Evaluation of the stress concentration of different incisal ridge preparations of porcelain veneers (Finite element analysis)

Abbas F. Al-Huwaizi, B.D.S., M.Sc., Ph.D. [1]

ABSTRACT

Background: Porcelain veneers are under a great deal of stress which may lead to clinical failure as fracture or dettachment. This study examined whether different finishing lines and lingual shoulder preparations in the incisal area of the maxillary central incisor affect the bond of the porcelain veneers.

Materials and methods: A two- dimensional finite element model was made. Location and magnitude of maximum Von Mises stresses were calculated in porcelain veneer. Six types of preparations were drawn as:incisal overlap of 0.5mm, 1mm and 1.5mm depth and lingual shoulder, and incisal overlap of 0.5mm, 1mm and 1.5mm depth without shoulder preparation.

Results: Stress formation is maximum in the incisal edge region. All the lingual shoulder preparations presented better stress distribution than the non shoulder preparations

Conclusion: Stress is distributed more evenly when the tested preparation possesses a good thickness of porcelain and the more the surface area with incisal overlap the less possibility of bond failure.

Key words: Porcelain veneer, stress distribution, finishing line. (J Bagh Coll Dentistry 2013; 25(4):1-4).

INTRODUCTION

Porcelain veneers may be used for many treatment modalities as for treating discoloured teeth or teeth with minor loss of the incisal edge. [1, 2]

The success rate of porcelain veneers was clinically ranges from 75-100% [3-7]. Factors affecting long term success of porcelain veneers are age, gender of the patient and fabrication techniques [6]. Therefore, failure in porcelain veneers seems to be associated with changes in bonding condition and / or the magnitude of incisal load [8].

The most recent adhesive techniques have given high bonding strength, therefore improving bond of the porcelain veneer efficiently to the tooth structure.

The marginal design of the finishing line was studied to verify the stress concentration by the use of 2 dimensional finite element analysis [9, 10], but none clearly emphasized on the effect of incisal porcelain thickness and lingual shoulder preparation on stress distribution

The purpose of this study was to examine the distribution of stresses in porcelain veneers in different incisal preparations with and without lingual shoulder preparation.

MATERIALS AND METHODS

The finite analysis was conducted using the ANSYS 5.4 finite element package (Swanson Analysis System, Housten, Pennsylvania).

(1)Assist. Professor, College of Dentistry, University of Kufa

Two dimensional finite element models of porcelain veneers on teeth with intermediate layers of bonding agent, and composite resin were designed according to the size of an average maxillary central incisor. The abutment was considered to be homogenous.

The dimensions of the preparation for the porcelain veneers were drawn according to Rufenacht in1992, where 0.3 mm was prepared cervically, 0.5 mm in the middle and 0.7 mm incisally. The porcelain veneer preparation was all within enamel.

Three types of finishing lines incisally were drawn to create models and as follows:

Group I: Incisal overlap 0.5 mm and lingual shoulder

Group II: Incisal overlap 1 mmand lingual shoulder

Group III: Incisal overlap 1.5 mm and lingual shoulder

Group IV: Incisal overlap 0.5 mm.

Group V: Incisal overlap 1 mm.

Group VI: Incisal overlap 1.5 mm

The composite resin was drawn to be 100 um thick [11] and the bonding agent was 1 um thick. [8]

The model was divided into 5 main areas representing porcelain laminate, composite cement layer, enamel bonding layer, enamel and dentine, while the pulp was assumed as a nul element. The properties for the material used in the study are listed in table 1.

The load of 50 N at 60^{o} labiocervically was applied at lingual slope of incisal edge. Ten areas were evaluated for stress concentration along the

interface between the veneer and the tooth structure (Figure 1).

Table 1: Materials' properties.[8]

Material	Esthetic Modulus (GPa)	Poisson's Ratio
Porcelain	70	0.19
Composite cement	6	0.4
Resin	5	0.4
Enamel	84	0.33
Dentin	19	0.31

RESULTS

Table 2 and figures 1-8 present the stress distribution picture along the porcelain veneer–tooth interface. Different stress concentrations are seen in the different points evaluated and are as follows:

Point 1: The incisal reduction with lingual shoulder preparations were comparable (0.2, 2 and 2) but preparations without shoulder showed more and unequal degrees of stress distribution (8,8 and 2MPa)

Point 2, 6 and 7: The more incisal reduction with lingual shoulder preparations the less stress accumulation and the same picture was seen in preparations without shoulder but with higher stress values.

Table 2: Distribution of stress in different points of the porcelain veneer preparation

	1	2	3	4	5	6	7	8	9	10
Incisal overlap 0.5 mm+ling. Shoulder	0.2	20	135	217	211	139	121	120	95	118
Incisal overlap 1 mm+ling. Shoulder	2	20	94	217	185	115	94	70	73	95
Incisal overlap 1.5mm+ling. Shoulder	2	11	51	190	204	93	61	51	54	53
Incisal overlap 0.5 mm	8	31	140	217	214	204	170	137	121	125
Incisal overlap 1 mm	8	24	89	216	214	125	101	95	55	92
Incisal overlap 1.5 mm	2	7	45	217	199	95	56	51	51	53

Point 4: Very high and comparable stress values were found in all the preparations except 1.5 mm incisal reduction with lingual shoulder preparation which was less (190 MPa compared with 217 MPa).

Point 5: Very high and comparable stress values were found in all the preparations except in 1 mmand 1.5 mm incisal reduction with lingual shoulder preparationand 1.5 mm incisal reduction with shoulder which was less (185-204 MPa compared with 214 MPa).

By dividing the porcelain veneer to 3 segments, it is evident that the labial segment (Points 1, 2 and 3) show the least stress concentration (maximum 8, 31 and 140 MPa respectively). The incisal segment (Points 4 and 5) presented the highest stress concentration (maximum 217 and 214 MPa respectively). The lingual segment (Points 6-10) presented another stress concentration picture (maximum 204, 170, 137, 121 and 125 MPa).

Points 3,8, 9 and 10: The more incisal reduction with lingual shoulder preparations the less stress accumulation and the same picture was seen in preparations without shoulder but with comparable stress values.

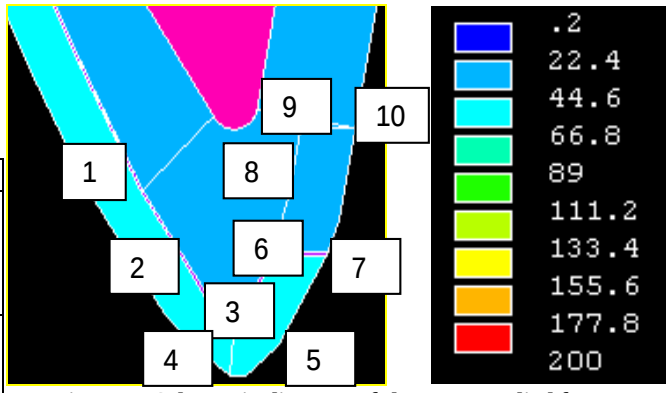

Figure 1: Schematic diagram of the spots studied for stress distribution

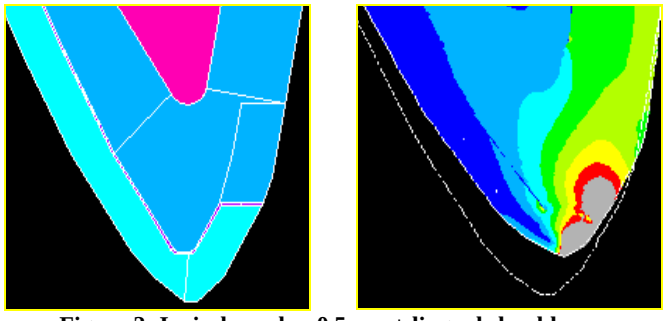

Figure 2: Incisal overlap 0.5 mm+ lingual shoulder

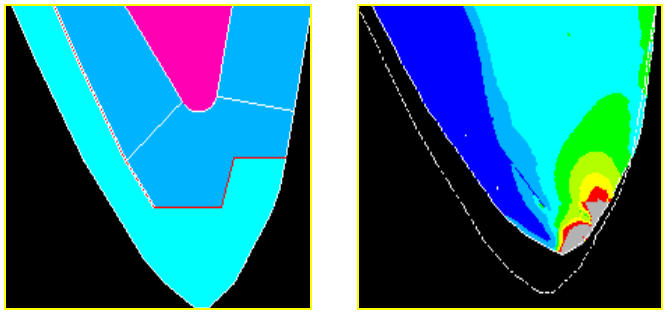

Figure 3: Incisal overlap 1 mm+ lingual shoulder

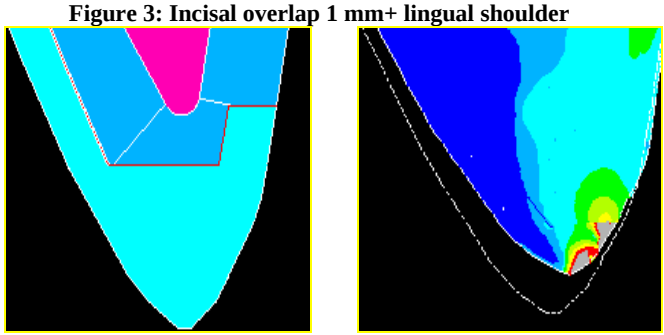

Figure 4: Incisal overlap 1.5 mm+ lingual shoulder

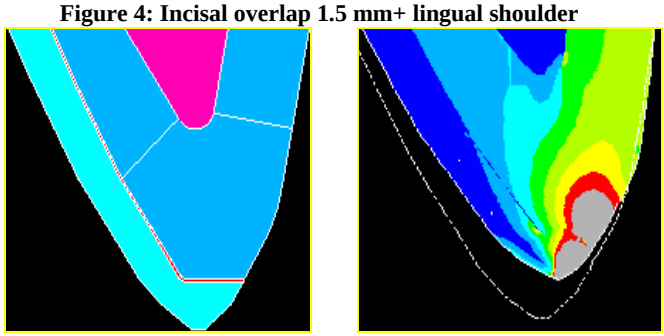

Figure 5: Incisal overlap 0.5 mm+ lingual without shoulder

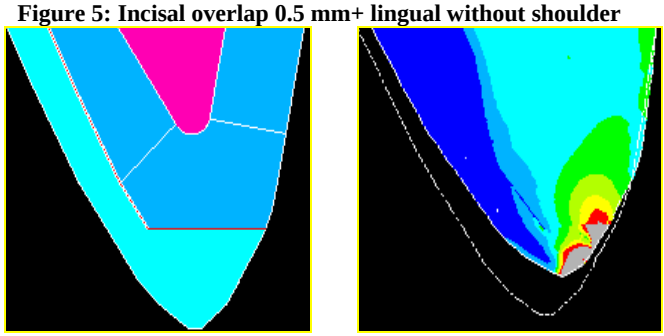

Figure 6: Incisal overlap 1mm+ lingual without shoulder

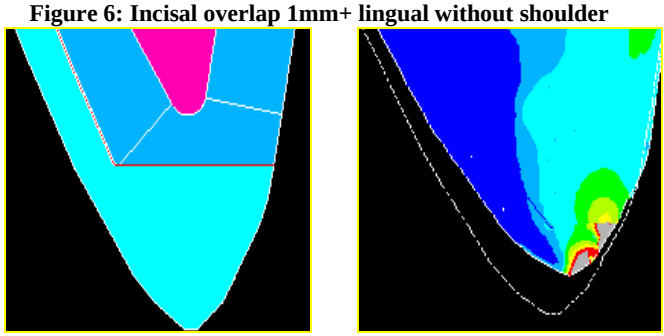

Figure 7: Incisal overlap 1.5 mm+ lingual without shoulder

DISCUSSION

The use of veneers to replace enamel during rehabilitations is recommended.[12] Regarding Point 1,lingual shoulder preparations produced more wrap around the incisal ridge surface area which decreased the dislodging force on Point 1 (the middle of the labial wall).

The stress distribution picture of Points 2,6 and 7 are comparable and show that the surface area of lingual shoulder is directly related to better stress distribution. This is in compliance with the results of Magne and Douglas (1999) [10]

Preparations with lingual shoulder and shallow incisal overlap (0.5 and 1 mm)have less surface area and wrap around incisal ridge therefore higher stress is seen.

Points 3,8,9 and 10 shared the same stress distribution. The thickness of the porcelain distributes the force . The force is at 90 degrees with the wall of the incisal porcelain which makes these points under compression and little value of the wraparound the incisal ridge. This agrees with the result of Sorrentino et al. (2009) who stated that compressive stresses were concentrated on the external surface of the buccal side of the veneer close to the incisal margin. [13]

Point 4 is the touching point with the force with maximum stress concentration reaching 217 MPa which comparable with the results of Chander and Padmanabhan(2009) [14]. In this point, the 1.5mm incisal reduction with lingual shoulder preparation has the least stress concentration because it has the most thickness of porcelain therefore stress is distributed more evenly in the porcelain.

The stress concentration in Point 5 showed that the more thickness of the porcelain and surface area distributes the stress.

From the segmental picture of the stress concentration of porcelain veneers, it is evident that the lingual area needs reinforcement because it is under considerable stress [12]

REFERENCES

1- Christensen GJ. The state of the art in esthetic restorative dentistry. J Am Dent Assoc 1997; 128: 1315-7

2- Calamia JR. The current status of etched porcelain veneer restorations. J Phlipp Dent Assoc 1996; 47: 35-41.

3- Christensen GJ, Christensen RP. Clinical observations of porcelain veneers: a three year report. J Esthet Dent 1991; 3: 174-9.

4- Nordbo H, Rygh-Thoresen N, Henaug T. Clinical performance of porcelain laminate veneers without incisal overlapping: 3- year results. J Dent 1994; 22: 342-5.

5- Denissen HW, Wijnhoff GF, Veldhuis AA, Kalk W. Five-year study of all-porcelain veneer fixed partial dentures. J Prosthet Dent 1993; 69: 464-8.

6- Dunne SM, Millar BJ. A longitudinal study of the clinical performance of porcelain veneers. Br Dent J 1993; 175: 317- 21.
7- Garber D. Porcelain laminate veneers: ten years later. Part I: tooth preparation. J Esthet Dent 1993; 5: 56-62.
8- Troedson M, Derand T. Effect of margin design, cement polymerization, and angle of loading on stress in porcelain veneers. J Prosthet Dent 1999; 82: 518-24.
9- Magne P, Douglas WH. Optimization of resilience and stress distribution in porcelain veneers for the Vol. 17(2) 2005 A finite element analysistreatment of crown-fractured incisors. Int J Perio Rest Dent 1999; 19(6): 543-53.
10- Magne P, Douglas WH. Design optimization and evolution of bonded ceramics for the anterior dentition: a finite-element analysis. Quintessence Int 1999; 30(10): 661-72.
11- Rufenacht CR. Fundementals of esthetics. 1st ed. Quintessence Books; 1992. p. 335.
12- Matson MR, Lewgoy HR, Barros Filho DA, Amore R, Anido-Anido A, Alonso RC, Carrilho MR, Anauate-Netto C. Finite element analysis of stress distribution in intact and porcelain veneer restored teeth. Comput Methods Biomech Biomed Engin 2012; 15(8):795-800.
13- Sorrentino R, Apicella D, Riccio C, Gherlone E, Zarone F, Aversa R, Garcia-Godoy F, Ferrari M, Apicella A.Nonlinear visco-elastic finite element analysis of different porcelain veneers configuration. J Biomed Mater Res B Appl Biomater 2009; 91(2):727-36.
14- Chander NG, Padmanabhan TV. Finite element stress analysis of diastema closure with ceramic laminate veneers. J Prosthodont 2009; 18(7):577-81.

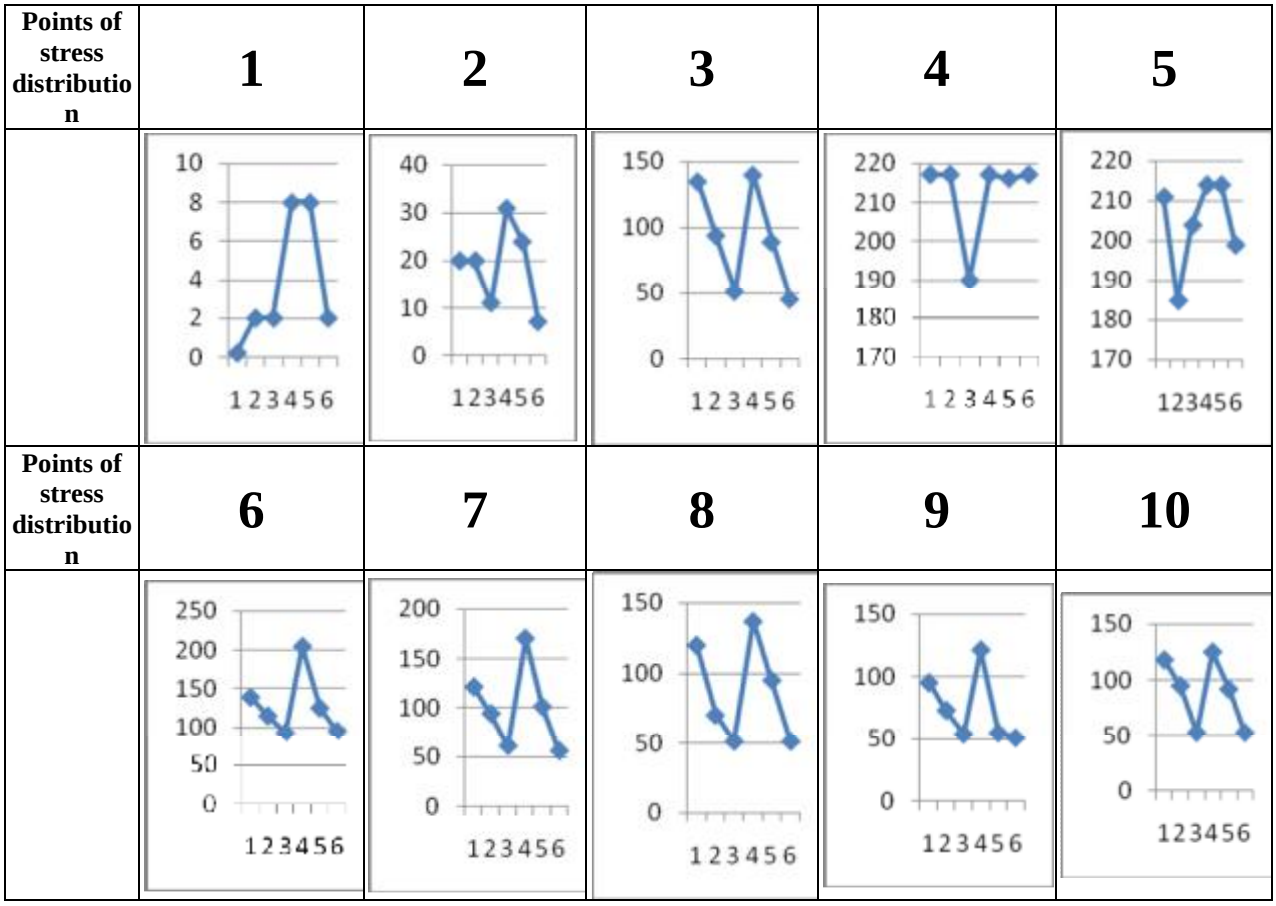

Figure 8: Distribution of stress in different points of the porcelain veneer preparation