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NUMERICAL SIMULATION OF ORTHODONTIC FORCES EFFECTS IN BONE LOSS CASES

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Abstract: *The biomechanical effects of orthodontic forces on a tooth with 3 degrees of periodontal loss were evaluated in this study. A geometrical model was constructed in order to simulate a real situation from orthodontic treatment. The model was constructed from 3D scans of an upper canine, with different degrees of bone loss(0mm, 3mm, 6mm). The surrounding bone and periodontal ligament was simulated according to the anatomical data. Material properties were taken from previous studies. The resulted numerical model was subjected to orthodontic forces similar to those used during orthodontic treatment. Von Mises tension and initial displacements were evaluated, for different intensities.*

Key words: *finite elements simulation, 3D scan,bone loss, orthodontics, dentistry.*

1. INTRODUCTION

The innovations in orthodontics consist in new materials, in improving the orthodontic devices, and also in new forms of cure plan and in new therapeutic concepts. This context requires the development of new applications on computer and of new methods that facilitate the prognostic and the cure plan, starting from Burstone's studies, who in the 70's built the first numeric models of assessing the orthodontic forces. Previous studies were done in order to study the biomechanical reactions after orthodontic loading, but they manly used anatomical characteristics, not 3D scans of human teeth. The effect of using orthodontic forces in periodontal patients is still unclear. Since the number of adult patients with periodontal disease is increasing(Szuhanek 2006), the purpose of our paper was to evaluate, by numerical methods, the effect of a labially oriented orthodontic force on a canine with different quantity of bone loss.

2. MATERIALS AND METHODS

The experiment was done in the Department of Strenght of Materials, from the Politechnica University of Timisoara. The algorithm of the research included obtaining 3D models of dental and periodontal structures by numerical simulation. In order to get a realistic model, we obtained the initial one by scanning 3D a human canine.

The geometrical model obtained was processed through a graphic program for numerical analysis, GEOSTAR in order to obtain the desired geometric coordinates. For obtaining the numerical model, we imported the geometric models in a numerical analysis program (COSMOSM 2.5), and we introduced the material characteristics took from the literature(Andersen 1991).
Forces with intensities of 0.5 and 1N were applied, in order to simulate those used during orthodontic treatment.

The role of this investigation was to evaluate the effect of orthodontic forces on teeth with periodontal bone loss. The orthodontic treatment in patients with adult ages and periodontal disease is increasing during the last years, therefore the subject of this study is more actual then ever.

The biomechanical effects were evaluated by means of initial displacements(mobility) and Von Mises tension(stress).

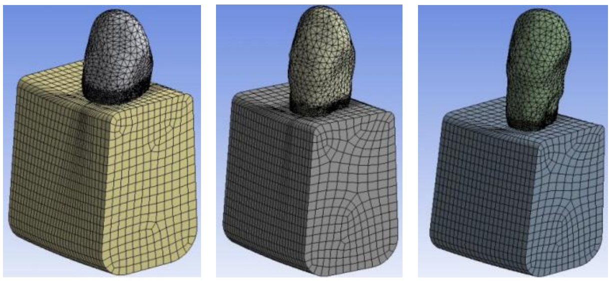

Fig.1 Geometrical models of the three situations taken into this study .(normal bone height, 3 mm bone loss, 6 mm bone loss).

3. RESULTS

The purpose of our paper was to evaluate, by means of finite elements analysis, the stress and displacements produced in the dental and bone structures after the application of orthodontic forces, with special attention on the alveolar bone loss cases. The variation of Von Misses stress and initial displacements are shown in the following images. The coloured scale represents the variation of stress concentration, or the distribution of initial displacements.

The system of forces taken into this study was represented by tipping forces used during different phases of orthodontic treatment. The forces varied between 0.5 and 1 N. The graphic of force application is shown above.
The amount of stress varied with the degree of bone loss. Higher concentration of stress were observed in the alveolar bone of models with 6 mm attachement loss(C) while the normal bone insertion model(A) showed minimal levels of Von Mises stress.

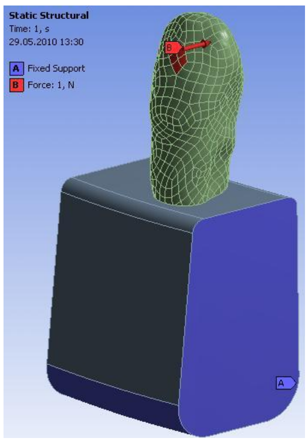

Fig. 2. Force system of the models taken into the study.

The distribution of stress showed the same pattern in the analysed cases, the only variation was of the Von Mises tension values. The concentrations of Von Mises tension were greater at the force application point, in the alveolar bone and in thecervical area of the tooth.

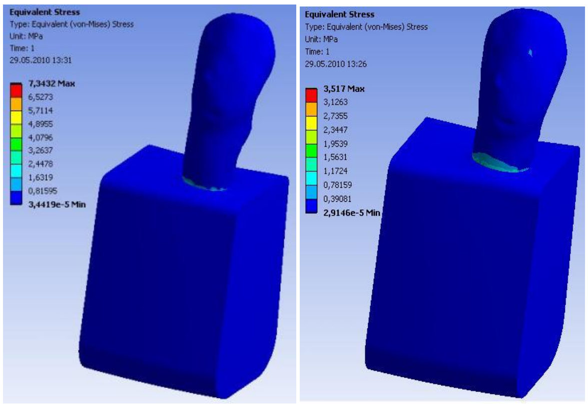

Fig. 3. Stress distribution of the model with 6 and 3 mm bone loss.

FORCE	MAXIMUM VON MISES TENSION		
	A	B	C
0.5 N	0.9722	1.785	3.6716
1 N	1,9445	3,517	7,3432

Tab.1. Variation of Von Mises tension after the application of different values of force.

The rate of initial displacement was lower in the A model(normal bone), than the bone loss models(B, C). This is important in clinical activities, since the rate of tooth movement highly depends on the force applied. The direction of forces applied has a great importance in obtaining the desired result. The maximum initial displacement value was shown in the incisal area, at the edge of the tooth, suggesting that this part will be the first to move during tipping, which is confirmed by the clinical experience.

The accuracy of force application is also very important in obtaining clinical success.

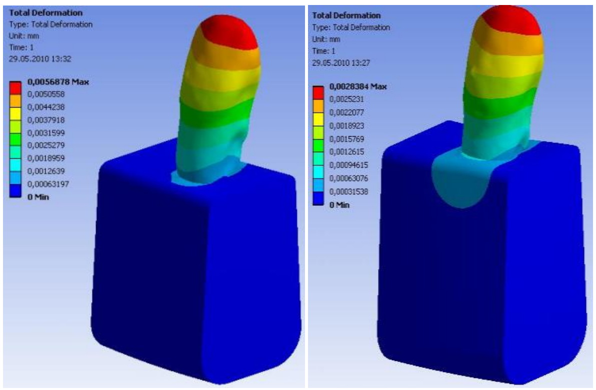

Fig.4. Initial displacement in a canine with 6 and 3 mm bone loss.

FORCE	MAXIMUM INITIAL DISPLACEMENT VALUES		
	A	B	C
0.5 N	0.0006927	0.0014419	0.0028439
1 N	0.0013855	0.0028838	0.0056878

Tab. 2. Variation of initial displacements after the application of orthodontic forces.

The limitations of our research are represented by the inability of finite elements analysis to predict some effects, such as long term displacements. The displacements analysed in this study are initial ones, but further investigations are required in order to obtain the biomechanical parameters on long term basis. On the other hand, in order to obtain realistic results, the geometrical models used should be obtained by 3D scanning of all the structures evaluated, including the periodontal ligament, which is difficult to obtain in human patients.

Also, in analyzing the initial displacements, a great attention should be given to the 3 components of initial displacements, oX, oY and oZ, because this components can apply rotational movements to the loaded tooth.

The location of the application point during orthodontic force loading is extremely important. The accuracy of choosing the exact application point will result in better results and less secondary and unwanted movements. The center of resistance is moving cervically in the bone loss cases, and the force application point should be elected carefully.

Our study has shown that there is a big difference in initial stress and displacements between cases with normal alveolar bone height and those with reduced height due to periodontal problems. In cases with less healthy bone level, a lower intensity of force can result in the same orthodontic movement as a case with better alveolar bone insertion and a stronger force applied.

Further investigations are required in order to evaluate more complex orthodontic situations, such as translation during space closure or the stress during tooth intrusion. The numerical investigation of cases with orthodontic implants will need a special attention.

4. CONCLUSIONS

1. Adult patients with periodontal bone loss represent a challenge in orthodontic treatment, due to the susceptibility of their dento-alveolar structures to develop unwanted stress concentrations.
2. Therefore, the dosage of force applied should be reduced at minimal levels in order to preserve the biology of dentoalveolar structures.
3. The finite elements method remains a powerful tool for investigating dento-alveolar reactions during and after orthodontic treatment.

5. ACKNOWLEDGMENTS

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