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Anterior C2–C3 fixation with screws: proposal of a new technique and comparative mechanical assays

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Abstract The technical difficulties involved in the anterior fixation of the C2–C3 vertebral segment by means of plates and screws, related to retraction of the structures around the vertebral segment, appropriate exposure of the site and positioning of the screws and plate, motivated the development of a new modality of fixation of this segment using only screws. Fixation of the C2–C3 vertebral segment according to the technique proposed requires less exposure of the vertebral segment and does not involve the technical difficulties of standard fixation with plates and screws. In order to study the mechanical properties of this new modality of vertebral fixation, mechanical tests were performed comparing the proposed technique (fixation solely with screws positioned in the craniocaudal direction) and routinely used fixation (H plate and screws). The tests were performed using 80 cervical spine segments from Landrace pigs aged 5 months. The vertebral segments fixed by the two techniques were divided into experimental groups of ten specimens each and submitted to mechanical tests of

flexion, extension, lateral bending and rotation in a universal testing machine. The mechanical properties used to compare the results were the load necessary to produce a pre-established deformation and stiffness. No significant differences were observed between the values obtained for the production of the pre-established deformation in the flexion and rotation tests. In the extension and lateral bending tests, the mean values obtained for vertebral segments fixed only with screws were significantly higher. Analysis of stiffness showed no significant difference in the flexion, rotation and lateral bending tests, whereas in the extension tests, the mean values for the group fixed only with screws were significantly higher. The results of the mechanical tests performed showed that fixation of the C2–C3 segment only with screws was not inferior from a mechanical point of view when compared to fixation with H plates of the Orozco type.

Keywords Cervical spine · Biomechanical testing · Spinal fusion

Introduction

Anterior spinal fusion of the C2–C3 segment is indicated in rare situations such as traumatic axis spondylolisthesis (hangman's fracture) and tumoral lesions [12, 13]. The

procedure for anterior cervical spinal fusion at the C2–C3 level involves technical difficulties related to the adequate exposure of the vertebral segment, retraction of the surrounded tissues and the application of the plate and its screws, which has been the method classically used for the

anterior fixation of this spinal segment [11–13]. The intraoperative difficulty in the fixation of the C2–C3 segment due to the factors mentioned above led us to perform additional fixation of the segment with screws. The stability observed during the surgical act with the use of screws for complementary fixation of the C2–C3 segment led us to think about using these implants separately for the fixation of this vertebral segment.

After the positive experience with the use of screws, we then developed an alternative fixation in order to obviate the technical difficulty in the fixation of this vertebral segment with screws placed in the caudocranial direction between the C3 and C2 vertebral bodies, which act as lag screws that join the vertebral bodies and compress the bone graft used between them.

The objective of the present investigation was to study the biomechanical characteristics of this modality of vertebral fixation by means of mechanical assays and compare it to fixation with plates, which is the method currently used.

Materials and methods

Eighty cervical spines of Landrace swine of both sexes aged 5 months were used in the study. The C2–C3 segment was prepared for study and the intervertebral disc was removed, with only the lateral and posterior portion of the fibrous annulus being left. The C2–C3 segment was stabilized with an Orozco type cervical plate or 4.0 mm cancellous screws, according to the experimental group. In order to standardize the procedure for vertebral fixation, fixed angle guides were used to perforate the orifices for the screw used in the H plate (Orozco plate) or in the fixation with screws. In the group fixed with plates, an H plate with four orifices was used and fixed with four cortical screws each 3.5 mm in diameter and 18 mm long. In the group fixed with cancellous

screws, two cancellous screws each 4.0 mm in diameter and 45 mm long were used. The screws were placed in parallel, penetrating the base of the C3 body and located 20° in the anteroposterior direction (Figs. 1, 2).

Eight experimental groups were set up according to the type of fixation (H plate or screw) and type of mechanical assay used (flexion, extension, lateral bending, and rotation). Each experimental group consisted of ten cervical spine segments with fixation of the C2–C3 segment.

The mechanical assays (flexion, extension, lateral bending, and rotation) were performed on a universal testing machine. The load cell capacity was 2,000 N, with a preload of 50 N and adjust time of 30 s. The test room's temperature was around 26°C. The specimens were kept frozen at –20°C. The defrost was realized in a freezer 12 h before the test. Afterwards, the specimens were kept at room temperature for 2 h until the termical balance was completed. A 4 mm limit of deformation was established for the flexion, extension, and lateral bending assays, and a limit of 6.5 mm was established for the rotation assays, corresponding to 9° of rotation. The rate of load application during the assays was 5 mm/min. The mechanical properties used to compare the two types of fixation were the load necessary to produce the pre-established deformation (4 mm in the flexion, extension, and lateral bending assays and 6.5 mm in the rotation assays) and stiffness.

The values obtained by the two methods of vertebral fixation were analyzed statistically by the Mann–Whitney nonparametric test, with the level of significance set at $P < 0.05$.

Results

In the flexion assays, the mean force needed to produce the preestablished deformation was 385.61 N for the

Fig. 1 **a** Anteroposterior and **b** profile radiograph of the C2–C3 segment fixed with an H plate

Fig. 2 **a** Anteroposterior and **b** profile radiograph of the C2–C3 vertebral segment fixed with two screws

vertebral segments fixed with the screws and 339.97 N for the vertebral segments fixed with plates. In the rotation assays, the mean value was 156.78 N for the vertebral segments fixed with screws and 160.02 N for the segments fixed with plates. There was no significant difference in the values observed in the flexion and rotation tests. In the lateral bending tests, the mean force needed to provoke the preestablished deformation was 346.45 N for the vertebral segments fixed with screws and 261.60 N for the segments fixed with plates. In the extension assays, the mean value was 320.25 N for the segments fixed with screws and 243.41 N for the segments fixed with plates. There was a statistically significant difference between the values observed for the vertebral segments fixed with screws and those fixed with plates in the extension and lateral bending assays.

The forces needed to produce the pre-established deformation in the assays are illustrated in Figs. 3, 4, 5, and 6.

Stiffness represents the resistance to deformation and the mean stiffness values observed in the flexion,

extension, lateral bending, and rotation tests are illustrated in Figs. 7, 8, 9, and 10. The mean stiffness value in the flexion tests was 90.36×10^3 N/m for the group fixed with screws and 72.39×10^3 N/m for the group fixed with plates. Mean relative stiffness for lateral bending and rotation was 69.50 and 23.71×10^3 N/m for the group fixed with screws and 57.04×10^3 and 24.53×10^3 N/m for the groups fixed with plates, respectively. There was no significant difference in stiffness between the two types of fixation in the flexion, lateral bending, and rotation tests. In the extension tests, stiffness was 71.13×10^3 N/m for fixation with screws and 47.06×10^3 N/m for fixation with plates, with a significant difference between the values obtained ($P=0.04$).

In general, the results obtained in the mechanical tests did not show a statistically significant difference between the two modalities of fixation. A significant difference in the force needed to produce the preestablished deformation was observed only in the tests of extension and lateral bending. Regarding stiffness, the difference between the two modalities was significant

Fig. 3 Curves for the arithmetic mean strength necessary to produce deformation in the flexion tests

only in the extension assays. The results of the mechanical assays showed that fixation of the C2–C3 segment with two screws was at least similar to fixation with the Orozco type H plate.

Discussion

The indication of anterior fixation of the C2–C3 segment is much less frequent compared to more distal levels of

Fig. 4 Curves for the arithmetic mean strength necessary to produce deformation in the extension tests

Fig. 5 Curves for the arithmetic mean strength necessary to produce deformation in the lateral bending tests

Fig. 6 Curves for the arithmetic mean strength necessary to produce deformation in the rotation tests

Fig. 7 Mean stiffness observed in the flexion tests

Fig. 10 Mean relative stiffness observed in the rotation tests

Fig. 8 Mean relative stiffness observed in the extension tests

Fig. 9 Mean relative stiffness observed in the lateral bending tests

the subaxial spine and is more related to posttraumatic instability, with emphasis on spondylolisthesis of the axis (hangman's fracture) or tumoral lesions [6–8, 10, 13, 14].

Anterior arthrodesis and vertebral fixation with plates and screws are technically more difficult to perform at the C2–C3 level compared to more distal segments of the cervical spine. The anatomical characteristics of this vertebral spine segment do not

permit easy retraction of the structures surrounding the vertebral spine and its limited exposure creates difficulties for the positioning and placement of the screws in the osteosynthesis plate [4, 13]. This technical difficulty for fixation of the C2–C3 segment with plates and screws motivated us to search for an alternative technique, and fixation with two screws analogous to the technique used for fixation of the odontoid process [2] seemed to us to be simpler and easy to perform without intense mobilization of the anatomical structures surrounding the vertebral segment.

The initial use of fixation of the C2–C3 segment by means of two screws positioned in the caudocranial direction between C2 and C3 was a decision made during a surgical procedure in which the fixation of this segment with a plate and screws did not provide the desired stability, with the two screws being used to complement fixation. The subjective evaluation of the stability provided by complementary fixation was satisfactory, to the extent that it was considered as a possible primary system for fixation of this vertebral segment.

Despite the subjective evaluation of the stability provided by the two screws and the good clinical course of the patients in whom this system was used for complementary fixation, the stability of this modality of vertebral fixation could only be evaluated by means of mechanical tests simulating its use and also by comparing its stability to that obtained by fixation with a plate and screws, which represent the modality most frequently used for anterior cervical fixation.

The difficulty in obtaining spinal segments from human cadavers due to Brazilian legislation led us to use spinal segments from swine. Despite the limitations imposed by the experimental model used, the results obtained can be considered valid since the two modalities of fixation were tested under similar conditions. However, the use of this material permitted the standardization of the breed, age and weight of the animals used. It should be mentioned that pigs have a high BMD, which is usually higher than humans and limits

the evaluation [12]. In the experimental model of the present study, the intervertebral disc was routinely removed and no type of support was used between vertebral bodies so that the stability of the fixations was accounted for exclusively by the implants used, without the possible interference of supports in the anterior spine of the vertebral segment studied [9].

The results of our mechanical assays showed that the mechanical stabilization obtained by using two screws provides stability similar to that obtained with the Orozco type cervical plate, and is even better in the extension assays. These results should be analyzed with caution because of the type of bone used in the study and other variables involving the mechanical assays. It should also be pointed out that the H plate modality used in the study (Orozco plate) is an unlocked plate-fixation system and monocortical fixation of the plate screws was used. In an experimental study, Lehman et al. [5] observed that neither locked nor unlocked anterior-plate fixation can increase stability in all models of testing. H-plate spondylodesis with unlocked screws seems to provide sufficient mechanical integrity in most cases of monosegmental lesions. It should also be remembered that without good bone fusion all fixation devices would eventually fail from either degeneration of bone-implant junction or failure by fatigue

of the implant itself. However, the results obtained can serve as a starting point for the refinement of the idea, since the results of the use of screws for fixation of the C2–C3 segment were at least comparable to those obtained with the use of Orozco type plates. The technique for fixation of the C2–C3 segment with screws uses the same dissection planes as used in the procedure involving Orozco plates. However, the exposure of the site of implant placement is less extensive compared to the standard technique, causing the procedure to be simpler and to involve a lower risk of injury to adjacent structures. Another possibility for the application of this technique, which we have already applied to patients, would be as complementary fixation in situations in which the stability provided by plate fixation is unsatisfactory or the procedure is impossible to perform in the C2–C3 segment. The possible disadvantage of this technique could be degeneration of the adjacent disc that is sometimes seen in anterior odontoid fixation.

No similar technique for the fixation of the C2–C3 segment has been reported in the literature, and the preliminary results of the present mechanical assays show that, from a mechanical viewpoint, this technique is not inferior to the currently used type fixation (H plate and screws).

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