

PREDICTIVE FACTORS OF THE INTRUSION OF THE MAXILLARY LATERAL INCISOR ASSOCIATED WITH THE PERIODONTAL DISEASE. A FEM ANALYSIS

Ionuț LUCHIAN¹, Mihaela MOSCALU², Ioana MÂRTU¹, Ioana VATĂ³, Cristel STIRBU⁴, Arina CIOCAN-PENDEFUNDA⁵, Liliana PĂȘĂRIN¹, Sorina SOLOMON², Silvia MÂRTU⁶

¹Lecturer, DMD, PhD, „Grigore T. Popa” University of Medicine and Pharmacy, Iași, Romania

²Assoc. Prof., DMD, PhD, „Grigore T. Popa” University of Medicine and Pharmacy, Iași, Romania

³Senior orthodontist, DMD, PhD, Private Practice, Iași, Romania

⁴Prof, PhD, „Gh. Asachi” Technical University of Iași, Romania

⁵Assist. Prof., DMD, PhD, „Grigore T. Popa” University of Medicine and Pharmacy, Iași, Romania

⁶Prof., DMD, PhD, „Grigore T. Popa” University of Medicine and Pharmacy, Iași, Romania

Corresponding author: Ioana Mârțu; e-mail:ioanamartu@gmail.com

Abstract

Introduction. Dental intrusion in patients whose support periodontium is deficient is a real and viable means for improving implantation, as the results of previous research are promising. **Materials and methods.** Catia V5R16 software and the attached Abaqus analysis software was used for investigating the behaviour of periodontal structures affected, to various extents, by periodontal disease. The mathematical models underwent repeated testings, using optimal (0.25 N) and super-optimal (1N, 2N, 3N and 5N) orthodontics forces, for assessing the response of the periodontal structures. **Results and discussion.** The values of σ_{ech} show an exponential increase, as well as the magnitude of the applied force, irrespective of the presence of the periodontal disease (Fig. 8). The values of σ_{ech} are the same for each level of applied force, whether the maxillary lateral incisor was affected or not. The values of the displacement recorded as a result of the application of intrusive forces on the maxillary lateral incisor, in cases when the periodontium was not affected or when it was affected to an extent of 33% by the periodontal disease, maintain a linear growth, along with the increase of the applied force, without any statistically significant differences as to the extent to which the periodontium was affected. **Conclusions.** The magnitude of the intrusive forces in the maxillary lateral incisor influences primarily the values of equivalent tensions, then those of orthodontic tooth movement, and lastly those of tensions in the direction of the applied force.

Keywords: maxillary lateral incisor, FEM, intrusion, periodontal disease.

1. INTRODUCTION

Recent treatment trends have included the interdisciplinary approach of cases and have stressed the importance of the orthodontic

treatment in optimising the outcome prognosis for patients with periodontal pathologies. [1,2]

Orthodontic treatment in adults is challenging, due to the periodontal complications that may occur. The inter-relation between orthodontics and periodontology is a widely debated topic in literature, but one that remains largely unclarified. [3,4]

Dental intrusion in patients with deficient support periodontium is a real and viable means for improving implantation, as the results of previous research are promising. [5,6]

Although introduced into research only a few decades ago, the finite element method (FEM) is a very useful technique. Advanced technologies in creating mathematical models that simulate reality, as well as the continued optimisation of biomechanical perimeters allow high-accuracy analysis, and elimination, to an ever-increasing extent, of the likelihood of error. At the same time, FEM is an avant-garde and also a non-invasive technique that facilitates structural analysis of pre-defined ensembles, translated into high-accuracy mathematical models.

Under such circumstances, a rigorous analysis of the behaviour of periodontal tissues under the action of orthodontic forces becomes mandatory, for establishing the indications and, more importantly, contraindications and limits of the orthodontic treatment in cases of periodontal disease. It goes without saying that the results of the FEM research will become benchmarks in

developing real and viable treatment protocols, while fundamental research in the clinical context are imperiously necessary. [7-10]

2. MATERIALS AND METHODS

Catia V5R16 and the attached Abaqus analysis software were used in the analysis of the behaviour of periodontal structures affected, to various extents, by horizontal bone loss.

A number of mathematical models that faithfully reproduce the maxillary lateral incisor, the periodontal ligament, as well as the alveolar bone has been elaborated, taking into account the health status of the periodontium: healthy, moderately affected (33%) and severely affected (66%).

The mathematical models were subjected to repeated testing using optimal (0.25 N) and super-optimal (1N, 2N, 3N and 5N) orthodontics forces, in order to assess the response of the periodontal structures.

To quantify the response, the following parameters were considered: the von Mises equivalent tensions in the tooth-periodontal ligament-alveolar bone complex (σ_{ech}), tensions in the direction the force is applied (σ_c), as well as the displacements observed after the application of the respective forces.

3. RESULTS AND DISCUSSIONS

The results of the tested situations are presented in Table I.

Table 1. Simulating the intrusion in the maxillary lateral incisor (MLI)

Applied force	Horizontal Bone Loss		
	Healthy	HBL 33%	HBL 66%
0.25 N	$\sigma_{ech}=0.171$ MPa	$\sigma_{ech}=0.171$ MPa	$\sigma_{ech}=0.171$ MPa
	$\sigma_c=0.0877$ MPa	$\sigma_c=0.03$ MPa	$\Sigma c=0.0419$ MPa
	$f=0.0614$ mm	$f=0.0563$ mm	$f=0.105$ mm
1 N	$\sigma_{ech}=0.685$ MPa	$\sigma_{ech}=0.685$ MPa	$\sigma_{ech}=0.685$ MPa
	$\sigma_c=0.351$ MPa	$\sigma_c=0.12$ MPa	$\sigma_c=0.168$ MPa
	$f=0.245$ mm	$f=0.225$ mm	$f=0.419$ mm
3 N	$\sigma_{ech}=2.05$ MPa	$\sigma_{ech}=2.05$ MPa	$\Sigma ech=2.05$ MPa
	$\sigma_c=1.05$ MPa	$\sigma_c=0.36$ MPa	$\sigma_c=0.503$ MPa
	$f=0.736$ mm	$F=0.676$ mm	$f=1.26$ mm
5 N	$\sigma_{ech}=3.42$ MPa	$\sigma_{ech}=3.42$ MPa	$\Sigma ech=3.42$ MPa
	$\sigma_c=1.75$ MPa	$\Sigma c=0.6$ MPa	$\sigma_c=0.839$ MPa
	$f=1.23$ mm	$F=1.13$ mm	$f=2.1$ mm

Representative iconographic elements in cases of intrusion of the maxillary lateral incisor using an 1N force (Figs. 1-3).

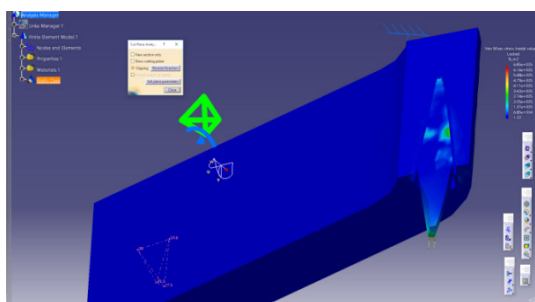


Fig.1A. Von Mises tensions, unaffected periodontium

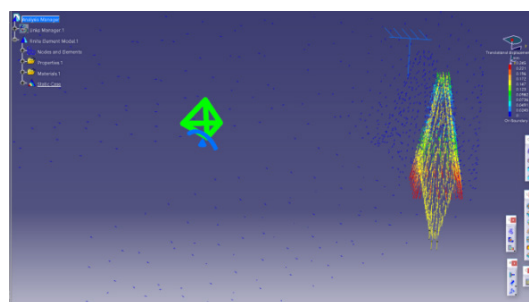


Fig. 1B. Resulting displacement, unaffected periodontium

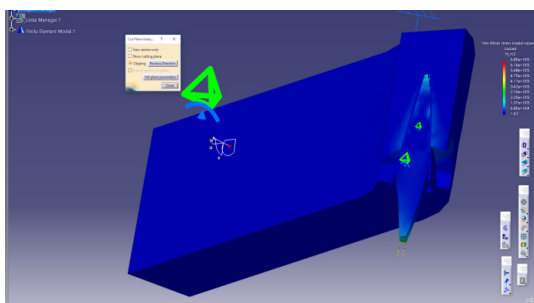


Fig. 2A. Von Mises tensions, periodontium affected 33%

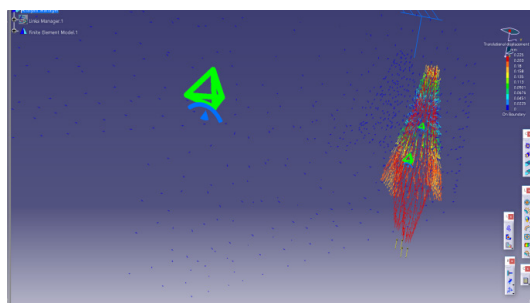


Fig. 2B. Resulting displacement, periodontium affected 33%

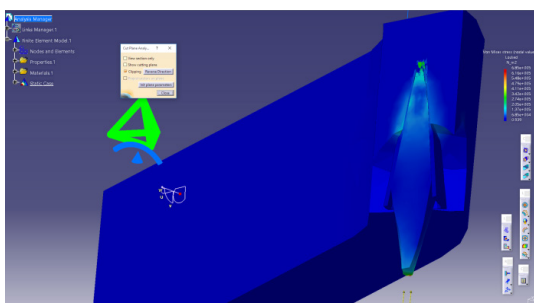


Fig. 3A. Von Mises tensions, periodontium affected 66%

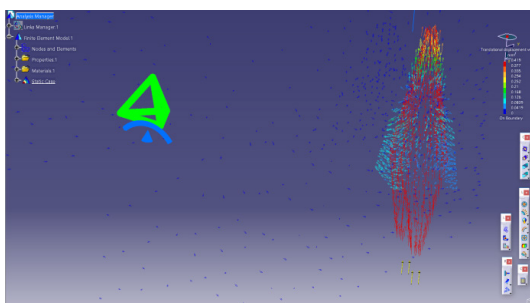


Fig. 3B. Resulting displacement, periodontium, affected 66%

Representative iconographic elements in cases of intrusion of the maxillary lateral incisor using a 3 N force (Figs. 4-6).

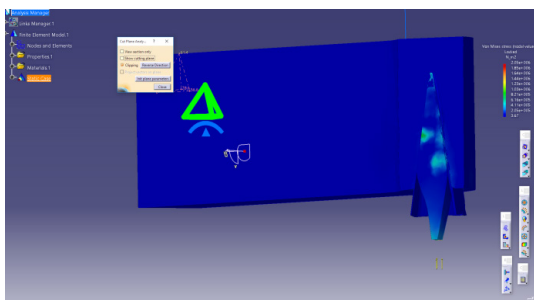


Fig. 4A. Von Mises tensions, unaffected periodontium

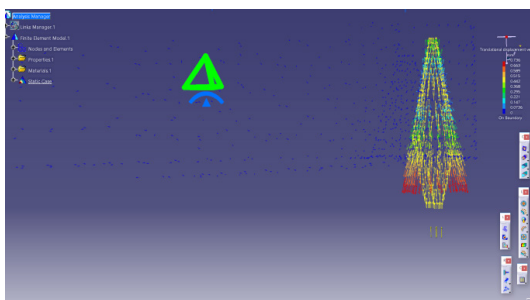


Fig. 4B. Resulting displacement, unaffected periodontium

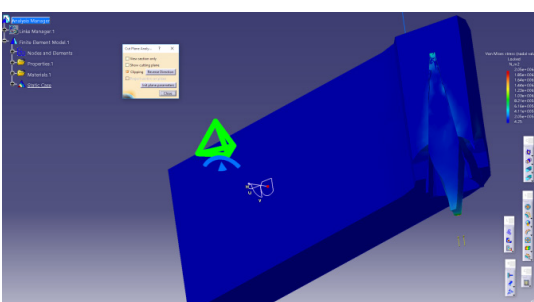


Fig. 5A. Von Mises tensions, periodontium affected 33%

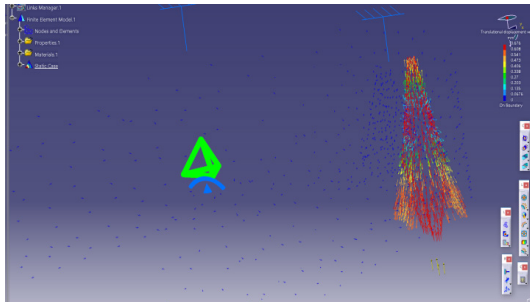


Fig. 5B. Resulting displacement, periodontium affected 33%

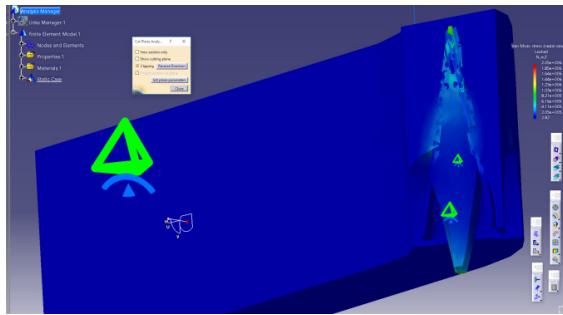


Fig. 6A. Von Mises tensions, periodontium affected 66%

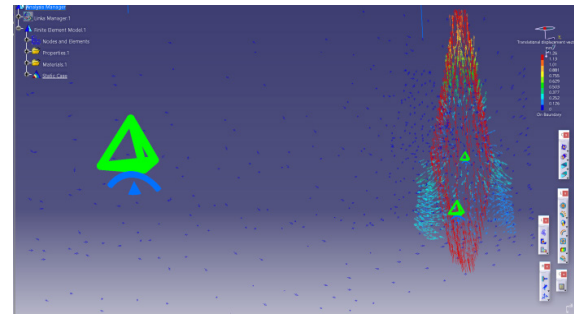


Fig. 6B. Resulting displacement, periodontium, affected 66%

In the maxillary lateral incisor (MLI), the results briefly presented below were obtained.

1. Equivalent tension in the tooth-periodontal ligament - alveolar bone complex [σ_{ech}] (Fig. 7)

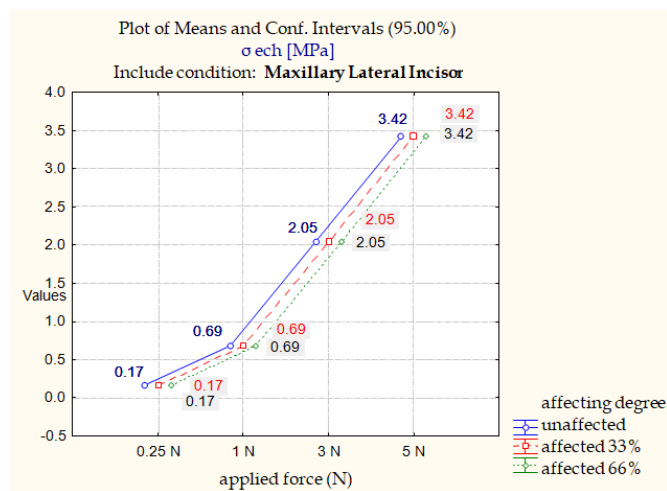


Fig. 7. Values of σ_{ech} as a function of the extent of HBL and applied force

Predictive factors for the modification of the equivalent tension values in the tooth-periodontal ligament - alveolar bone complex [σ_{ech}]

The present study assessed, using multivariate analysis, the importance of the parameters influencing the σ_{ech} tension values, the included independent variables being the applied force and the extent to which the periodontium is affected. Analysis of the results of the multiple correlation shows that only the applied force has a major impact on σ_{ech} ($\beta_f=0.99$, $p<<0.001$).

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2. Tension in the direction in which the force is applied, in this case a force perpendicular to tooth's incisal surface [σ_c] (Fig. 8)

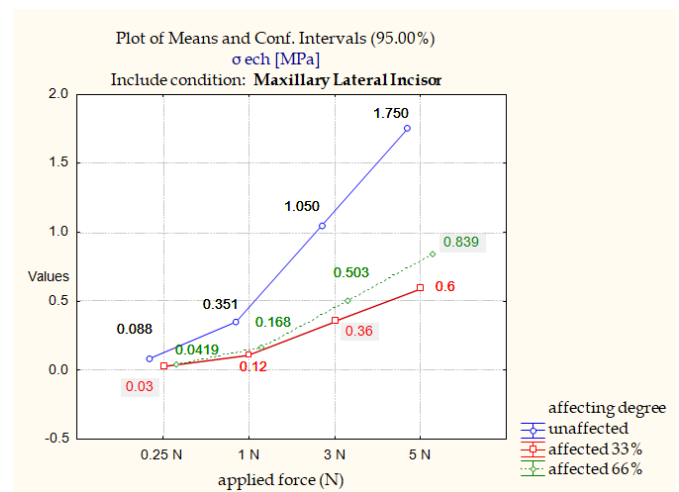


Fig. 8. Values of σ_c as a function of the extent of HBL and applied force

The σ_c values show a linear growth, depending on the force applied wherever the periodontium is not affected and where it is affected up to 33% and 66%. (Fig. 9) In the cases in which the periodontium is unaffected, the σ_c values show significantly higher values compared to those seen in the cases in which the periodontium is affected, and the increase depending on the applied force is exponential. To conclude with, in this situation, the values of σ_c differ significantly, depending both on the degree to which the periodontium is affected and on the applied force.

Predictive factors of the modification of the tension values in the direction in which the force is applied, in this case a force perpendicular to tooth's incisal surface [σ_c].

The study evidenced, using multivariate analysis, the importance of the parameters influencing the σ_c tension values, the included parameters being the applied force and the extent to which the periodontium is affected.

3. Orthodontic tooth movement as a result of the applied force f (Fig. 9)

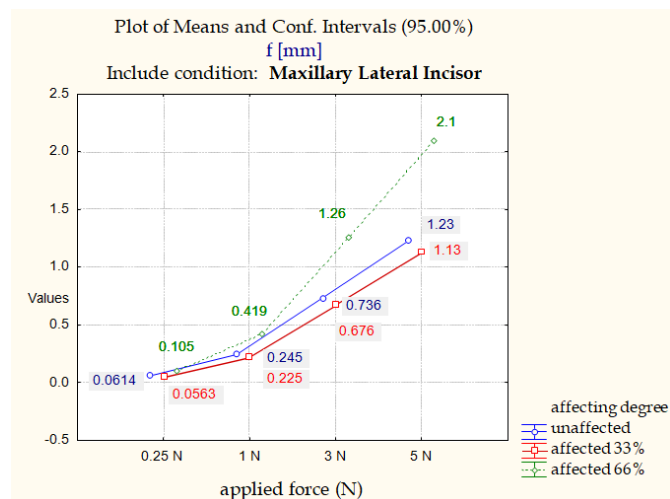


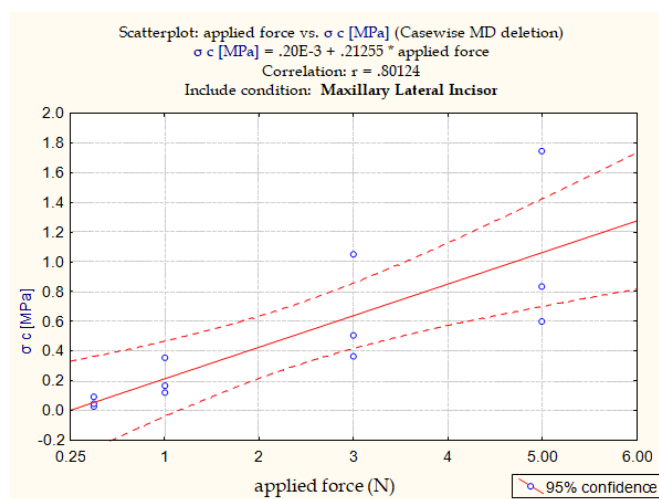
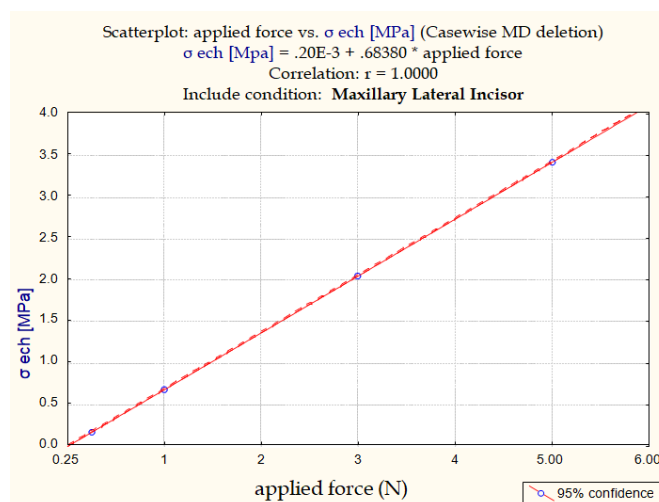
Fig. 9. Values of f as a function of the extent of HBL and applied force

The values of displacement resulting from the application of force have a significant linear increase, along with the increase in the magnitude of the applied force, in cases with no initial periodontal disease and in cases affected up to 33%, with no statistically significant differences between the non-affected and the affected ones. (Fig.10) Wherever the periodontium is affected up to 66%, the increase of the f values depending on the applied force is exponential, along with significantly higher values than those registered in cases in which the periodontium was not affected or it was affected to an extent of 33% ($H=0.54$, $p=0.08$, 95% CI).

Predictive factors of the modification of displacement values as a result of an intrusion force application

The subsequent study established, using multivariate analysis, the importance of the parameters influencing the values of displacement as a result of the applied forces, the independent variables being the applied force and the extent to which the periodontium is affected.

Analysis of the results of multiple correlation shows that the applied force has a major impact upon f ($\beta_f=0.905$, $p=0.00001$), and also that the presence of the periodontal disease ($\beta_{Af.P}=0.27$, $p=0.035$) significantly influences the f values. (Fig 10)



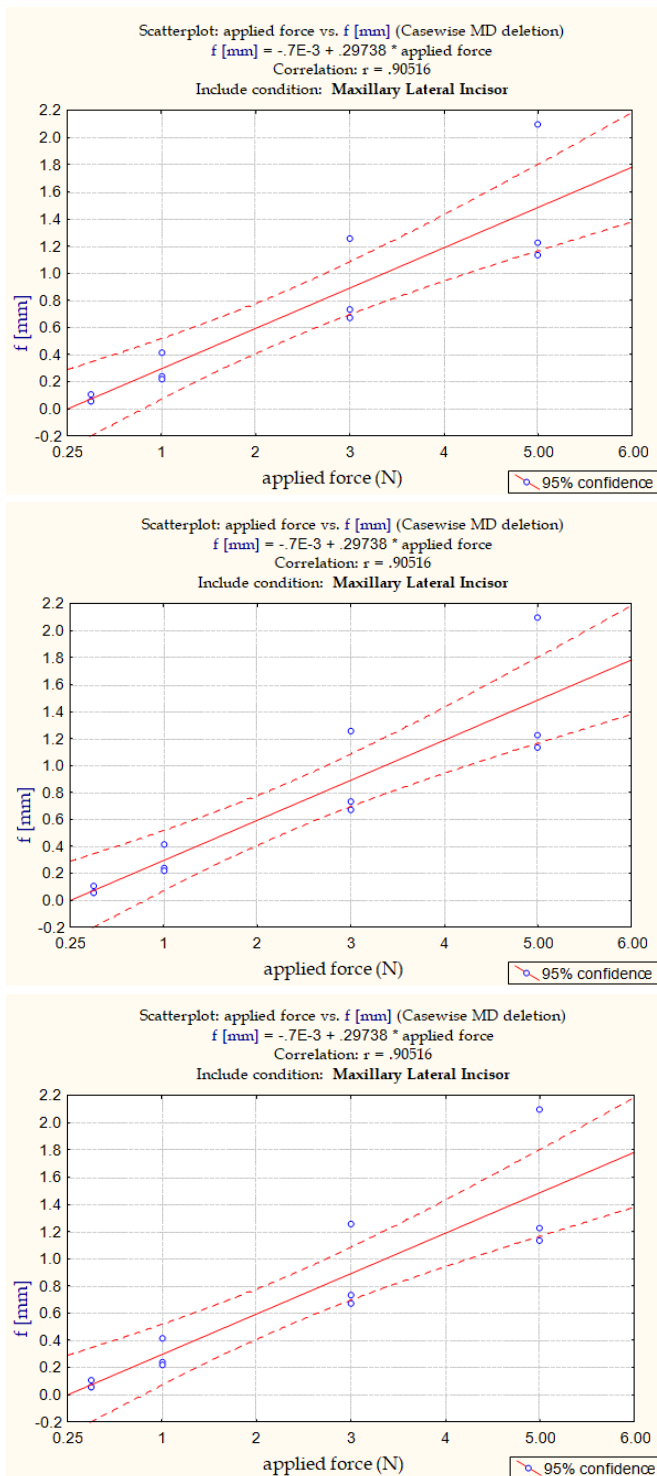


Fig. 10. Regression line in the correlation σ_{ech} , σ_c and f vs. applied force

During intrusion of the maxillary lateral incisors, the equivalent tension in the tooth-periodontal ligament-alveolar bone complex ($\sigma_{ech} - r=0.99$) was seen as being mostly affected

by the magnitude of the applied force; the following affected value is the displacement ($f - r=0.90$), and the last one is the value of the tension in the direction in which the force is applied ($\sigma_c - r=0.80$). (Table V)

In the maxillary frontal group, the values of σ_{ech} show an exponential increase depending on the applied force, and on whether the periodontium is affected or not.

The values of σ_{ech} remain constant for each level of the applied force, both for the situations with existing periodontal pathology and without periodontal troubles.

Considering all the above aspects, one can conclude that the decision to perform intrusion for improving implanting is justified, because the implant alternative is also subject to a number of risks and complications. [11-15]

In patients with a systemic pathology, it is necessary to carry out comprehensive assessments, and the periodontal treatment must be adapted depending on the specificities of each case, before starting any intrusive type orthodontic tooth movements. [16-21]

In the case of intrusion of maxillary lateral incisors, the values of σ_c decrease, along with the onset of the periodontal disease, but increase slightly together with the magnitude of forces, whereas, for the intrusion of the maxillary central incisors, other studies showed that the values of σ_c increase proportionally both with the magnitude of the forces and also with the extent to which the periodontium is affected, from 33 to 66%.

In cases in which the periodontium is not affected, the values of σ_c have significantly higher values compared to those recorded in the case of affected periodontium in the maxillary frontal group.

In cases in which the periodontium is affected up to 66%, increase of the values of displacement through intrusion, f , depending on the magnitude of the applied force, is exponential; it also has significantly higher values than in the cases in which the periodontium is not affected or in which it is affected to an extent of 33%.

4. CONCLUSIONS

In the maxillary frontal group, the values of σ_{ech} show an exponential increase, depending either on the applied force or whether the periodontium is affected or not.

In cases in which the periodontium is not affected, the values of σ_c have significantly higher values compared to those registered in the case of affected periodontium.

In the situation in which the periodontium is affected up to 66%, the increase of the values of orthodontic tooth movement through intrusion, f , depending on the magnitude of the applied force, is exponential; it also has significantly higher values than in the cases in which the periodontium is not affected or it is affected to an extent of 33%.

The magnitude of the intrusion forces in the maxillary lateral incisor influences primarily the values of equivalent tension, then those of displacement, and lastly those of the tensions in the direction in which the force is applied.

It appears that the maxillary lateral incisor has a better intrusive periodontal prognosis than the maxillary central incisor, even in the context of slightly super-optimal forces.

References

1. Martu I, Luchian I, Diaconu-Popa D, Doscas AR, Bosanceanu DG, Vitalariu A, Luca O, Tatarciuc M. Clinical and technological particularities regarding unidental restoration using ceramic crowns with a zirconia infrastructure. A case report. *Rom J Oral Rehab.* 2017;9(1):27-31.
2. Becker A, Zogakis I, Luchian I, Chaushu S. Surgical exposure of impacted canines: Open or closed surgery? *Semin Orthod.* 2016;22(1):27-33.
3. Luchian I, Vata I, Martu I, Tatarciuc M, Pendefunda V, Martu S. Challenges in Ortho-Perio and General Dentistry Interrelationship. Limits and Perspectives. *Rom J Oral Rehab* 2016;8(1):80-3.
4. Ogodescu AS, Morvay AA, Balan A, et al. Comparative Study on the Effect of Three Disinfection Procedure on the Streptococcus pyogenes Biofilm Formed on Plastic Materials Used in Paedodontics and Orthodontics. *Mater Plast.* 2017;54(1):116-8.
5. Luchian I, Vata I, Martu I, Stirbu C, Sioustis I, Tatarciuc M, Martu S. The Periodontal Effects of an Optimal Intrusive Force on a Maxillary Central Incisor. A FEM Evaluation. *Rom J Oral Rehab.* 2016;8(2):51-5.
6. Luchian I, Moscalu M, Martu I, Curca R, Vata I, Stirbu C, Tatarciuc M, Martu S. A FEM Study regarding the Predictability of Molar Uprighting Associated with Periodontal Disease. *International Journal of Medical Dentistry.* 2018;22(2):183-8.
7. Martu I, Luchian I, Goriuc A, Tatarciuc M, Ioanid N, Cioloca DP, Bodnariu GE, Martu C. Comparative Analysis of some Antioxidant Markers in Periodontal Disease. *REV.CHIM. (Bucharest).* 2016;67(7):1378-81.
8. Luchian I, Martu I, Ioanid N, Goriuc A, Vata I, Martu-Stefanache A, Hurjui L, Tatarciuc M, Matei MN, Martu S. Salivary IL1 β : a Biochemical Marker that Predicts Periodontal Disease in Orthodontic Treatment. *REV.CHIM. (Bucharest).* 2016;67(12):2479-83.
9. Luchian I, Martu I, Goriuc A, Vata I, Hurjui L, Matei MN, Martu S. Salivary PGE2 as a Potential Biochemical Marker during Orthodontic Treatment Associated with Periodontal Disease. *REV.CHIM. (Bucharest).* 2016;67(10):2119-23.
10. Luchian I, Martu I, Martu C, Goriuc A, Beldiman A, Martu S.. Changes in Biochemical Parameters Associated with Periodontal Disease. *REV.CHIM. (Bucharest).* 2016; 67(6):1073-5.
11. Nicolae V, Chiscop I, Ibric Cioranu VS, Martu MA, Luchian AI, Martu S, Solomon SM. The Use of Photoactivated Blue-O Toluidine for Periimplantitis Treatment in Patients with Periodontal Disease. *REV.CHIM. (Bucharest).* 2015;66(12):2121-23.
12. Solomon SM, Stoleriu S, Forna AD, Tampu D, Martu A, Ursarescu IG, Martu S. The Quantitative and Qualitative Assessment of Dental Substance Loss as Consequence of Root Planing by Three Different Techniques. *Mater Plast.* 2016;53(2):304-7.
13. Martu I, Goriuc A, Martu MA, Vata I, Baciu R, Mocanu R, Surdu AE, Popa C, Luchian I. Identification of Bacteria Involved in Periodontal Disease Using Molecular Biology Techniques. *REV. CHIM. (Bucharest).* 2017;68(10):2407-12.
14. Solomon SM, Filioreanu AM, Stelea CG, Grigoras SI, Sufaru IG, Maftai GA, Martu S, Scutariu MM, Popa C. The Assessment of the Association Between Herpesviruses and Subgingival Bacterial Plaque by Real-time PCR Analysis. *REV. CHIM. (Bucharest).* 2018;69(2):507-10.
15. Solomon SM, Filioreanu AM, Stelea CG, Grigoras SI, Sufaru IG, Maftai GA, Martu S, Scutariu MM, Popa C. Assessment of the Association Between Herpesviruses and Subgingival Bacterial Plaque by Real-time PCR Analysis. *REV. CHIM. (Bucharest).* 2018,69(2):507-10.
16. Solomon S, Pasarini L, Ursarescu I, Martu I, Bogdan M, Nicolaiciuc O, Ioanid N, Martu S. The effect of non-surgical therapy on C reactive protein and IL-6

- serum levels in patients with periodontal disease and atherosclerosis. *Int J Clin Exp Med*. 2016;9(2):4411-7.
17. Solomon SM, Matei M, Badescu AC, Jelihovschi I, Martu-Stefanache A, Teusan A, Martu S, Iancu LS. Evaluation of DNA Extraction Methods from Saliva as a Source of PCR - Amplifiable Genomic DNA. *REV. CHIM. (Bucharest)*. 2015;66(12):2101-03.
18. Boatca RM, Scutariu MM, Rudnic I, Martu Stefanache MA., Hurjui L, Rezus E, Martu S. Evolution of Inflammatory Biochemical Markers Within Periodontal Therapy to Patients with Rheumatoid Arthritis. *REV. CHIM. (Bucharest)*. 2016;67(4):741-4.
19. Martu S, Nicolaiciuc O, Solomon S, Sufaru I, Scutaru M, Rezus C, Popescu E. The Evaluation of the C Reactive Protein Levels in the Context of the Periodontal Pathogens Presence in Cardiovascular Risk Patients. *REV. CHIM. (Bucharest)*. 2017;68(5):1081-4.
20. Sufaru IG, Solomon SM, Pasarin L, Martu-Stefanache MA, Oanta AC, Martu I, Ciocan-Pendefunda A, Martu S. Study regarding the quantification of RANKL levels in patients with chronic periodontitis and osteoporosis. *Rom J Oral Rehab*. 2016;8(4):42-46.
21. Martu MA, Solomon SM, Sufaru IG, Jelihovschi I, Martu S, Rezus E, Surdu AE, Onea RM, Grecu GP, Foia L. Study on the prevalence of periodontopathogenic bacteria in serum and subgingival bacterial plaque in patients with rheumatoid arthritis. *REV. CHIM. (Bucharest)*. 2017;68(8):1946-9.