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Effekt of Design Modifikations on Lingual Bars Rigidity

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Introduction

It has been widely accepted that rigidity is one of the desirable characteristics of removable partial dentures major connectors. Failure of the major connectors to provide rigidity may damage the supporting oral structures like abutment teeth, residual ridges and underlying tissues. The basic forms of mandibular major connectors are half-pear and half-oval. The dentist and the dental technician are responsible for the appropriate design and achievement of the major connectors depending on each clinical situation. The relative height of the floor of the mouth is very important.

Objectives

The aim of the research was to investigate the effect of lingual bar major connector design on flexing and torque resistance by means of three-dimensional finite element analysis.

Material and Methods

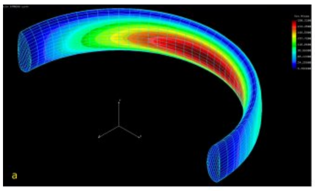
Eighteen designs of lingual bars of different cross-sectional shapes and dimensions (4-5 mm height, 1.5-3 mm thickness, 0.3-0.75 thickness/height ratio) were developed using finite element analysis modeling. The geometrical models of these were generated using three-dimensional elements. A three-dimensional finite element analysis software (Cosmos/M, version 2.5; Structural Research and Analysis, Santa Monica, California) was used for the study of structural simulations. The finite element method was selected because it is known as an established theoretical technique for engineering problems.

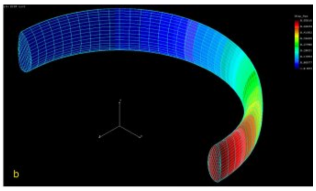
Two groups of half-pear and half-oval shapes with different cross-sections (5.88-10.59 mm²) were constructed for comparison. The analysis required the creation of a computer simulated model. The basic procedure was to consider the complete structure as an assemblage of individual elements. Therefore, each model was divided or meshed into 4000 individual, finite elements. Eight-node three-dimensional elements were used. Adjacently elements were connected to 5324 nodes on their common boundaries.

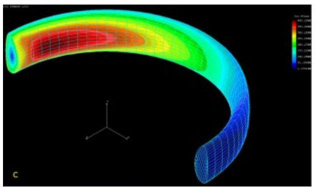
In building the finite element model, the characteristics of the Co-Cr alloy (Wironium®LA; Bego, Bremen, Germany) used for the framework were entered into the computer programme. The characteristics included were: tensile strength (Rm) of: 940 MPa, ductile yield (Rp0.2) of: 640 MPa, elasticity modulus (E) of: 2.2×10^5 MPa, Vickers hardness (HV) of: 360, and Poisson's ratio (v) of: 0.3. Vertical and horizontal forces of 30 N were applied to one end of the bars, while the opposite side was fixed in all directions. Considering that the load values used were those that appear normally during mastication, it was sufficient to limit the study at this interval.

The rigidity of the experimental Co-Cr major connectors was evaluated by measuring relative displacements and von Mises stresses generated under simulated torsional and compressive loads for both groups. Generated Von Misses equivalent stresses and displacements were calculated numerically and plotted graphically. Results were displayed as coloured stress contour plots to identify regions of different stress concentrations. For each load case, its own legend was attached, where stresses are reproduced in MPa and displacements in mm. Figures 1-4 display the Von Mises equivalent stress which was evaluated for all situations considered, under different loading values.

Results







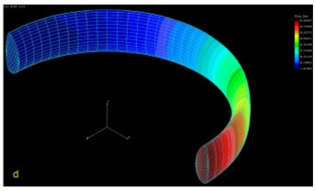


Fig. 1. Results of the finite element analysis of a half-pear lingual bar (dimensions 5 mm/2 mm): a. stresses under compressive load, b. displacements under compressive load, c. stresses under torsional load, d. displacements under torsional load.

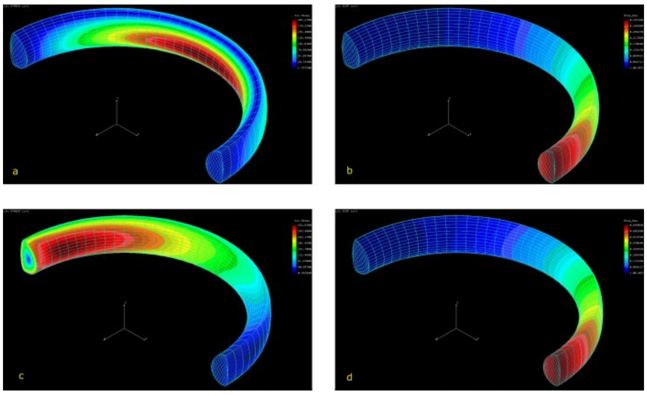


Fig. 2. Results of the finite element analysis of a half-pear lingual bar (dimensions 4 mm/2.5 mm): a. stresses under compressive load, b. displacements under compressive load, c. stresses under torsional load, d. displacements under torsional load.

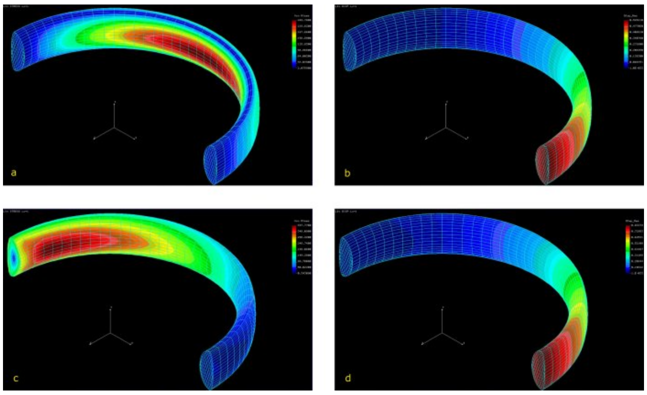


Fig. 3. Results of the finite element analysis of a half-oval lingual bar (dimensions 5 mm/2 mm): a. stresses under compressive load, b. displacements under compressive load, c. stresses under torsional load, d. displacements under torsional load.

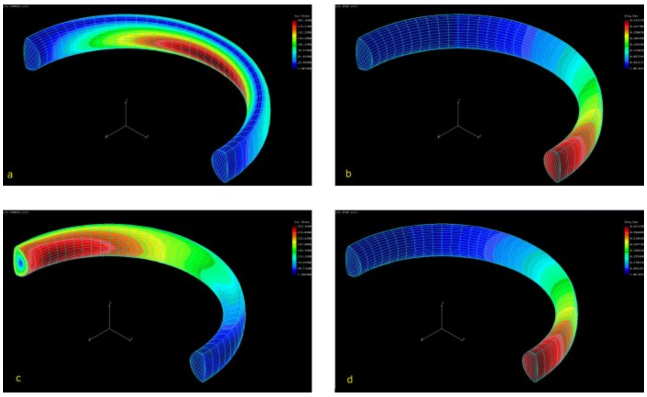


Fig. 4. Results of the finite element analysis of a half-oval lingual bar (dimensions 4 mm/ 2.5mm): a. stresses under compressive load, b. displacements under compressive load, c. stresses under torsional load, d. Displacements under torsional load.

Stresses and displacements under compression loading simulating vertical forces were lower than those obtained for torsional loading simulating horizontal forces (61-63% for stresses and 41-74% for displacements). The displacements for compressive loading became closer to them for torsional loads with the decrease of the thickness/height ratio. Resulted displacements and stresses were smaller for bars with an increased thickness/height ratio. Values measured for half-oval designs were not significantly higher than those for the half-pear shapes (table 1).

Table 1. Stresses and displacements under compression and torsional loading for all load cases.

Load case	Height (mm)	Thickness (mm)	Section area (mm²)	Stress under compressive load (MPa)	Displacement under compressive load (mm)	Stress under torsional load (MPa)	Displacement under torsional load (mm)
1	5	2.5	9.810	160.750	0.272	255.990	0.470
2	5	2	7.849	250.320	0.558	401.290	0.844
3	5	1.5	5.888	442.450	1.394	714.280	1.872
4	4.5	3	10.594	124.600	0.167	199.160	0.361
5	4.5	2.5	8.829	178.770	0.303	284.880	0.560
6	4.5	2	7.064	278.300	0.621	446.810	0.989
7	4	3	9.417	140.300	0.188	229.040	0.453
8	4	2.5	7.848	201.270	0.341	322.630	0.689
9	4	2	6.279	313.220	0.700	504.340	1.190
10	5	2.5	9.810	160.590	0.265	253.340	0.464
11	5	2	7.849	249.780	0.545	397.770	0.833
12	5	1.5	5.888	440.810	1.368	709.150	1.849
13	4.5	3	10.594	124.640	0.163	193.790	0.357
14	4.5	2.5	8.829	178.640	0.295	281.150	0.553
15	4.5	2	7.064	277.800	0.607	442.170	0.976
16	4	3	9.417	140.370	0.184	221.810	0.448
17	4	2.5	7.848	201.160	0.333	315.260	0.681
18	4	2	6.279	312.750	0.684	498.440	1.174

Conclusions

The results of this in vitro study suggest that the thickness of the lingual bar major connector should be increased to improve the rigidity of the framework to torsional and compressive loads.
Cross-section shapes of the lingual bars have a lesser effect on rigidity from biomechanical point of view.

Literature

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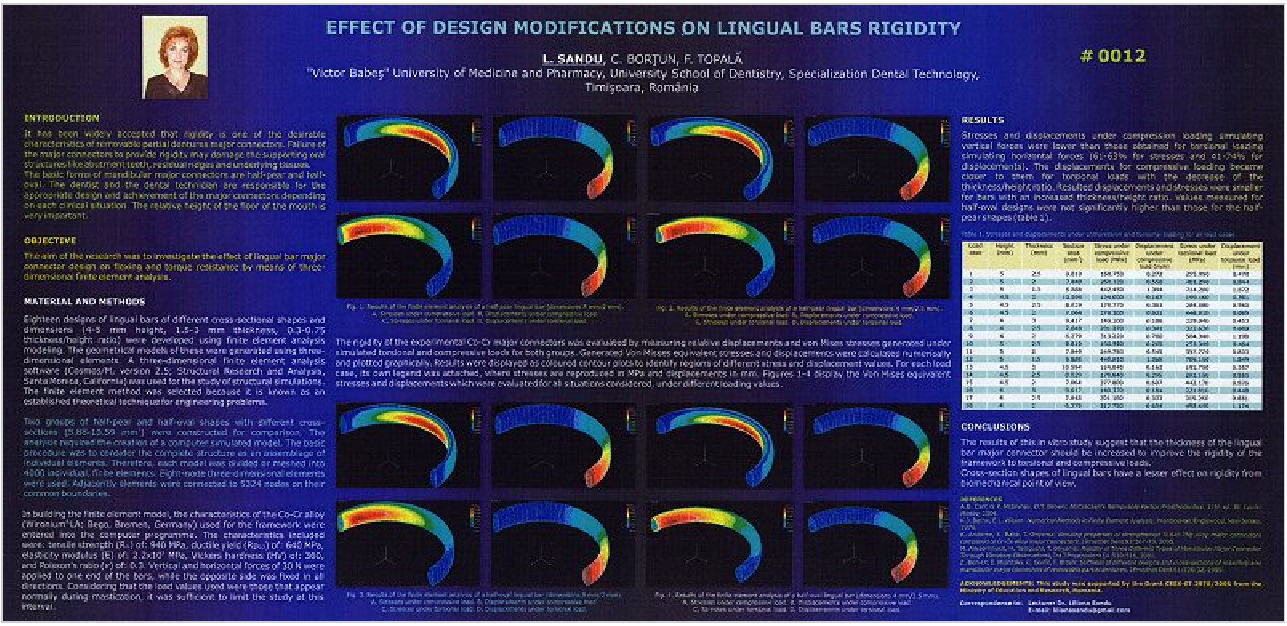

EFFECT OF DESIGN MODIFICATIONS ON LINGUAL BARS RIGIDITY

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