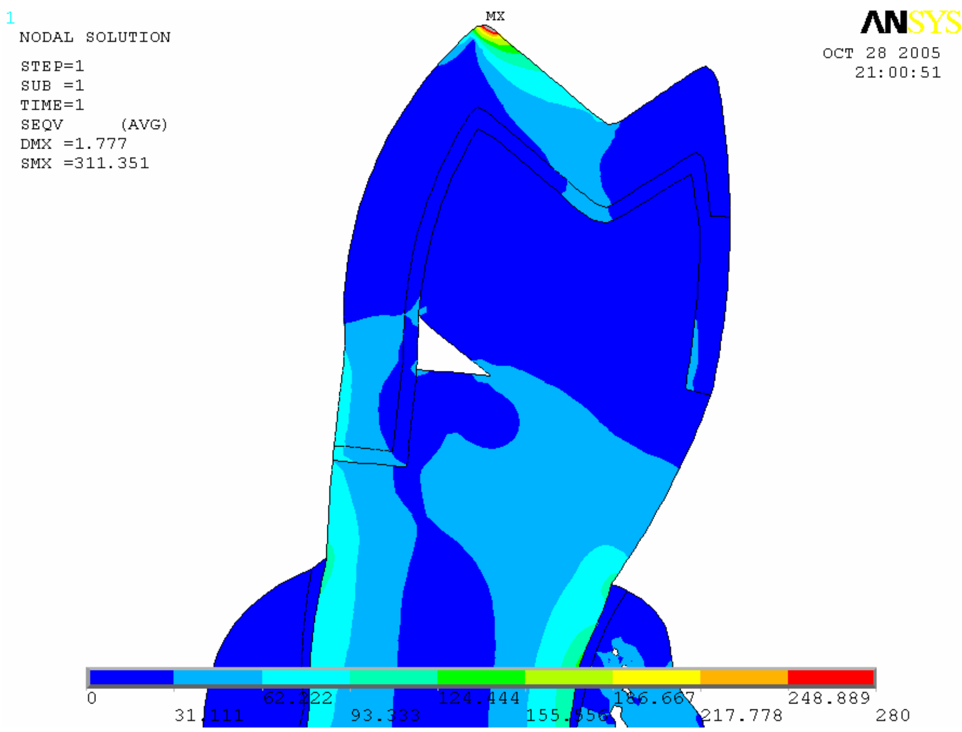


Figure 11. von Mises stress distribution in the case that the finish line of metal-ceramic crown is set 2㎜ below the lower border of wedge-shaped defect.

4. Metal-ceramic crown-restored, composite resin filled

Figure 12 represent von Mises stress distribution in the case that metal-ceramic crown was modeled after the wedge-shaped defect was restored with the composite resin. The stress is not concentrated at the lower border and the apex of the abfraction lesion. The stress distribution pattern is similar to the normal tooth model (chapter 3.1)

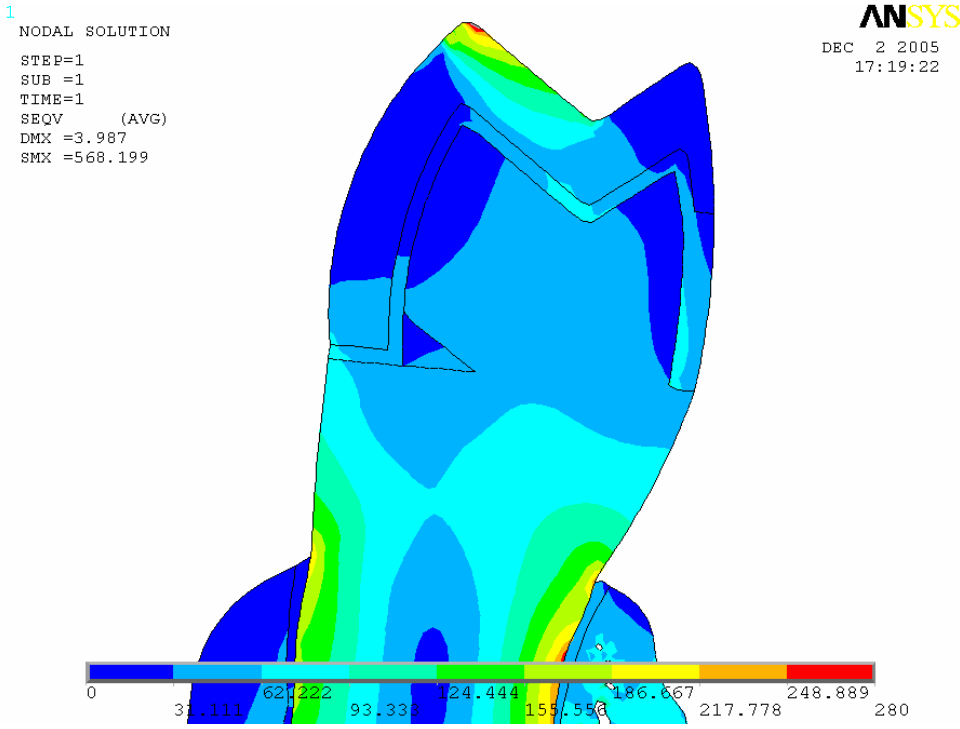


Figure 12. von Mises stress distribution in the case that metal-ceramic crown was modeled after the wedge-shaped defect was restored with the composite resin.

IV. Discussion

Some assumptions were made in order to simplify the calculations. Absolute bonding was considered among enamel, dentin, composite resin and metal-ceramic crown. The enamel was modeled as an anisotropic material as described by Rees and Jacobsen(1995) with a principal elastic modulus E_X =80GPa and $E_Y = E_Z$ =20GPa. Despite its intrinsic anisotropic nature, dentin can be assumed as homogeneous and isotropic (Darendeliler et al.,1998; Versluis et al., 1996) since their anisotropy belongs to a microscopic scale whereas the tooth model is macroscopic. Furthermore, all materials were considered elastic throughout the entire deformation, a reasonable assumption for brittle materials in non-failure condition(Rees et al.,1995). The pulp chamber was modeled as a part of the dentine because Chon et al.(2005) showed that the 2-dimensional FEM excluding the pulp represented a similar result to a 3-dimensional FEM.

The functional cusp of the lower 1st premolar is a buccal cusp. As the occlusal load is applied at the buccal cusp of the lower 1st premolar, von Mises stress is highest at the cervical area as in Figure 7. Especially, von Mises stress at the buccal CEJ area is higher than that at the opposite side. Abfraction lesion is commonly found at the buccal side. The buccal cervical area is tensile, whereas the lingual side is compressive. Therefore, thin cervical enamel at buccal side is weak to tensile force.

Stress distribution of the premolar with abfraction lesion is different from that of normal tooth on occlusal load as shown in Figure 8. At the lingual side, premolar with wedge-shaped defect and normal tooth show similar stress distribution patterns. On the other side, stress around buccal alveolar bone crest decreases and a lot of stress concentrates on the apex of defect. Much stress of occlusal load is concentrated on the apex of 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 (Grippo, 1992).

As the lesion increases, the apex of lesion approximates the pulp. A cascade of inflammatory reaction can occur in the pulp. 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. The relationship between the finish line of the metal-ceramic crown and wedge defect changes the stress distribution of the metal-ceramic crown and abutment tooth under occlusal load as shown in Figure 9, Figure10 and Figure 11. In the case where the finish line of metal-ceramic crown is set just at the lower border of the wedge defect(experiment 0), stress level at the apex of the abfraction lesion decreases than that at figure 10. However, the stress is concentrated at the apex of the wedge-shaped defect. The stress distributes from the finish line of the metal-ceramic crown, 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 is still high as compared with the abfraction model.

When the finish line is set 1㎜ below the lower border of lesion(experiment 1), buccal stress band and lingual stress band are separate. Stress concentrates at the apex of the lesion, but not at the finish line of the metal-ceramic crown. The stress around the finish line of the metal-ceramic crown is transmitted to the buccal side of the root, but neither the apex of lesion nor lingual cervical area are affected. The possibility of tooth fracture can not be as high as in the case of experiment 0.

In a situation where the finish line of metal-ceramic crown is set 2㎜ below the lower border of defect(experiment 2), the stress distribution is similar to that of experiment 1. Although the finish line of metal-ceramic crown in experiment 2 is extended 1㎜ lower than that in experiment 1, the results are similar. It is a role such as *ferrule* that the finish line of metal-ceramic crown is set 1㎜ below the lower border of wedge defect. In this study, the minimal finish line of metal-ceramic crown needs 1㎜ to decrease the possibility of horizontal tooth fracture.

Clinically, the lower border of abfraction lesion is found at equi-gingival or subgingival level. In general, abfraction lesion is not found commonly at the periodontally-compromised tooth. Usually, it is difficult for the finish line of crown to be set low enough to cover the abfraction lesion because of the encroachment on biological width.

In the figure 12, the premolar with the abfraction lesion was restored with metal-ceramic crown after the wedge-shaped defect was restored with the composite resin. The stress is not concentrated at finish line of full veneer crown, and especially, the apex of the abfraction lesion. The stress distribution pattern is similar to that of the normal tooth model. It was assumed that bonding between composite resin, dentin and type Ⅲ gold was complete. The bonding between the dentin, the composite resin and type Ⅲ gold was assumed to be complete. Shear bonding strength between the metal-ceramic crown and cement is at least 10 ㎫ (Piwowarczyk,2004) and microtensile bonding strength between the composite resin and dentin are 53.1㎫(Tay,2004). Also, resin bonding strength decreases over time (De Munck,2005). When the wedge-shaped defect is restored with composite resin, the stress distribution is similar to that of the normal tooth model. That means the possibility of crown fracture is low. When the defect size is large, it is recommendable to restore the abutment with full veneer crown after the defect is restored with composite resin. However, the dentin bonding is not complete.

Many studies many studies about the *ferrule* size have been accomplished in case of endodontally-treated tooth. Also in case of tooth with abfraction lesion, a great number of studies about composite resin restoration have been accomplished. Further studies about the relationship of the finish line of crown and the lower border of abfraction lesion are thought to be required in the other method such as strain gauge method.

Conclusion

The effect of full veneer crown on the stress distribution has not been studied yet. 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. The finite element model was developed using Micro-CT image and the variables were established as the location of finish line of full veneer crown and restoration of the abfraction lesion. The change of stress distribution was analyzed adopting finite element analysis.

Within the limitation of the study design, the following conclusions may be drawn:

1. Full veneer crown alleviated the stress concentrated at the apex of the abfraction lesion
2. It is suitable the finish line of full veneer crown was set below the lower border of the abfraction lesion due to the favorable stress distribution.

3. It is recommendable that the wedge-shaped defect is restored with composite resin if though the tooth with the abfraction lesion is restored with full veneer crown.

Since the abfraction lesion is found clinically at equi-gingival or subgingival level and not commonly at the periodontally-compromised teeth, the biological width should be taken into consideration to be violated. 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.

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Abstract in Korean

금속도재관으로 수복된 Abfraction lesion이 있는 치아에 가해지는 교합력의 응력 분포 분석

치관의 굴곡으로 발생된 abfraction 병소에 집중된 응력은 병소의 진행과 치수 노출이 유발시키고 결과적으로 치관을 파절시킬 수 있다. 복합레진은 abfraction 병소의 치료 방법으로 가장 먼저 고려되지만 협설측 또는 치아 주위에 발생한 병소에서는 전장관이 추천되었다. 임상적으로 볼 때 근관치료를 받은 치아나 bridge의 지대치도 전장관의 적응증이 될 수 있다.

수복물의 장기적 성공을 검증하기 위해서는 응력분포의 분석이 필요하다. 하지만 전장관이 abfraction 병소의 적응증인 경우 전장관이 응력 분포에 미치는 영향을 밝히는 연구는 아직 없다.

본 연구의 목적은 abfraction 병소가 있는 치아를 수복하는 전장관이 바람직한 응력 분포를 나타낼 수 있는 조건을 알아 보고자 함이다. 치아, 주위조직과 금속도재관의 외형을 반영한 2차원 유한요소모델을 제작하고 교합력 하에서의 응력분포를 유한요소분석법으로 분석하였다. 전장관의 finish line 위치와 결손부의 수복 여

부를 변수로 설정하였다. 금속도재관의 협측 finish line 위치를 쐐기모양의 결손부의 하연에(실험 0), 그리고 결손부의 하연보다 1㎜ 하방(실험 1)과 2㎜ 하방(실험 2)에 위치시켰다. 또한 결손부의 수복 여부에 따른 응력분포를 분석하였다.

실험 0에서 von Mises stress는 금속도재관의 finish line과 결손부의 첨부에 집중되었고 응력띠는 치아 장축을 가로지르는 양상을 보였다. 이는 수평치관파절의 가능성을 시사한다. 실험 1과 실험 2에서의 응력분포양상은 비슷하게 나타났다. 응력은 결손부의 첨부에 집중되지만 협측과 설측의 응력띠는 서로 분리된 양상으로 나타났다. 이는 수평치관파절 가능성의 감소를 의미한다. 결손부를 복합레진으로 충전한 후 금속도재관으로 수복한 경우의 응력분포는 수평치관파절의 가능성이 감소하는 경향을 보였다.

본 연구에서 치관 파절의 예방을 위해 전장관의 finish line은 abfraction 병소의 하연보다 하방에 설정하여야 하고 금속도재관으로 수복할 경우일지라도 결손부를 복합레진으로 충전하는 것이 추천된다.

핵심되는 말 : Abfraction, 금속도재관, Finish line, 응력분포, 유한요소분석법