BIOMECHANICAL STABILITY OF ANTERIOR FIXATION IN CERVICAL SPINE OF SWINES

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***Abstract**. The fixation system has been extensively used in modern spine surgery in order to provide stability of the vertebral segment and/or to correct deformities. The objective of the current study was evaluate the biomechanical stability of anterior vertebral fixation with graft and H-plate during flexion-compression, lateral flexion and torsion strengths. The experimental models were constituted by vertebrae, H-plate, graft and cervical screws. Thirty vertebral were divided in three experimental groups. Group1(n=10): Intact vertebrae. Group 2 (n=10): An assembly with a graft. Group 3 (n=10): An assembly with graft and H-plate. Mechanical assays of flexion-compression, lateral flexion and torsion were performed with a Universal Testing Machine EMIC® using specific acessories for each type of test. Data were statistically analyzed by ANOVA and by Tukey-Kramer tests, with the level of significance of 5%. The measured parameters in each mechanical assay were: maximum strength, stiffness and bending. The behaviors of all the analyzed parameters during flexion-compression assays showed that the group three had the highest mechanical values followed by the group two and, the group one reached the smallest results (G3>G2>G1). There was statistical difference between the intact group and the group with graft plus H-plate. To the lateral flexion assays, the group one had the highest mechanical values followed by the group three and, the group two obtained the smallest results (G1>G3>G2). There was statistical difference between intact group and graft, and also between intact group and the group with graft plus H-plate. To the torsion assays the behavior of the results was similar to the anterior parameter (G1>G3>G2), but the significant difference was between the intact group and the group with graft. So, we concluded that the H-plate was able to re-establish the biomechanical stability during flexion and torsion moviments but did not re-establish during the lateral flexion.*

***Keywords**: Cervical Spine, H-plate, Cervical Screw, Graft, Mechanical Tests*

1. INTRODUCTION

The cervical spine in humans is very susceptible to traumas occurred by automobilist, occupational and sports accidents that can cause fractures and luxation and consequently instability and disorders. These lesions change the biomechanical function of the spine providing additional overload to the stable structures and make easier the damage of the spine cord and nervous roots by compression or crush, causing in many cases irreversible neurological deficits.

In focus to provide the alignment and its maintenance, the protection of the Central Nervous System (CNS) and the early rehabilitation of the patients, several surgical techniques were developed to the stability and alignment of the spine (AN, 2001).

The first studies of the arthrodesis of the cervical spine were realized in the 50 and 60 decades (LAMBIRIS et al., 2003), and in the 70, Orosco and Llovet (apud LAMBIRIS et al., 2003) made *osteossíntese* by anterior side with metal plates with evolution to H shape and in 1976, Senegas and Gauzere described the use of an H plate similar to the Association Study Internal Fixation (ASIF).

Nowadays, the use of anterior *osteossíntese* of the inferior cervical spine with inoxidable steel or titanium H plates increased significantly in the surgeries to the stabilization of the lesions, specially in the anterior spine lesions such as fractures of the vertebral body and the fractures with luxation and *osteoligamentares* lesions, predominantly posterior (LAMBIRIS et al.; AEBI et al., 1991).

However, in spite of being widely used in the surgeries for cervical spine stabilization, the results of biomechanics assays studies are still discussed in the literature to determine the mechanical resistance in experimental models undergone to flexion and traction strengths (DO KOH, et al., 2001; RICHTER, et al., 1999; GRUBB, et al., 1998; MONTESANO, et al., 1991; ULRICH et al., 1991; OLIVEIRA, 1987), as well as the influence of variables involved in the models assembly, such as: thickness, graft shape and material plates (inoxidable steel or titanium) in the resistance of the cervical spine fixations (TRUUMEES, 2002).

The purpose of this study was evaluate the biomechanical stability of the anterior fixation with H plates using swine cervical vertebrae during mechanical flexion-compression, lateral flexion and torsion assays.

2. MATERIAL AND METHODS

2.1. Preparation of the experimental models

In this study swine vertebrae, H plates, cervical screws and grafts were used to the preparation of the experimental models. The swine spine was obtained from Cold Storage from Ribeirão Preto region. The cervical vertebrae were isolated, dissected and cleaned of soft tissues. After this, they were frozen in Freezer at -20ºC, until the day of the models assembly and the realization of the mechanical assays. Thirty segments were used (C3-C4) , from Landrace pigs that were abated when they got adult (around 150 days), with weight between 80 and 90 kilogrammes (kg), without difference of gender.

Ten monosegment H plates were used with 5 holes in inoxidable steel F138 with 28 millimeters (mm) of length (Picture 2A) and 20 screws with 3,5 mm of thread in inoxidable steel 138, with 20 mm of length. Both of them are from the Trautec® company.

The graft with elliptic shape was made with swine vertebral body (aleatory) of the cervical segments that were not used in the assays. The measures were 25 mm of length, 15 mm of width and 3 mm of thickness (Figure 1).

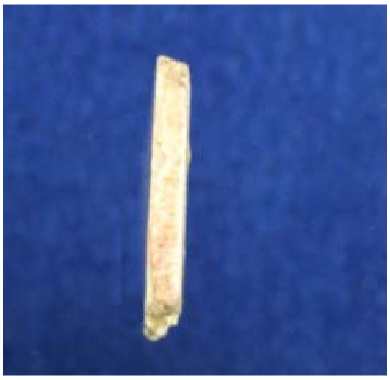

Figure 1. Graft of 3 mm of thickness.

2.2. Experimental groups

The experimental group was based on the use of the swine cervical segments with different type of lesions artificially produced in the intervertebral discs and ligaments. The vertebral spine was sectioned in the suboccipital region and 7th cervical vertebrae level. With a scalpel, the cervical segments C3 and C4 were isolated from the spine. After this, the vertebrae was sectioned taking off the paravertebral muscle, ligaments and intervertebral discs which are a part of the segment stability complex.

After providing the lesions, the arthrodesis with inoxidable steel H plates and grafts with thickness of 3 mm were made in order to increase the stability of the vertebral segment. To the experimental models assembly, the cervical segments C3 and C4 were fixed in a screw vice to avoid any movement during the perforation of the vertebral body.

Using a guide, four hole in the vertebral body were made with a manual electrical drilling machine and a metal drill with 2 mm of thickness. After that each hole was made, a guide line was inserted in order to avoid movement of the plate.

The inoxidable steel H plate was fixed to the vertebral bodies with intracortical screws and the final insertional torque was measured and standarded at 0,4 N.m, evaluated with a Mackena® torquimeter. The experimental models were divided in 3 groups with 10 specimens in each group to realize the mechanical assays.

2.2.1. Group I: Intact

The cervical segments (C3-C4) (Picture 4) were isolated from the spine and dissected, taking the adjacent muscle off, but keeping the ligaments and intervertebral discs (n=10).

2.2.2. Group II: 3 mm graft

The cervical segment (C3-C4) were isolated from the spine and dissected, taking the adjacent muscle off and undergone to the discectomy, but keeping the posterior ligaments. A 3 mm graft from vertebral body was inserted in the place of the intervertebral disc (n=10).

2.2.3. Group III: Fixation with Inox plate and 3 mm graft

After the preparation of the cervical segments and realized the discectomy keeping the posterior ligaments, a 3 mm graft of thickness was inserted and the assembly with plate was done (n=10)(Figure 2).

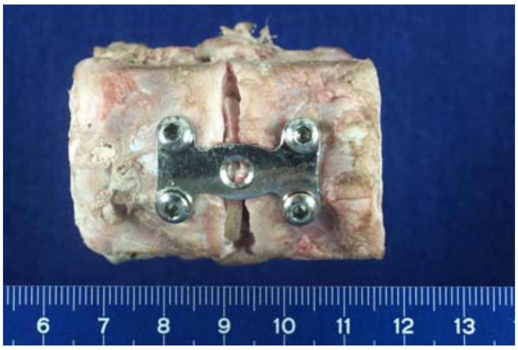

Figure 2. Cervical segment C3 and C4 with H plate and graft of 3mm of thickness.

2.3. Mechanical assay

The specimens were undergone to flexion-compression, flexion lateral and torsion (axial rotation), allowing the comparison of the mechanical properties of the models, such as: bending, *momento rotacional* and stiffness. The mechanical assays were done with an universal assay machine - EMIC® from the Laboratory of Bioengineering of the Faculty of Medicine of Ribeirão Preto of University of São Paulo (FMRP-USP). The datas were analyzed by the Tesc® program. A cell of load with capacity to measure until 200 Kgf was used during the mechanical assays. The assays and the type of assays were based on studies made by Defino, Néri and Shimano in 2006.

2.3.1. Flexion test

To the flexion-compression mechanical assay was programmed a pre load with 10 N, application speed of 5 mm/min and linear deformation limit of 4 mm. The vertebral segments were placed horizontally with the spinal process faced inferiorly, into a cylindrical accessory fixed in a metal platform that was fixed in the universal assay machine. In order to allow the placement of the models in the cylindrical accessory, the transverse and spinal processes were sectioned (Figure 3).

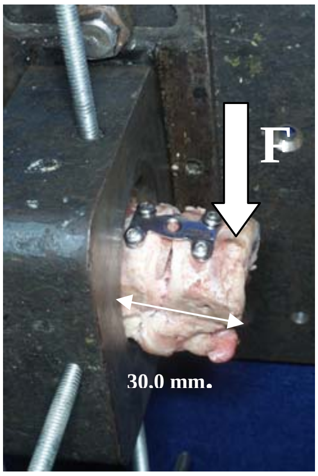

Figure 3. Placement of the specimen during the flexion test

The point for strength application was in the anterior side of the C4 vertebral body 30 mm from the margin of the cylindrical accessory (bending). The load was applied axially. The tests were recorded by the

Tesc® 1.13 software that created curves of the deflexion versus strength.

The bending and the stiffness were calculated with these curves using a maximal deflexion of 4 mm.

2.3.2. Lateral flexion test

To the lateral flexion tests were used a pre load with 10 N, application speed of 5 mm/min and linear deformation limit of 3 mm. The vertebral segments were placed horizontally parallel to the basis of the machine , fixed in C3, while C4 was free and without support (Figure 4).

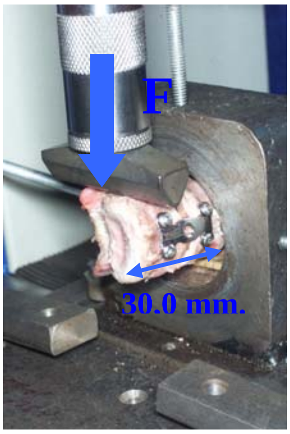

Figure 4: Placement of the specimens in the lateral flexion assay

The load was applied from a distance of 30 mm. of bending in the lateral side of the C4 vertebral body, axially. The bending and the stiffness were calculated using these curves to a deflexion of 3 mm.

2.3.3. Torsion test

To the torsion test was used a pre load with 50 N, application speed of 5 mm/min and linear deformation limit of 6,5 mm was correlated to a rotation of 15º. The vertebral segments were placed horizontally with the spinal process faced inferiorly, into a cylindrical accessory with both the extremity fixed (Figure 5).

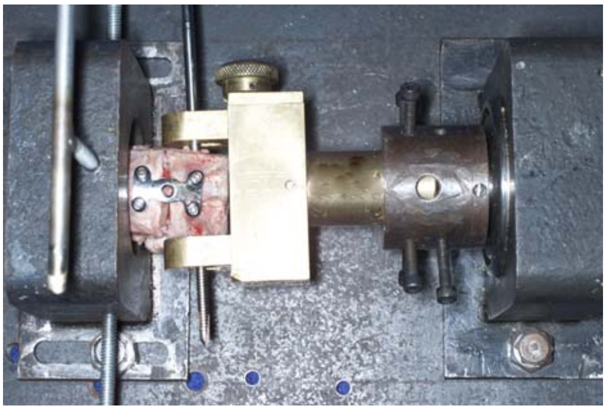

Figure 5.. Placement of the specimens in the torsion assay

One of the extremities had a gyratory mechanism that allowed the axial totation of the embassy. An steel cable joined the gyratory mechanism to the universal assay machine, and being fixed to the cell of load a force provided a traction in the model. The bending and the stiffness were calculated using these curves to an angular deflexion of 15º.

2.4. Studied parameter

The bending was defined as the value of the load applied to a deflexion established in each assay multiplied by the length.In the torsion tests (axial rotation), the moment calculated was called by torsion bending. The stiffness means the bending of the linear region of the curve x deflexion, and it was obtained by the calculus of the tangent of the angle of the curve. The stiffness is expressed by M/m, and it is calculated by the tangent of the angle θ (angle between the abscissa and the straight line of the curve).

2.5. Statistical analysis

Initially, datas about strength, bending and stiffness were undergone to the Kolmogorov-Smirnov normality test and all variables in every studied groups agreed the supposition of the datas normality. After this the datas were undergone to the Levene test to evaluate the variation homogeneity. In some groups the homogeneity normality was not enough. In these groups, to re-establish the datas homogeneity, the log (x) transformation was applied. In order to detect differences between the studied groups, the variation analysis of a factor was used (ANOVA-F) and then the Tukey test of multiples comparison. To describe the relation between strength (N) and deflexion (mm) in each assay and lesion group, a linear regression analysis, or not linear, was done, including dispersion graphic and coefficient linear correlation when appropriated. The variables were express by the described measurements, minimal, maximal and mean values, median and deviation standard. The significance level to the statistical tests was α=5%.

3. RESULTS AND DISCUSSION

3.1. Flexion-compression Test

3.1.1 Maximal strength

The table 1 shows the values of the arithmetic mean, median, deviation standard, minimal and maximal of the different groups, to the maximal strength (N) to the 4 mm deflexion in the flexion-compression tests.

Table 1- Arithmetic mean, median and deviation standard of the maximal strength (N) to the flexion test

Groups	Maximal Strength		
	Mean	Median	DS
I	80,81	77,71	26,18
II	110,49	116,66	22,94
III	158,66	153,39	58,34

DS - deviation standard

The datas showed in the table 1 indicate that the smallest arithmetic mean of the maximal strength (N) was obtained from the intact group (GI) (80,81 N ± 26,18 N). There was no statistical difference between GI and GII. The highest arithmetic mean of the maximal strength (N) was obtained from the fixation group with H plates, 3,0 mm graft and intact posterior ligaments (GIII). There was statistical difference between GI and GIII, p=0,0003.The maximal strength mean was reached by the group III (158,66 ± 58,34 N) indicate an increase in the mean maximal strength in 94,34% when compared to the intact group.

3.1.2. Stiffness

The stiffness and the bending are variables dependents of the strength (N). In this way, the behavior in the groups to the mean maximal strength will be similar to the behavior about stiffness and bending.

The table 2 shows the values of the arithmetic mean, median, deviation standard, minimal and maximal from the different groups, to the stiffness (N/m.10^3), in the flexion-compression assays.

Table 2- Arithmetic mean, median and deviation standard of the stiffness (N/m.10^3) to the flexion-compression tests

Groups	Stiffness (N/m.10^3)		
	Mean	Median	DS
I	20,20	19,43	6,53
II	27,62	29,16	5,74
III	39,67	38,35	14,59

DS - deviation standard

The data in the table 2 showed that the smallest values to the stiffness was in the intact group (GI) (20,20 ± 6,53) 10^3 N/m. The statistical analysis indicated significant difference between GI and GIII ($p<0,05$). Between GI and GII there was no statistical difference. The highest measure obtained was from the group III (39,67±14,59). There was statistical difference between GI and GIII.

3.1.3. Bending

The table 3 presents the values of the arithmetic mean, median, deviation standard, minimal and maximal from the different groups, to the bending (N.m), in the flexion-compression assays.

Table 3- Arithmetic mean, median and deviation standard of the bending (N.m) to the flexion tests.

Groups	Bending (N.m)		
	Mean	Median	DS
I	2,42	2,33	0,79
II	3,31	3,49	0,69
III	4,76	4,60	1,75

DS - deviation standard

The smallest result was obtained by GI (2,42 ± 0,79) N.m. The GIII obtained the highest value of bending (4,75 ± 1,75) N.m. There was significant difference between GI and GIII ($p<0,05$).

Based on the datas we can observe that the group with graft and also the group with graft associated with H-plate obtained satisfatory mechanical results being that the values of maximal force, stiffness and bending were higher in group with graft plus H-plate than in the others. And the group with only graft also obtained higher mechanical results than the group intact, but smaller than group with graft plus H-plate.

3.2. Lateral Flexion Test

3.2.1. Maximal strength

The table 4 shows the values of the arithmetic mean, median, deviation standard, minimal and maximal of the different groups, to the maximal force to a 3,0 mm deflexion, in the lateral flexion tests.

Table 4- Arithmetic mean, median and deviation standard of the maximal strength (N) to the lateral flexion tests.

Groups	Maximal Strength		
	Mean	Median	DS
I	118,61	120,84	22,64
II	45,76	43,34	10,54
III	59,84	57,82	5,75

DS - deviation standard

The datas showed in the table 4 indicate that the smallest arithmetic mean of the maximal strength (N) was from the GII that obtained 45,75 N ± 10,54 N. The mean value from GIII was 59,83 ± 5,75 N. The highest arithmetic mean of the maximal force (N) was obtained from the intact group GI (118,61 N ± 22,64N). There was statistical difference between GI and the others (GII, GIII).

3.2.2. Stiffness

The table 5 shows the values of the arithmetic mean, median, deviation standard, minimal and maximal from the different groups, to the stiffness ($N/m.10^3$), in the lateral flexion assays.

Table 5- Arithmetic mean, median and deviation standard of the stiffness to the flexion-compression tests.

Groups	Stiffness ($N/m.10^3$)		
	Mean	Median	DS
I	39,54	40,28	7,55
II	15,25	14,45	3,51
III	19,94	19,27	1,92

DS - deviation standard

The datas showed in the table 5 indicate that the smallest value to the arithmetic mean was obtained by GII $(15,25 \pm 3,51)10^3$ N/m and GIII obtained $(19,94 \pm 1,92)10^3$ N/m.The highest arithmetic mean of the stiffness were obtained by GI $(39,54 \pm 7,55)10^3$ N/m. There was statistical significant difference ($p=0,0001$)

between GI and the others (GII, GIII).

3.2.3. Bending

The table 6 presents the values of the arithmetic mean, median, deviation standard, minimal and maximal from the different groups, to the bending (N.m), in the lateral flexion assays.

Table 6- Arithmetic mean, median and deviation standard of the bending to the lateral flexion tests.

Groups	Bending (N.m)		
	Mean	Median	DS
I	3,56	3,63	0,68
II	1,37	1,30	0,32
III	1,79	1,73	0,17

DS - deviation standard

The smallest mean were obtained by GII (1,37 ± 0,32) N.m and GIII (1,79 ± 0,17) N.m and the GI obtained the highest means to the bending with values of (3,56 ± 0,68) N.m. There was significant difference (p=0,0001) between GI and the other groups.

Based on datas cited it is possible to verify that both graft and H-plate and, even these together, the mechanical results showed a significant difference when compared to intact group.It shows that the graft and graft with H-plate did not re-established the mechanical proprieties of the segment.

3.3. Torsion Tests

3.3.1. Maximal moment

The table 7 shows the values of the arithmetic mean, median, deviation standard, minimal and maximal of the different groups, to the maximal strength to a 6,5 mm deflexion, in the torsion assays.

Table 7- arithmetic mean, median and deviation standard of the maximal strength (N) to the torsion tests.

Groups	Maximal Moment (N.m)		
	Mean	Median	DS
I	318,18	322,04	30,74
II	222,20	230,05	49,16
III	282,70	295,49	38,09

DS - deviation standard

The datas showed in the table 7 indicate that the smallest The smallest value was from GII that obtained 222,20 ± 49,1 N. and the highest arithmetic mean of the maximal strength (N) was obtained by GI (318,18 N ± 30,74) N. There was statistical significant difference between GI and GII (p=0,0006). The mean value from GIII were 282,70 ± 38,09 N.

3.3.2. Stiffness

The table 8 shows the values of the arithmetic mean, median, deviation standard, minimal and maximal from the different groups, to the stiffness ($N/m.10^3$), in the torsion assays.

Table 8- arithmetic mean, median and deviation standard of the stiffness ($N/m.10^3$) to the torsion tests.

Groups	Stiffness ($N/m.10^3$)		
	Mean	Median	DS
I	48,95	49,54	4,73
II	34,18	35,39	7,56
III	43,49	45,46	5,86

DS - deviation standard

The data showed that the smallest value if stiffness were from GIII(34,18±7,56). GIII obtained (43,49 ± 5,86)10^3 N/m and the highest value was obtained by GI (48,54±4,73). There was no statistical difference, (p=0,6327) between GI and GIII.

3.3.3. Bending (N.m)

The table 9 presents the values of the arithmetic mean, median, deviation standard, minimal and maximal from the different groups, to the bending (N.m), in the torsion assays.

Table 9- Arithmetic mean, median and deviation standard of the bending (N.m) to the torsion tests.

Groups	Bending (N.m)		
	Mean	Median	DS
I	9,55	9,66	0,92
II	6,67	6,90	1,47
III	8,48	8,86	1,14

DS - deviation standard

In the torsion assays, the bending was called by torsional moment. The smallest value of torsional moment was obtained by GII (6,67±1,47)N.m. GIII presented as result (8,48 ± 1,14) N.m. There was no statistical difference, p=0,6327, between GI and GIII.

After analyzing the data of the mechanical results of the torsin assay it could be seen that the graf and graft plus H-plate had different properties when compared to inatact group. But the group with graft and H-plate pointed resuts more similar to the intact group.

4. CONCLUSIONS-

The cervical spine anterior arthrodesis associated to H-plate re-established the biomechanical stability during flexion and torsion moviments but did not re-establish during the lateral flexion. It shows that the lateral flexion is the most critical moviment of the cervical spine after an anterior discectomy.

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