Effects of occlusal load on the stress distribution of four cavity configurations of noncarious cervical lesions: A three-dimensional finite element analysis study

Sang-Je Jeon[1], Jeong-Kil Park[1], Hyeon-Cheol Kim[1], Sung-Gwan Woo[2],
Kwang-Hoon Kim[2], Kwon Son[2], Bock Hur[1]*

[1]Department of Conservative dentistry, College of Dentistry, Pusan National University
[2]Department of Mechanical design engineering, College of Engineering, Pusan National University

ABSTRACT

The objective of this study was to investigate the effect of excessive occlusal loading on stress distribution on four type of cervical lesion, using a three dimensional finite element analysis (3D FEA).

The extracted maxillary second premolar was scanned serially with Micro-CT. The 3D images were processed by 3D-DOCTOR. ANSYS was used to mesh and analyze 3D FE model. Four different lesion configurations representative of the various types observed clinically for teeth were studied. A static point load of 500N was applied to the buccal and lingual cusp (Load A and B). The principal stresses in lesion apex, and vertical sectioned margin of cervical wall were analyzed.

The results were as follows

1. The patterns of stress distribution were similar but the magnitude was different in four types of lesion.
2. The peak stress was observed at mesial corner and also stresses concentrated at lesion apex.
3. The compressive stress under load A and the tensile stress under load B were dominant stress.
4. Under the load, lesion can be increased and harmful to tooth structure unless restored. 〔J Kor Acad Cons Dent 31(5):359-370, 2006〕

Key words: Cervical lesion, Finite element analysis, Occlusal load, Stress distribution, Compressive stress, Tensile stress

** Corresponding Author: **Bock Hur***

Department of Conservative Dentistry
College of Dentistry, Pusan National University,
1-10, Ami-dong, Seo-gu, Busan, 602-739, Korea
Tel: 82-51-240-7455
E-mail: bhur@pusan.ac.kr

Ⅰ. INTRODUCTION

Noncarious cervical lesions (NCCLs), characterized by the loss of dental hard tissue at the cemento-enamel junction (CEJ) in the absence of caries, are conditions commonly encountered in dental practice[1]. These defects can occur on facial, lingual and/or interproximal surfaces.

Traditionally, this has been assumed to be due to the effect of abrasion and/or erosion[1-6]. More recently, an additional mechanism for cervical tooth loss that links with occlusal loading has been proposed[2,3,5,7].

There is some clinical evidence for the association of abfraction lesions with heavy occlusal loads. There is also a marked association of these lesions with bruxism. For example, Bradley et al.[2] evaluated 103 teeth with NCCLs in 32 subjects and found that 15 teeth did not have toothbrush abrasion or chemical erosion. They suggested that although the presence of wedge-shaped NCCLs did not correspond with the dimensions of occlusal wear facet, many subjects did relate a history of bruxism; their dentitions frequently contained prematurities in centric occlusion, interferences in lateral excursions or both.

Radentz et al.[8] also reported that angular wedge shape defects were observed more commonly than the rounded varieties. The defects were also observed more commonly on anterior teeth and premolars, possibly because these smaller teeth are more fragile to the applied occlusal load. These lesions were rarely found on the lingual surface of teeth and one recent study reported that only 2% of cervical lesions were found lingually[9]. This study also reported a strong relation between cervical lesions and occlusal tooth wear or occlusal erosion, having a cervical lesion and the evidence of occlusal pathology in 96% of teeth

NCCLs are present in a variety of forms. They vary from shallow groove to broad dish-out lesions to notch-shaped defects. The floor of the lesion may range in shape from flat to round or sharply angled. Levitch et al.[10] suggested types commonly observed include simple flat-floored grooves, defects that are C-shaped in cross-section with round floors undercut defects with a flat cervical wall and a semicircular occlusal wall, as well as typical V-shaped grooves with oblique walls that intersect axially. There are some opinions[1,4,10-12] about correlation of NCCL formation and cavity shape. In general, erosion has saucer cavity form, abfraction notch shape cavity, abrasion combined shape (occlusal is notch, gingival is saucer) and

in dental clinic, U-shape cavity is also found. Therefore, NCCL configurations can be found in an oral cavity are four types.

Kuroe et al.[13] suggested that, regardless of lesion shape, stress developed at the apex of an unrestored cervical lesion was higher than any other portion of the tooth when the cusp located above the lesion was loaded. There were some differences between the notch-shape and saucer-shape lesions in terms of stress distribution. The notch-shape lesion had a sharp line angle at the apex of the lesion, and location with the highest stress concentration corresponded with the sharpest geometric discontinuity. For the saucer-shape lesion did not have a sharp angle, a somewhat less severe concentration of stress occurred. Therefore, the severity of geometric discontinuity of NCCL can be expected to have strong influence on the development of internal stress in the tooth[13]. These types of stress concentration may contribute to fatigue of tooth structure and accelerate the progression of abfraction[14]. Also, the processes of abrasion and erosion may advance more rapidly on damaged tooth structure[8,13]. Therefore, once a cervical lesion is formed, regardless of its main etiology, occlusal load-induced stresses may have greater influence on the progression of the NCCLs in combination with other factors. For cervical lesions act as stress concentrators, NCCLs, especially abfraction lesions, may become larger if not restored[13].

In vitro dental stress studies of NCCLs generally have employed two methods; photoelastic stress models and finite element (FE) analysis. In photoelastic models, the weakness lies in the complex analysis of quantitative measurements using a three-dimensional (3D) model and that can not fully reproduce the properties of original structure[15]. Kuroe et al.[13] proposed that effects of cervical tooth structure lesions on stress distribution within tooth with photoelastic investigation. Rees et al.[16] examined the effect of cuspal flexure on a buccal Class V restoration using two-dimensional FE analysis. It is hard to find the report about the effect of occlusal loading on stress distribution upon different types of cervical lesions,

using a 3D FE analysis.

The purpose of this study was to investigate the stress analysis of four shapes of NCCLs using a 3D FE analysis.

II. MATERIALS AND METHODS

FE model

For developing a 3D FE model, an intact normal extracted human maxillary second premolar was selected in this study. The premolar was scanned serially with Micro-CT (SkyScan1072; Skyscan, Aartselaar, Belgium) to exposure the tooth sections perpendicular to the long axis of the tooth (58 ㎛ in thickness) and parallel to the occlusal plane. 3D-DOCTOR (Able Software Co., Lexington, MA, USA) image processing software was employed to detect the boundaries of enamel, dentin and pulp from the sectioned two dimensional images and to make 3D surface model. Rhino 3D (Robert McNeel & Assoc., Seattle, WA, USA) was used to reduce useless nodes from the surface model and ANSYS (Swanson Analysis System. Inc., Houston, USA) to mesh and analyze 3D FE model.

For clinically observed representative lesion configurations of various types were studied. The characteristics of the lesions are described below and shown in Figure 1.
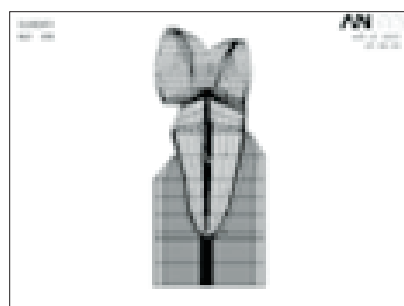
1. Notch-shape lesion: there is a sharp line angle at the bottom of the lesion.
2. Saucer-shape lesion: the lesion is enlarged occlusally relative to the notch, and there is no sharp line angle.
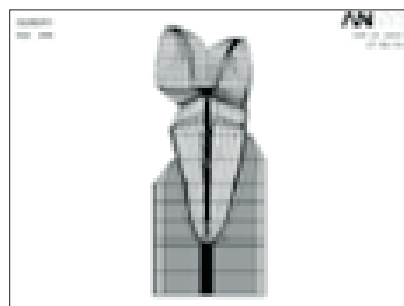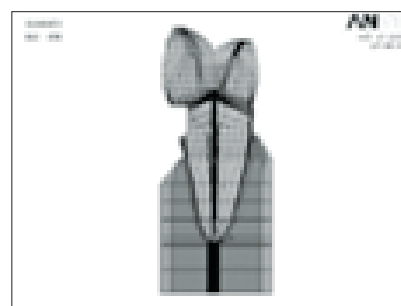
1. Notch-shape
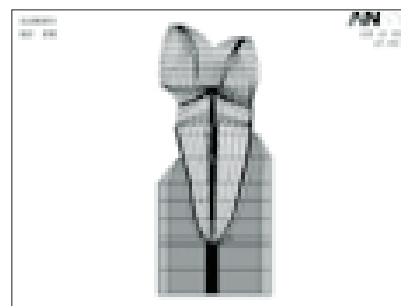
2. Saucer-shape

3. Combined shape

4. U-shape

**Figure 1.** Four types of lesion configurations.

Table 1. Numbers of nodes and elements for each cavity

Model	Notch	Saucer	Combined	U
Node	18245	18236	18434	18709
Element	16668	16668	16780	17056

Table 2. Mechanical properties of the tooth used in the study

Materials	Mechanical properties Young's modulus (MPa)	Poisson's ratio (ν)
Enamel	84000 [a]	0.33 [a]
Dentin	18000 [a]	0.31 [a]
Periodontal ligament	0.667 [b]	0.49 [b]
Cancellous bone	13700 [b]	0.38 [b]
Cortical bone	34000 [b]	0.26 [b]

[a]: Katona *et al.*[20], [b]: Geramy *et al.*[21]
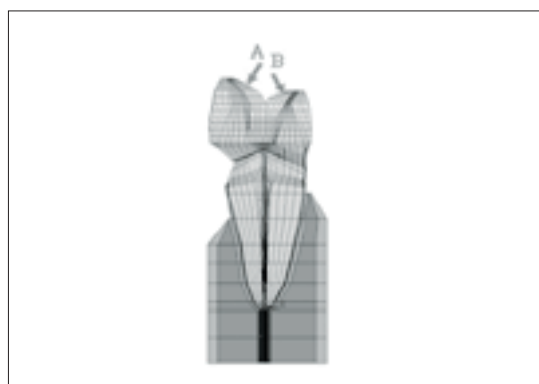
Figure 2. Design of loading conditions.

3. Combined shape lesion: the occlusal surface is similar to notch shape and cervical surface is similar to saucer-shape.
4. U-shape lesion: box-shape lesion.

The table 1 shows nodes and elements of each model. All the vital tissues were presumed linearly elastic, homogeneous and isotropic. The corresponding elastic properties such as Young's modulus and Poisson's ratio were determined according to literatures[20,21] (Table 2). The periodontal ligament was assumed to be 0.3 ㎜ wide, and the dimensions of surrounding compact and cancellous bone were derived from standard texts[17,18]. The

Table 3. Mechanical properties of teeth (MPa)*

Compressive strength of enamel	277 - 384
Compressive strength of dentin	249 - 347
Tensile strength of enamel	10 - 24
Tensile strength of dentin	32 - 103
Tensile strength of DEJ	52

*: Litonjua *et al.*[15]

alveolar bone was also modeled by growing the outer surface of the tooth model from 2 ㎜ below CEJ[17,18]. The pulp region was modeled as a hollow[19]. In these models, the alveolar bone model was fixed in order to prevent rigid body motion for FE analysis.

Loading conditions

A static load of 500 N was applied to all cavities for the following loading conditions (Figure 2). Load A: Perpendicular loading on the upper third of palatal slope of the buccal cusp. Load B: Perpendicular loading on the upper third of buccal slope of the palatal cusp.

Stress Analysis

The principal stresses were analyzed in the lesion apex by ANSYS. After that shear stress was set to be 0, normal stress was set to be S1, S2 and S3. And then, S1 was appointed as maximum principal stress and S3 as minimum principal stress. The data of compressive strength and tensile strength of enamel and dentin are cited from the report of Litonjua *et al.*[15]. The limit properties as the condition of failure used in this study were as following table 3.

Ⅲ. RESULTS

Principal stress

Buccal cervical stress contours on the tooth surface in response to a static point 500 N load are shown in Figure 3. The patterns of stress distribution were similar but the magnitude was different.
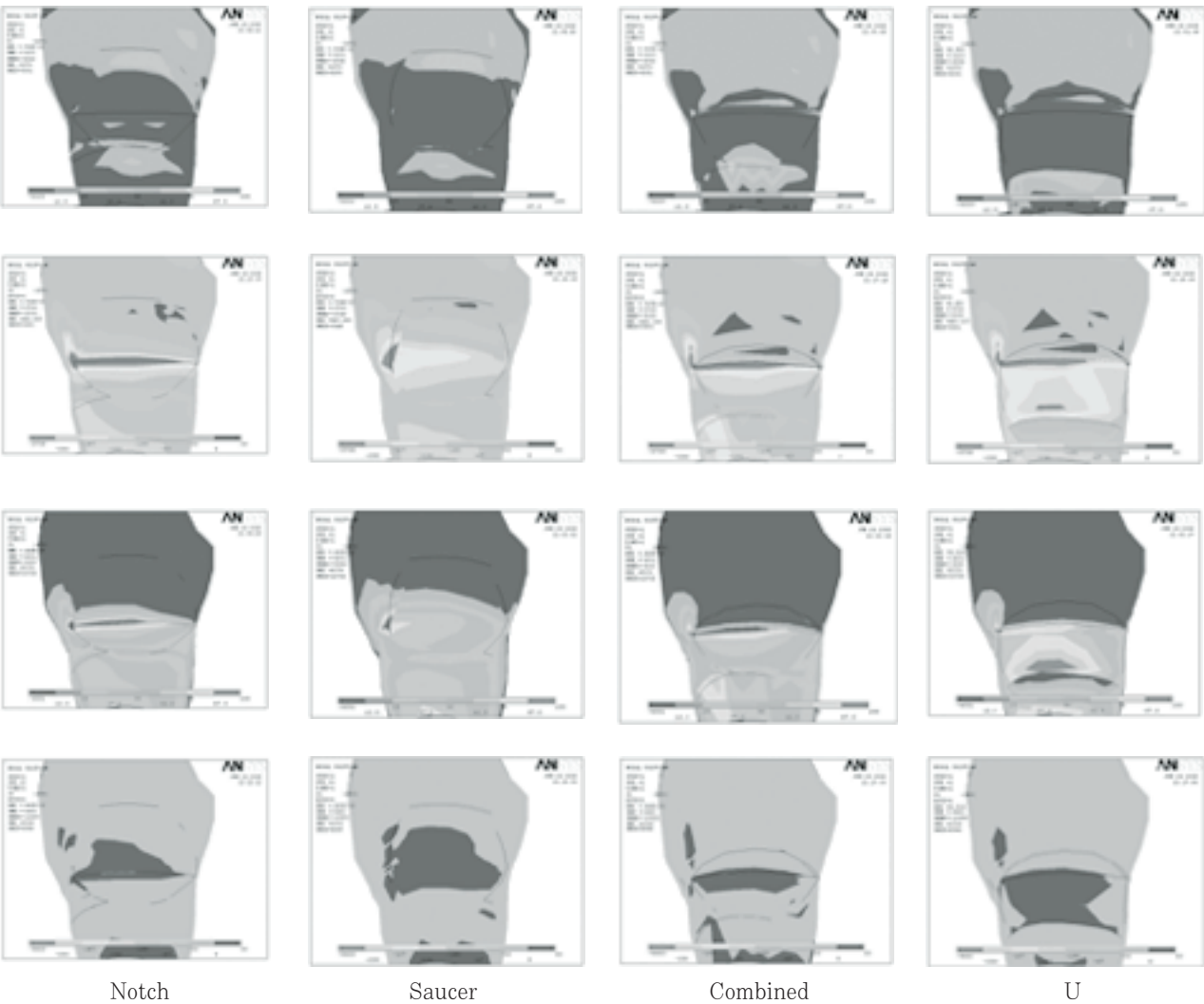

| Notch | Saucer | Combined | U |

Figure 3. The Principal stress distribution of four cavities under Load A and B(Upper 2 rows: maximal and minimal principal stress under load A, Lower 2 rows; maximal and minimal principal stress under load B. From left line, notch-shape showed, followed by saucer, combined, U-shape lesion)

Lesion apex (Table 4, Figure 4)

At the lesion apex, the peak principal stress

with load A and B were shown in Table 4 and principal stress distributions were shown in Figure 4.

Table 4. Peak stresses of lesion apex of four cavities

		Load A				Load B			
		1st Peak		2nd Peak		1st Peak		2nd Peak	
		MPa	Node	MPa	Node	MPa	Node	MPa	Node
Notch	Max	12.4	6	10.9	20	193*	1	104.3*	5
	Min	−558*	1	−279*	13	40.2	6	NS	NS
Saucer	Max	14.6	1	8.8	16	123.0*	1	55.8*	13
	Min	−330.0*	1	−203.3	13	NS	NS	NS	NS
Combined	Max	10.0	M1	18.3	D3	195.5*	1	108.3*	6
	Min	−606.7*	1	−320.7*	7	NS	NS	NS	NS
U	Max	17.8	D3	13.9	M1	147.9*	1	71.1*	7
	Min	−500.9*	1	−268.7*	13	NS	NS	NS	NS

*: Excessive stresses over the failure range.
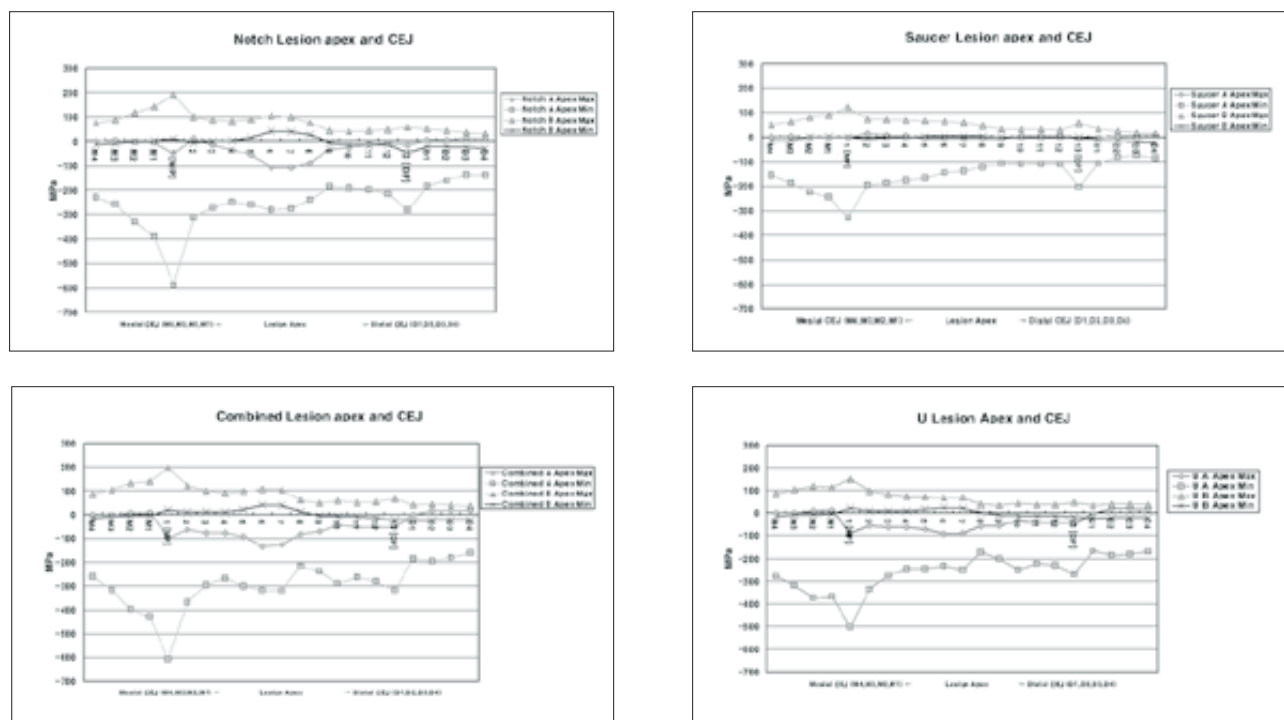
NS: Not significant

Figure 4. Principal stresses of lesion apex of 4 shape lesion.

(M1, M2, M3, M4: nodes near mesial point angle, D1, D2, D3, D4: nodes near distal point angle. If the value of one principal stress of an element was positive, the element was determined to be in the tensile condition, if it was negative, the element was determined to be in the compressive condition).

Notch

At the mesial corner, peak compressive stress (588 MPa) with load A and peak tensile stress (193 MPa) with load B were observed.

Saucer

At the mesial corner, peak compressive stress (330 MPa) with load A and peak tensile stress (123 MPa) with load B were observed.

Combined

At the mesial corner, peak compressive stress (606 MPa) with load A and peak tensile stress (195 MPa) with load B were observed.

U

At the mesial corner, peak compressive stress (501 MPa) with load A and peak tensile stress (148 MPa) with load B were observed.

The magnitude of stress increases as follows: saucer-shape, U-shape, notch-shape and combined shape.

Vertical distribution of principal stresses at cavity wall (Table 5, Figure 5)

Notch

At the lesion apex, peak compressive stress (280 MPa) with load A and peak tensile stress (104 MPa) with load B were observed.

Saucer

At the lesion apex, peak compressive stress (157 MPa) with load A and peak tensile stress (62 MPa) with load B were observed.

Combined

At the lesion apex, peak compressive stress (318 MPa) with load A and peak tensile stress (108 MPa) with load B were observed.

U

At the occlusal lesion apex, peak compressive stress (240 MPa) with load A was observed and at cervical lesion apex, peak tensile stress (101 MPa) with load B was observed.

Table 5. Peak stresses values of inner cavity wall vertically

| | | Load A | | | | Load B | | | |
| | | 1st Peak | | 2nd Peak | | 1st Peak | | 2nd Peak | |
		MPa	Node	MPa	Node	MPa	Node	MPa	Node
Notch	Max	33.7*	4	25.5	17	104.3*	13	NS	NS
	Min	−280.4*	13	−58.8	18	40.2	13	NS	NS
Saucer	Max	30.8	3	15.2	17	61.9*	13	53.0*	16
	Min	−157.1	10	−98.1	16	7.8	9	4.4	13
Combined	Max	36.8	17	14.7	6	108.3*	9	42.0*	19
	Min	−317.7*	1	−44.2	19	41.1	9	NS	NS
U	Max	36.01	19	11.3	6	100.7*	15	76.6*	9
	Min	−240.5	10	−207.3	15	22.7	9	2.7	15

*: Excessive stresses over the failure range.
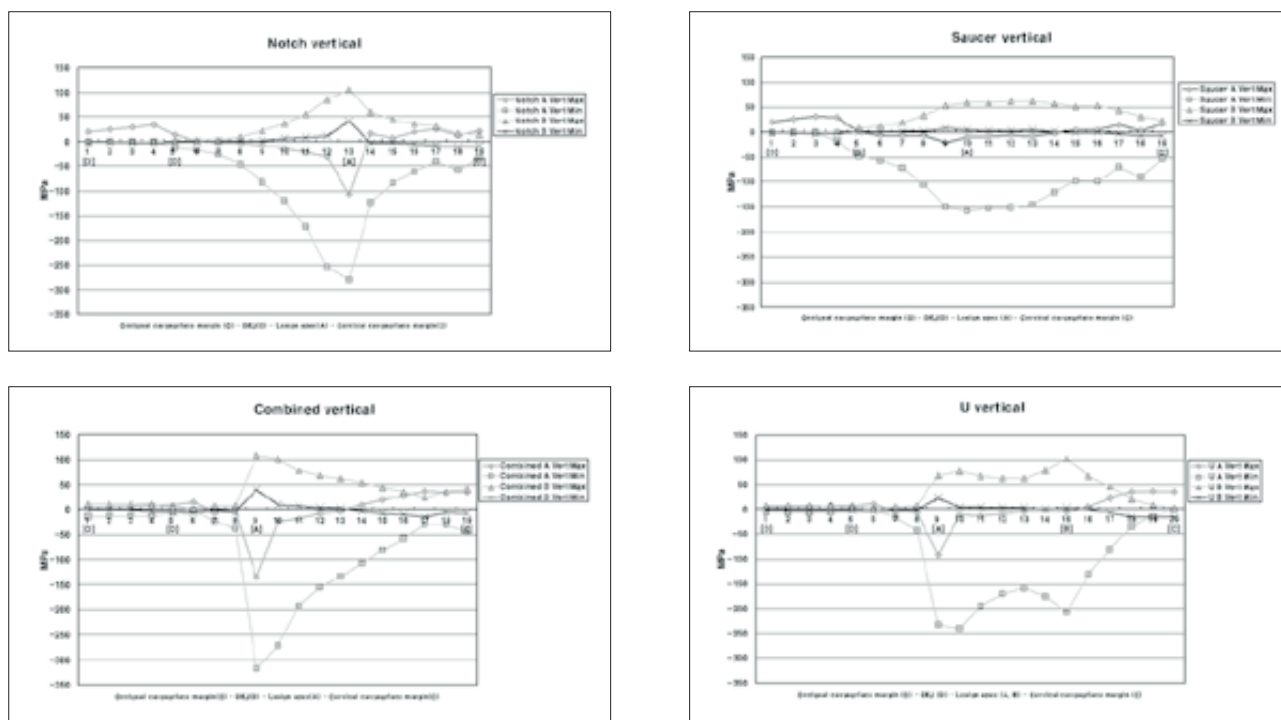NS: Not significant

Figure 5. Vertical distribution of principal stresses at cavity wall in 4 shape lesion.
(If the value of one principal stress of an element was positive, the element was determined to be in the tensile condition, if it was negative, the element was determined to be in the compressive condition).

Ⅳ. DISCUSSION

More recently, NCCLs pathogenesis has been considered to be multifactorial with contributions from occlusal loading, erosion and abrasion with occlusal loading becoming increasingly prominent in recent years. It has been proposed that occlusal loads cause the cusps to flex and this generates stresses in the cervical region of the tooth.

AW *et al.*[22)] investigated the characteristics of NCCLs and evaluated shape, dimensions, sensitivity, sclerosis and occlusion. They came to conclusion that although the presence or contribution of occlusal stresses in the direct formation of these lesions could not be measured directly, the possibility of abfraction could not be completely excluded. But they did not investigate the stress distribution and stress magnitude of NCCLs

In order to determine the load conditions such as magnitudes, directions, occlusal contacts (i.e.,

point or surface, centric or eccentric), preliminary investigation was performed using the data gathered by literature review[23,24)]. Based upon these data, 170 N was assumed as the chewing force for premolars and 500 N was assumed as the heavy parafunctional load of bruxism and traumatic occlusion. In this study, a tooth model loaded by a point load of static 500 N was considered more representative of high-risk loading situation, in contrast to other FE analysis[21,31)].

Once cervical lesion is formed, it becomes a geometric discontinuity. Principles of biomechanics state that a geometric discontinuity induces a stress concentrating effect and that severity of the discontinuity governs the intensity of the stress concentration[25)]. Therefore, a cervical lesion will change the distribution of stress within a tooth.

Ziemiecki *et al.*[26)] suggested that deep notch-shape lesions were demonstrated to retain adhesive restorations better than shallow saucer-

shape lesions, which offer less retention sites and provide less bulk for the restoration. In our study, the magnitude of stress was observed rather smaller, meaning saucer is more beneficial in terms of the distribution of stress.

Whitehead *et al.*[27] demonstrated the extent of tooth flexure under axial loading using profilometry. Their results indicate that changes occur in the labial profile of premolar teeth that are subjected to axial loading which could be considered to represent vertical barreling. Changes in the profile of artificial saucer-shape lesion prepared at the cervical lesion suggested that the floor of the lesion was seen to be raised on application of load, and artificial notch-shape lesion, there was smaller change to the depth of the cavity than are apparent at the periphery of the cavity, particularly at the gingival aspects of the cavity, when loaded. Contrary to this, our study showed that greater stress concentration on the lesion apex was observed in notch-shape than in saucer-shape.

In principal stress analysis, there were some differences in stress distribution among the different type of cervical lesion. The notch, combined and U-shape lesions had a sharp line angle at the apex of the lesion, and the location of the highest stress concentration corresponded with the sharpest geometric discontinuity. Because the saucer-shape lesion did not have a sharp line angle, a somewhat less severe concentration of stress occurred. The angle of combined shape was acute than that of notch shape. So the peak stress at axial line angle of combined shape was larger than that of notch.

In this study, there are some differences between stress concentration site and stress magnitude of four cavities. In contrast, Browning *et al.*[28] suggested that despite various cavity configurations, and thus resultant interfacial stress, the mechanical properties of the composite used are relatively unimportant. Since significant stress concentration was observed in each area for all lesions, the effectiveness of the stress releasing through restoration remains in question.

In all cavities, the peak tensile stress was observed near DEJ and this result was the same as Rees *et al.*[7]. They have suggested that initial phase of abfraction lesion formation involves loss of dentin in the DEJ. Dentin is more susceptible to erosion than enamel, and this may lead to a preferential loss of dentin in the cervical area, thereby undermining the enamel which would be more prone to fracture. Furthermore the DEJ cervically lacks the normal scalloping of this structure that is seen elsewhere in the tooth. This scalloping is thought to impart this structure with its strength, and the lack of this structure cervically may cause the enamel in this region to be more susceptible to cracking[7].

Our 3D FEA model may not fully represent intricate dental anatomy and complex occlusal functions. The degree of the stress which occlusal forces initiates and propagate cervical lesion is not fully understood. Kubo *et al.*[29] reported that repeated labiolingual loading could possibly generate greater tensile stress at the adhesive interface than axial loading, which may result in bond degradation. This is the same as the distribution of tensile stresses with load B in this study.

So we investigated principal stress for analysis of characteristic of the stresses. As analysis of the principal stresses from load A, compressive stresses were dominant, and from load B, we found that the tensile stresses were dominant on the mesial corner of cervical lesion, lesion apex and cervical cavosurface margin. In this study, the values of the tensile stress and compressive stress with load A and load B were higher than threshold value of tooth enamel and dentin shown in the previous article[15]. Therefore, it is considered that the tooth structure over the stress threshold value has risk of microcrack. Regardless of the shapes of cavities, fundamental treatment is recommended in order to prevent the spread of cervical lesion. Suitable treatments for this problem can be choice of proper restorative materials, modified restorative technique and occlusal adjustment.

Leinfelder *et al.*[11] mentioned three ways of stress relief. First, the restored, notch shaped abfracted lesion give rise to considerably greater

shear stresses than do the saucer of continuous concave type. During mastication, the restored notch-shaped defect will build up strong shear stresses along the restoration-preparation interface. These shear stress concentrations can be reduced dramatically by modifying the axial wall from a V-shaped configuration to one that is somewhat more concave design. Proper shaping can be accomplished with a No.4 or No.6 round bur. Second, the next consideration for tooth preparation is to establish a well-defined finish line or chamfer line along the cervical edge of the defects. This configuration makes exact margins of completed restoration and results in a great bulk of material. This technique reduce the extent of to which the shrinking resin stresses the interface and provide mechanical retention of the restoration. Third, placing slight bevel (0.5 - 1 ㎜) along the enamel margin visually minimizes the demarcation between the restoration and enamel margin[11].

Clinically, as shown in this study, there are various types of lesion configurations. In our study, as we investigated the distribution of stress according to the shape of lesion, various stress concentration was shown for each area. So, it is not proper to restore the cervical lesion with one material, but appropriate to select the restorative method with regard to various configurative characters of NCCLs, and it is recommended to investigate the materials and methods for restoration of NCCLs considering the stress distribution of a cavity configuration.

Ⅴ. CONCLUSIONS

1. The patterns of stress distribution were similar but the magnitude was different in four types of lesion.
2. The peak stress was observed at mesial corner and also stresses concentrated at lesion apex.
3. The compressive stress under load A and the tensile stress under load B were dominant stress.
4. Under the load, lesion can be increased and harmful to tooth structure unless restored.

REFERENCES

1. James D, Linda C, Levitch. How dentists classified and treated non-carious cervical lesions. *J Am Dent Assoc* 124(5):46-54, 1993.
2. Bradley T, William B, Hancock. Examining the prevalence and characteristics of abfraction like cervical lesions in a population of U.S. veterans. *J Am Dent Assoc* 132(12):1694-1701, 2001.
3. Lee WC, Eakle WS. Stress-induced cervical lesions: Review of advances on the past 10 years. *J Prosthet Dent* 75:487-494, 1996.
4. Grippo JO. Abfractions: A new classification of hard tissue lesions of teeth. *J Esthet Dent* 3(1):14-19, 1991.
5. Gallien GS, Kaplan I, Owen BM. A review of noncarious dental cervical lesions. *Compend Contin Educ Dent* 15(11):1366-1372, 1994.
6. Grippo JO, Schreiner S. Attrition, abrasion, corrosion and abfraction revisited-A new perspective on tooth surface lesion. *J Am Dent Assoc* 135(8):1109-1117, 2004.
7. Rees JS, Hammadeh M. Undermining of enamel as a mechanism of abfraction lesion formation: a finite element study. *Eur J Oral Sci* 112:347-352, 2004.
8. Radentz WH, Barnes GP, Cutright DE. A survey of factors possibly associated with cervical abrasion of tooth surface. *J Periodontol* 47:148-154, 1976.
9. Kahn F, Young WG, Shahabi S, Daley TJ. Dental cervical lesions associated with occlusal erosion and attrition. *Aust Dent J* 44:176-186, 1999.
10. Levitch LC, Bader JD, Shugars DA, Heymann HO. Non-carious cervical lesions. *J Dent* 22:195-207, 1994.
11. Leinfelder KF, Restoration of abfracted lesions. *Compend Contin Educ Dent* 15(4):1396-1400, 1994.
12. Park Jk, Hur B, Lee HJ The effect of configuration on marginal leakage of class 5 restoration. *J Kor Acad Cons Dent* 26(2):162-170, 2001.
13. Kuroe T, Itoh H, Caputo AA, Konuma M. Biomechanics of cervical tooth structure lesions and their restoration. *Quint Int* 31(4):267-274, 2000.
14. Grippo JO. Noncarious cervical lesions: The decision to ignore or restore. *J Esthet Dent* 4:118-132, 1992.
15. Litonjua LA, Andreana S, Patra AK, Cohen RE. An assessment of stress analyses in the theory of abfraction *Biomed Mater Eng* 14:311-321, 2004.
16. Rees JS, Jacobsen PH. The effect of cuspal flexure on a buccal Class V restoration: a finite element study. *J Dent* 26(4):361-367, 1998.
17. Lindehe J, Karring T. Textbook of Clinical Periodontology, 2nd edition, Munksgaard, Copenhagen, p19-69, 1989.
18. Schroeder HE, Page RC. Periodontal Diseases, 2nd edition, Lea & Fabiger, Philadelphia, p 3-52, 1990.
19. Rubin C, Krishnamurthy N, Capilouto E, Yi H. Stress analysis of the human tooth using a three-dimensional finite element model. *J Dent Res* 62:82-86, 1983.
20. Katona TR, Winkler MM. Stress analysis of a bulk-filled class V light-cured composite restoration. *J Dent Res* 73(8):1470-1477, 1994.
21. Geramy A, Sharafoddin F. Abfraction: 3D analysis by means of the finite method. *Quint Int* 34(7):526-533, 2003.
22. AW TC, Lepe X, Johnson GH, Mancl L. Characteristics of noncarious cervical lesions: A clinical investigation.

J Am Dent Assoc 133(6):725-733, 2002.
23. Widmalm SE, Ericsson SG. Maximal bite force with centric and eccentric load. *J Oral Rehabil* 9:445-450, 1982.
24. Gibbs CH, Mahan PE, Lundeen HC, Brehnan K, Walsh EK, Holbrook WB. Occlusal forces during chewing and swallowing as measured by sound transmission. *J Prosthet Dent* 46:443-449, 1981.
25. Caputo AA, Standlee JP. Biomechanics in Clinical Dentistry. Chicago *Quintessence Int* 21-27, 1987.
26. Ziemiecki TL, Dennison JB, Charbeneau GT. Clinical evaluation of cervical composite resin restorations placed without retention. *Oper Dent* 12:27-33, 1987.
27. Whitehead SA, WilsonNHF, Watts DC. Demonstration of "Vertical Barreling "using profilometry. *Eur J Prosthodont Restor Dent* 7(4):131-134, 1999.
28. Browning WD, Brackett WW, Gilpatrick RO. Two-year clinical comparison of a microfilled and hybrid resin based composite in noncarious class V lesions. *Oper Dent* 25:46-50, 2000.
29. Kubo S, Yokota H, Sata Y, Hayashi Y. The effect of flexural load cycling on the microleakage of cervical resin composites. *Oper Dent* 26:451-459, 2001.

국문초록

네 가지 형태의 비우식성 치경부 병소의 3차원 유한요소법적 응력분석

전상제[1] · 박정길[1] · 김현철[1] · 우성관[2] · 김광훈[2] · 손 권[2] · 허 복[1*]

[1]부산대학교 치과대학 치과보존학교실
[2]부산대학교 공과대학 기계설계공학과

본 연구의 목적은 네 가지 형태의 비우식성 치경부 병소에 과다한 교합하중을 가했을 때 각 와동에 나타나는 응력분포를 3차원적으로 조사하고자 하였다.

임상적으로 많이 관찰되는 다양한 형태의 병소 중 4가지 형태의 서로 다른 병소를 대표적으로 선택하여 발치된 상악 제2소구치에 3차원 유한요소 모형을 제작하였다. 형성된 모형에 협측교두와 설측교두에 500 N의 하중을 가한 후 치경부병소 첨부와 수직 절단면의 주 응력을 분석하여 다음과 같은 결과를 얻었다.

1. 서로 다른 네 가지 형태의 와동에서 응력분포 양상은 비슷했지만 응력의 크기가 서로 달랐다.
2. 최대치 응력은 근심협측 우각부에서 나타났으며, 또한 병소의 첨부에 응력의 집중을 보였다.
3. 하중 A에서는 주된 응력이 압축 응력이었고 하중 B에서는 주된 응력이 인장 응력이었다.
4. 이러한 하중 하에서 수복치료를 하지 않으면 와동의 크기는 점차 커지고 치아구조에는 유해하게 작용하리라 생각된다.

주요어: 치경부병소, 유한요소분석, 교합응력, 응력분포, 압축응력, 인장응력