International Journal of Engineering, Mathematical and Physical Sciences
ISSN: 2517-9934
Vol:5, No:6, 2011

FEA for Teeth Preparations Marginal Geometry

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Abstract**—**Knowledge of factors, which influence stress and its distribution, is of key importance to the successful production of durable restorations. One of this is the marginal geometry. The objective of this study was to evaluate, by finite element analysis (FEA), the influence of different marginal designs on the stress distribution in teeth prepared for cast metal crowns. Five margin designs were taken into consideration: shoulderless, chamfer, shoulder, sloped shoulder and shoulder with bevel. For each kind of preparation three dimensional finite element analyses were initiated. Maximal equivalent stresses were calculated and stress patterns were represented in order to compare the marginal designs. Within the limitation of this study, the shoulder and beveled shoulder margin preparations of the teeth are preferred for cast metal crowns from biomechanical point of view.

Keywords**—**finite element, marginal geometry, metal crown

I. Introduction

THE junction between a cemented tooth restoration and the tooth is always a potential for recurrent caries because of dissolution of the luting agent and inherent roughness [1]. A well-designed preparation has a smooth and even margin. Rough, irregular margins substantially reduce the adaptation of the restoration. The cross-section configuration of the margin has been the subject of much analysis and debate [1]. The minimization of crown marginal gaps is an important goal in prosthodontics. Smaller marginal gaps produce less gingival irritation and cement washout, improving the clinical outcome and longevity of the restoration [2].

The incomplete fit of full cast crown restorations remains a critical problem for dentists, leading many researchers to study this problem [3]. Marginal and internal accuracy of fit is valued as one of the most important criteria for the clinical quality and success of complete crowns [4].

The geometry of tooth preparation has been the subject of many debates without clear evidence that one type of tooth preparation or method of fabrication provides consistently superior marginal fit [5].

Traditional tooth preparation margin designs are still advised by most manufacturers for indirect restorations [6]. Mainly five margin designs are used: shoulderless, chamfer, shoulder, sloped shoulder and shoulder with bevel.

Although they are conservative for tooth structure, shoulderless crown preparations should be avoided because they fail to provide adequate bulk at the margins. Overcontoured restorations often result from shoulderless preparations. Under most circumstances, these kinds of margins are unacceptable.

A chamfer margin is particularly suitable for cast metal crowns. It is distinct and easily identified, provides space for adequate bulk of material, although care is needed to avoid leaving a ledge of unsupported enamel.

Shoulder margins always offer space for the crown material. It should form a 90 degree angle with the unprepared tooth surface.

A 120 degree sloped shoulder margin is used as an alternative to the 90 degree shoulder. The sloped shoulder reduces the possibility of leaving unsupported enamel and leaves sufficient bulk to allow thinning of the metal framework.

A beveled shoulder margin removes unsupported enamel and may allow some finishing of the metal. From biological point of view this kind of margin has to be avoided because the margin will be closer to the epithelial attachment.

It was also found that margin design is a determining factor in establishing the extent of the minimal preparation for a cast metal crown [6].

The shoulder preparation emerged as the recommended preparation design from both mechanical and periodontal points of view. As for a less invasive preparation design, the slight chamfer preparation would be the recommended option [7].

Beside the described advantages and disadvantages of different margin designs for complete crown preparations, they influence the stress distribution in the prepared teeth. Load-bearing capacity is a further a crucial factor influencing the clinical long-term reliability of crowns [8].

Knowledge of factors, which influence stress and its distribution, is of key importance to the successful production of durable restorations [9].

II. Objective

The objective of this study was to evaluate, by finite element analysis (FEA), the influence of different marginal geometries on the stress distribution in teeth prepared for cast metal crowns.

III. Materials And Methods

To evaluate the influence margin design on stresses in the prepared teeth for complete cast crowns, a pilot study was achieved. Experimental models were created to simulate the simplified geometry of the prepared crowns. Five margin designs were taken into consideration: shoulderless, chamfer,

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shoulder, sloped shoulder and shoulder with bevel. For each kind of preparation three finite element models were created in order to evaluate also the influence of meshing options (fine, medium, coarse).

These preparations were covered with simplified crowns to simulate la physiologic loading conditions. A load of 5N was applied on the occlusal surface of the simplified crown.

IV. Results And Discussions

This study was a preliminary evaluation of five margin preparation designs proposed for cast metal crowns. It clarified the magnitude, distribution of stress caused by three different simulations (fine, medium, coarse).

The values of the maximal equivalent stress were higher for the shoulder and beveled shoulder in all studied cases (Fig. 1-4). Regarding the distribution the maximal values, they are located under the preparation line.

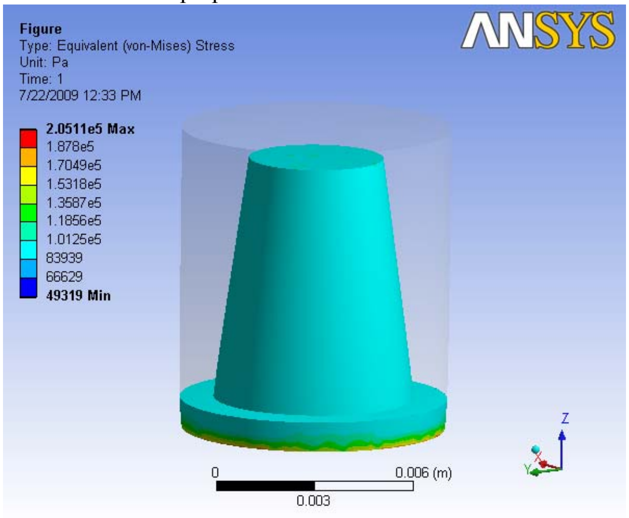

Fig. 1 Maximal equivalent stress in a tooth preparation with shoulder margin (fine simulation)

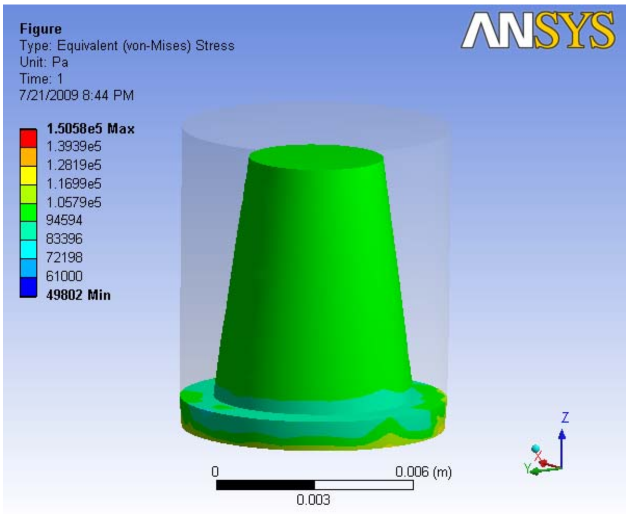

Fig. 2 Maximal equivalent stress in a tooth preparation with shoulder margin (coarse simulation)

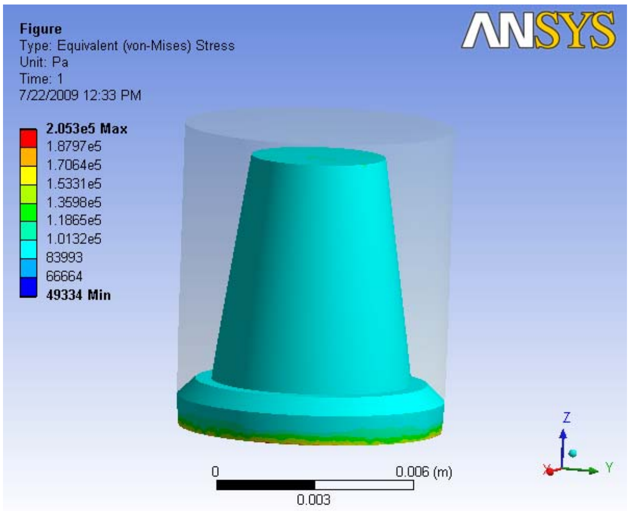

Fig. 3 Maximal equivalent stress in a tooth preparation with beveled shoulder margin (fine simulation)

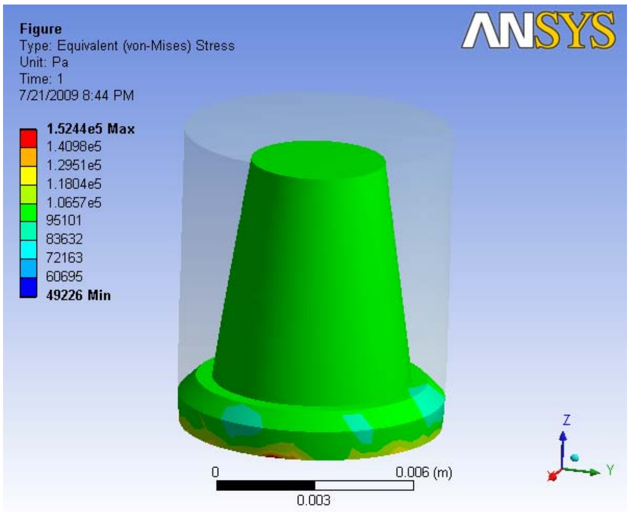

Fig. 4 Maximal equivalent stress in a tooth preparation with beveled shoulder margin (coarse simulation)

For the fine simulations the values were higher, but the distribution was the same. All simulations (fine, medium and coarse) indicated similar results. It means that also a coarse simulation can be used for a pilot study (Table I and II).

TABLE I
MAXIMAL STRESS IN THE TOOTH PREPARED WITH SHOULDER MARGIN

Simulation	Maximal equivalent stress [Pa]
fine	2.0511e+5
medium	1.8581e+5
coarse	1,5058e+5

TABLE II
MAXIMAL STRESS IN THE TOOTH PREPARED WITH BEVELED SHOULDER MARGIN

Simulation	Maximal equivalent stress [Pa]
fine	2.0530e+5
medium	1.8575e+5
coarse	1.5244e+5

For the other type of margin designs: chamfer, sloped shoulder, and shoulderless, the values of the maximal stresses were smaller (Table III, IV, and V).

Stresses were located also under the preparation line (Fig. 5-10). This is a favorable aspect because the stresses are not in the luting agent areas. This avoids being an additional factor for cement washout. Chamfer preparations are the most unfavorable from this point of view. The stress patterns lead to stresses at the junction of the teeth with the restorations.

TABLE III
MAXIMAL STRESS IN THE TOOTH PREPARED WITH CHAMFER MARGIN

Simulation	Maximal equivalent stress [Pa]
fine	1.8070e+5
medium	1.6435e+5
coarse	1.3991e+5

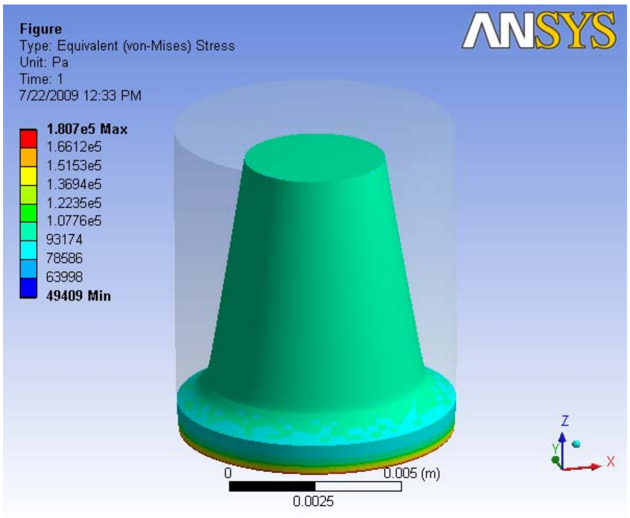

Fig. 5 Maximal equivalent stress in a tooth preparation with chamfer margin (fine simulation)

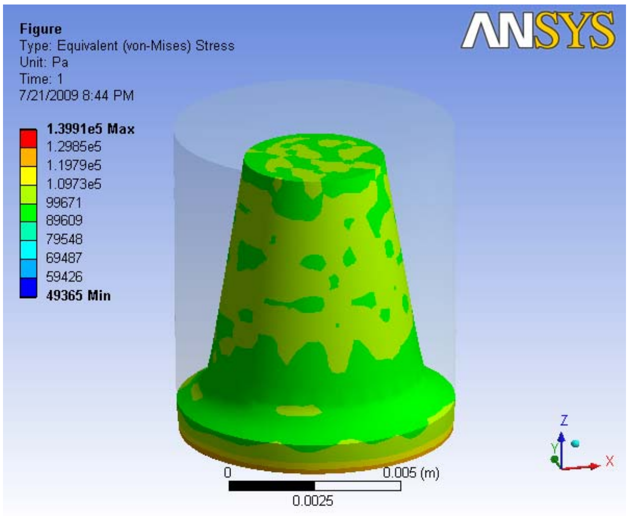

Fig. 6 Maximal equivalent stress in a tooth preparation with chamfer margin (coarse simulation)

TABLE IV
MAXIMAL STRESS IN THE TOOTH PREPARED WITH SLOPED SHOULDER MARGIN

Simulation	Maximal equivalent stress [Pa]
fine	1.7844e+5
medium	1.8458e+5
coarse	1.5176e+5

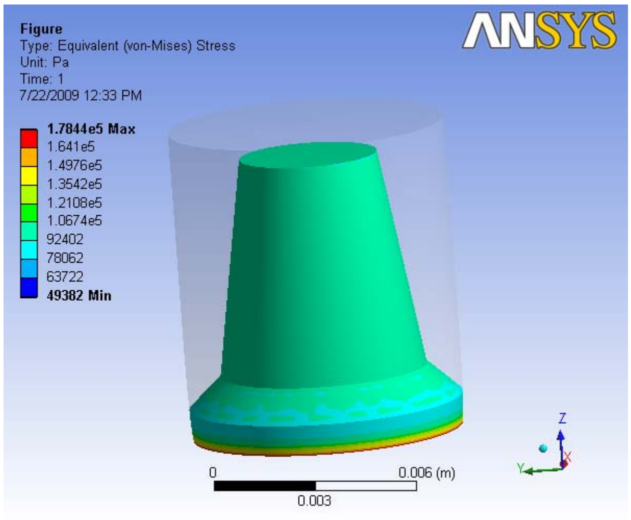

Fig. 7 Maximal equivalent stress in a tooth preparation with sloped shoulder margin (fine simulation)

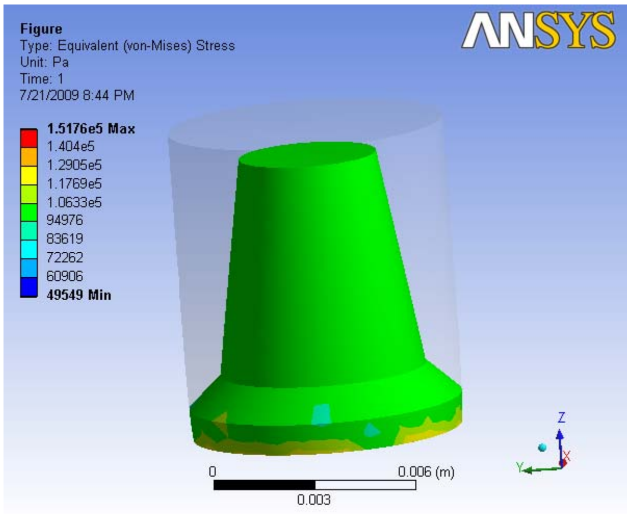

Fig. 8 Maximal equivalent stress in a tooth preparation with chamfer margin (fine simulation)

TABLE V
MAXIMAL STRESS IN THE TOOTH PREPARED WITH SHOULDERLESS MARGIN

Simulation	Maximal equivalent stress [Pa]
fine	1.9173e+5
medium	1.6844e+5
coarse	1.3982e+5

Regarding the stress distribution for the last three preparation designs, the largest area is present for the chamfer preparation, followed by the sloped shoulder and shoulderless preparation. The stresses present in the preparation areas are an additional unfavorable factor for cracks in the luting agent.

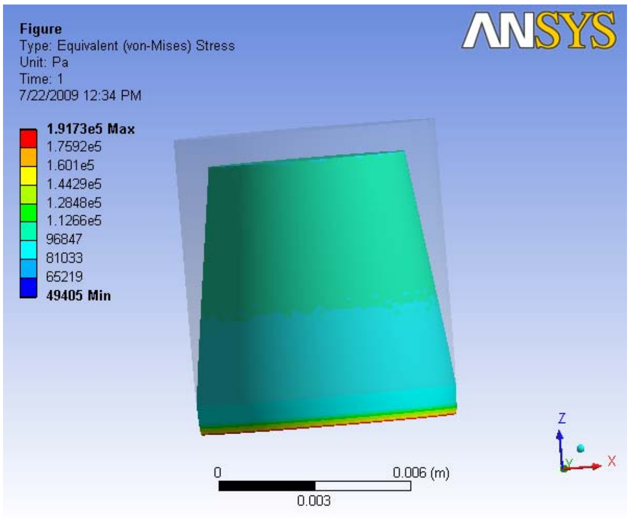

Fig. 9 Maximal equivalent stress in a tooth preparation with shoulderless margin (fine simulation)

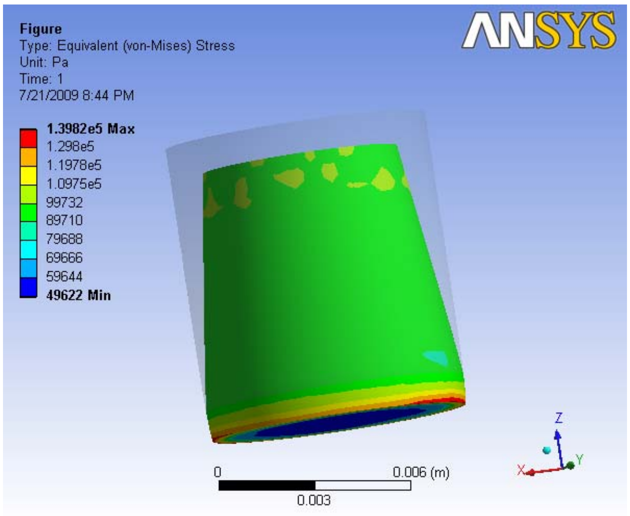

Fig. 10 Maximal equivalent stress in a tooth preparation with shoulderless margin (coarse simulation)

The structural integrity and design of the teeth structures is an important problem in prosthodontics [10, 11].

A possible reason for the most favorable stress distribution associated with shoulder margin preparations this could be that the occlusal forces were also borne by the circumferential shoulder, and there was less stress concentration on the axial walls compared to other preparation designs.

The favorable results of the stress distribution at shoulderless preparation might be explained by the stress distribution pattern during loading. When load on the coping was increased, the coping could slide down the axial wall of the die without being limited by the margin.

The chamfer, and beveled shoulder preparations did not differ significantly with regard to breaking load. This could be attributed to the adequate strength attained with preparation designs that require minimal removal of sound tooth structure. In light of this result, consideration should be given to these designs from a prophylactic point of view with emphasis on conserving tooth structure and preventing preparation trauma [7].

V. Conclusions

Within the limitations of the present study, the shoulder preparation (shoulder and beveled shoulder) emerged as the recommended preparation design from biomechanical point of view. Regarding stress values and distribution, it is followed by the shoulderless preparation. Chamfer and sloped shoulder margins are less favorable only from this point of view.

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