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Is the Revision Screw for Re-insertion of Lateral Mass Screw Useful?: Biomechanical Cadaveric Experiment

Ki-Hyoung Koo, M.D.[1)], S. Tim Yoon, M.D.[2)], Jangyun Lee, M.D.[1)], William C. Hutton, DSc, M.D.[2)]

Department of Orthopaedic Surgery, Dongguk University Ilsan Hospital, Goyang-city, Gyeonggi, Korea[1)]
Department of Orthopaedic Surgery, Emory Spine Center, Atlanta, GA, USA
Veterans Affairs Medical Center, Atlanta, GA, USA[2)]

Objective: To compare the pull-out strength of polyaxial general screws and rescue screws when inserted into the lateral mass through cadaveric biomechanical experiment
Materials and Methods: Twenty three segments of the human cervical spine (from C3 to C7) were prepared. Two biomechanical studies were progressed. In the first experiment (13 segments), each segment was instrumented with 3.5×12 mm polyaxial screws on both sides. In one side, the inserted screw was removed and then the rescue screw was inserted to the same screw hole. In the second experiment (10 segments), all segments were instrumented with 3.5×12 mm polyaxial screws on both sides and all screws were removed. In one side, removed same screw was reinserted and in the other side, the rescue screw was inserted without change of the screw trajectory. All specimens were fixed to the specially designed frame with the cement. Universal Material Test Machine (Mini Bionix 858) was used to assess the pull-out strength of the screws. All data were compared with non-parametric paired test (Wilcoxon's signed rank test).
Results: There was no crack or fracture around the screw hole. No significant difference was noted between the original screws (not reinserted) and the rescue screws in the first experiment ($p=0.753$). There is no significant difference between the same screw reinsertion and the conversion to the rescue screw ($p=0.646$).
Conclusions: The overall results of this study showed the conversion to the rescue screw with the same screw trajectory could offer no biomechanical advantage over reinsertion of the same screw. In case of secure screw hole after removal of the screw, the reinsertion of the same screw could be recommended.

Keyword: Cervical spine, Lateral mass screw, Rescue screw, Biomechanics, Pull-out strength.

Introduction

The cervical lateral mass screw was used for stabilization of various cervical instabilities.[1,2)] They have been popular since its description by Roy-Camille et al.[1,3)] It is simpler, safer, and more effective than other fixation techniques in the cervical spine.[4,5,6)] Several techniques of screw insertion have been described by several authors and some trajectories for screw also have been introduced.[2,3,4,7)]

The fixation strength of the screw is dependent on various factors including bone mineral density (BMD), cortical fixation, screw orientation and screw design. Some authors have proposed a thicker screw design to strengthen the bone-screw interface, whether involving a thicker core or expanding design.[6,7,8)] The thicker-core-diameter screws are more commonly used and are often named rescue screws.[9,10)] Despite various studies about the lateral mass screw, there have been only a few studies about the rescue screw.

The strategies for change of the pedicle screw in thoracic

Corresponding author: Ki Hyoung Koo, M.D.
Department of Orthopaedic Surgery, Dongguk University Ilsan Hospital
Dongguk University College of medicine 27 Dongguk-ro, Ilsan-gu, Goyang-city, Gyeonggi, 10326, Korea
TEL: +82-31-961-7294, **FAX:** +82-31-961-7290
E-mail: drkookh@gmail.com

and lumbar spine have included the usage of the screws with bigger diameter and/or longer length, screw-hole augmentation, different screw paths[11-13]. However the conversion of the lateral mass screw to rescue screw has some differences compared with the thoracic or lumbar pedicle screws[7,9]. Lateral mass is too small to insert the screw with bigger diameter and/or longer length[9,10]. It is also technically demanding to insert the screw with the different paths[9,10]. It would be another potential salvage option to convert to a cervical pedicle screw[9,10]. Cervical pedicle screw is able to provide more rigid stability for posterior instrumentation although it is more technically demanding procedure with potential for neurovascular complications[4, 5]. One more alternative is the use of rescue screw with the same path. Some studies showed the biomechanical advantage of rescue screw in the same path over trajectory revision[7,9,10].

However it is not clear whether the re-insertion of general polyaxial screw adversely affect its pull-out strength and the use of rescue screw is necessary for screw change in the cervical lateral mass screw.

The primary objective of the current study is to compare the pull-out strength of re-inserted polyaxial screws and rescue screw when inserted into the lateral mass in the cervical spine.

Materials And Methods

Preparation of Specimens

Twenty three segments of the cervical spine (from C3 to C7) were harvested from five fresh cadavers and prepared for this study. Each specimen was carefully disarticulated into individual cervical vertebra with all preserved osseous anatomy. The vertebrae were all examined grossly to rule out any malignancy or fractures that could have affected the result. Each vertebra was then frozen at -20℃ until the day before testing.

Instrumentation of Specimens

After thawing at the room temperature overnight, all specimens were prepared for screw insertion. Prominent spinous processes were removed to allow enough lateral trajectory during the insertion of the screws. Lateral mass screws were inserted using the trajectory described in the modified Magerl's technique. Polyaxial screws 3.5 mm in diameter were used (DePuy Spine, Raynham, MA, USA). Pilot holes were drilled and tapped prior to placing the screws. The screws were 12 mm in length and inserted until the screw head touched the lateral mass.

In the first experiment for 13 segments (original screw vs rescue screw), each segment was instrumented with 3.5×12 mm polyaxial screws on both sides. In one side, the inserted screw was removed and then the rescue screw was inserted to the same screw hole without any change of screw trajectory and length.

In the second experiment for remaining 10 segments (re-inserted screw vs rescue screw), all segments were instrumented with same screws and then all screws were removed. In one side, removed screw was re-inserted and the other side, the rescue screw was inserted without any change of screw trajectory.

Biomechanical Testing

Biomechanical testing was performed using the materials testing machine (858 Mini Bionix Test System, MTS, Minneapolis, MN, USA). Each specimen was individually embedded in a polyvinyl chloride end cap 10 cm diameter using dental cement (Heraeus Kulzer Inc., South Bend, IN, USA)[10,14]. The end cap with the embedded vertebra was then clamped in the testing machine in the upright position (Fig. 1)[14]. All screws inserted into the lateral masses underwent tensile pull-out by applying a tensile force down the long axis of the screw. The tensile force was applied at a displacement rate of 2 mm/sec. The pull-out strength of the screw was recorded as the peak force seen on the load-displacement curve.

Statistics

The difference in pull-out strength between two screws was evaluated using a non-parametric paired test (Wilcoxon's signed rank test) which compared side to side on each vertebra. A p value ≤ 0.05 was considered statistically significant.

Results

There was no significant fracture or crack seen around the

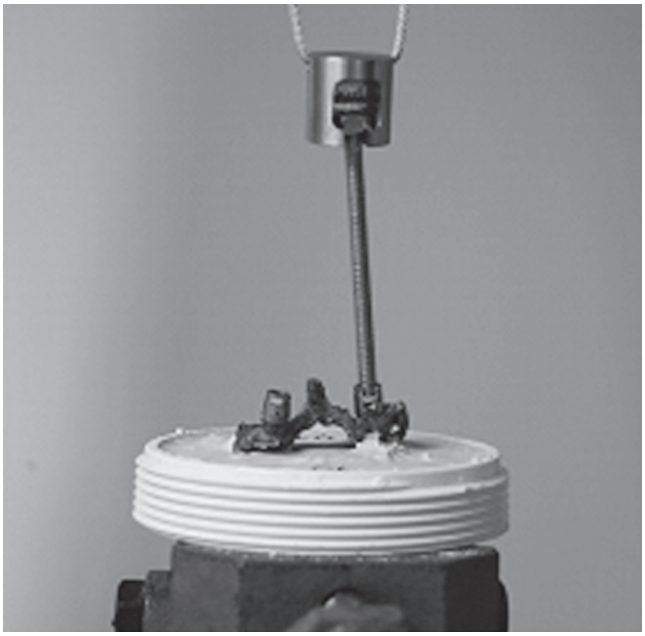

Fig. 1. Biomechanical Testing.
Each specimen was individually embedded in a polyvinyl chloride end cap 10 cm diameter using dental cement. The end cap with the embedded vertebra was then clamped in the testing machine (858 Mini Bionix Test System, MTS, Minneapolis, MN, USA) in the upright position.

screw hole. A total of twenty three vertebrae were tested.

Biomechanical Testing

In the first experiment, the average pull-out strength for original screws and rescue screws were 315.54 (±159.39) vs 343.77 (±166.87). Wilcoxon's signed rank test showed no significant difference in side to side comparison (p=0.753).

In the second experiment, the average pull-out strength for re-inserted screws and rescue screws were 488.0 (±220.34) vs 547.5 (±220.08). Wilcoxon's signed rank test showed no significant difference in side to side comparison (p=0.646). Therefore, there is no significant difference between the same screw re-insertion and the conversion to the rescue screw.

Discussion

The main result of this study using cervical vertebrae showed the conversion to the rescue screw with the same screw trajectory could offer no biomechanical advantage over reinsertion of the same screw. The rescue screws showed similar pull-out strength compared with those of original screws.

If screw-based constructs such as screw-rod system are used for cervical fixation, secure screw fixation should be as firm as possible for optimal initial stability. Therefore tight fixation of screws is required to obtain sufficient initial stability of cervical segments.

In practice, if screw should be changed, the surgeon can consider several options: the change of rehabilitation schedule, a new screw insertion to an alternative hole or trajectory, the application of supplemental fixation, the usage of bone void filler including bone cement, leave the stripped screw in place, or exchange the removed screw for a rescue screw.[1,7,9,10,15] Some authors have proposed a thicker screw design often named rescue screws.[9,10]

Rescue screws of various descriptions and effectiveness are used in spine and maxillofascial surgery.[9-13] However the results of such studies are difficult to compare because the test for pull-out strength were carried out on various screw systems and in various anatomical sites and/or materials, such as animal model, cadaveric cortical or cancellous bone, and artificial bone model. Some authors have reported the rescue screws can even surpass the pull-out strength of the original screws, but others have found them to be ineffective in re-establishing fixation in a stripped hole.[9,10,11,16] Wall et al[13] reported no advantage in using a cancellous screw over a cortical screw in bicortical fixation in the osteoporotic bone, but the rescue screw provided greater pull-out strength than the stripped screw. Pitzen et al[16] showed recue screws inserted damaged initial pilot holes of the cervical vertebral body did not strengthen the screw-bone interface compared with the strength initially conferred using a standard screw.

However there has been there have been only a few studies about the rescue screw in the lateral mass.[9,10,13] The conversion of the lateral mass screw to rescue screw has some difficulties because of its small size.[10] It can be technically demanding or risky to insert rescue screw with a thicker design to same screw hole.[9, 10] It can give rise to breakage or crack around the screw holes. In our study, rescue screw showed equivalent pull-out strength compared with original screw, but cannot surpass re-inserted original screw .

One strength of our study design was that we used side-to-side comparison within one vertebra. This allowed for matching of bone density and the shape and size of lateral masses; this eliminated the variability that would have been there if we had compared vertebra with vertebra.

Microcomputed tomography (micro CT) was not available to us. However gross examination of the bone around screw entry (before screw pull-out) did not showed any cracks or small fractures in all specimen.

In our study, all screws were inserted by one surgeon who had completed a spine fellowship and had had more than six years of clinical experience. During the instrumentation, all bony structures were exposed; this made it possible for the surgeon to insert each screw anatomically and exactly. Inspection after the biomechanical testing revealed that all screws had been inserted without any violation.

The level of cervical spine can be important factor in the pull-out strength of lateral mass screws.[6,7)] In our study, the pull-out strength was the greatest at the fourth cervical level, decreasing cephalad and caudad. However the comparison of the difference in pull-out strength from level to level was not relevant in our analysis since we compared the result obtained for the left side with the result obtained for the right side in every vertebra.

In our study we measured pull-out strengths of the screws. Pull-out strength testing of screws is not a truly representative mode of fixation failure.[8,10)] However, it is reproducible and has been accepted as the most basic (or first) measure of fixation strength. It could be considered more clinically relevant to have applied fatigue loading to the screws. However, a fatigue experiment requires a great number of specimens in order to work out applied load amplitude and frequency of the applied cycles. The vagaries of post mortem collection only allowed the harvest of 23 “good” specimens: too few for a fatigue experiment but enough for a pull-out experiment.

In a conclusion, the conversion to the rescue screw with the same screw trajectory did not have any biomechanical advantage over reinsertion of the same screw. In case of reinsertion after removal of the screw, the re-insertion of the same screw could be recommended to prevent additional risk of screw hole breakage or crack in the cervical lateral mass.

Conclusion

The overall results of this study showed the conversion to the rescue screw with the same screw trajectory could offer no biomechanical advantage over reinsertion of the same screw. In case of secure screw hole after removal of the screw, the reinsertion of the same screw could be recommended.

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외측괴 나사못의 재삽입 시에 rescue screw가 효과적인가?: 생역학적 사체 연구

구기형[1)], S. Tim Yoon[2)], 이장연[1)], William C. Hutton, DSc[2)]
동국대학교 의과대학 정형외과학교실[1)], Department of Orthopaedic Surgery, Emory Spine Center, Atlanta, GA, USA·Veterans Affairs Medical Center, Atlanta, GA, USA[2)]

연구목적: 외측괴 나사못의 재삽입 시에 rescue screw가 나사못의 고정 강도를 유지하는데 도움을 주는지에 대하여 사체 실험을 통하여 살펴보고자 하였다.

대상 및 방법: 5구의 사체에서 얻은 제 3-7경추를 대상으로 하여 각 분절을 분리하여 연부 조직을 제거한 총 23분절을 실험하였다. 각 분절간의 골 밀도, 외측괴의 크기, 삽입된 나사못의 길이에 의한 영향을 배제하고자 각 분절별로 좌우 비교를 시행하였다. 첫 13분절(나사못 삽입군과 나사못 재삽입군 비교)은 양쪽 모두에 외측괴 나사못(3.5 mm×12 mm, polyaxial screw)을 삽입한 후 무작위로 배정하여 좌우 한쪽은 최초 삽입된 나사못을 그대로 두고 나머지 한쪽은 삽입된 나사못을 제거한 후 다시 삽입하여 외측괴 나사못 재삽입할 경우의 생역학적 강도를 비교하고자 하였다. 나머지 10분절(나사못 재삽입군과 rescue screw 삽입군 비교)에서는 양쪽 모두에 외측괴 나사못을 삽입한 후 마찬가지로 무작위 배정하여 한쪽은 삽입된 나사못을 제거한 후 제거된 나사못을 재삽입 하였고 나머지 한 쪽은 rescue screw를 삽입하여 동일 나사못 재삽입군과 rescue screw 삽입군과의 생역학적 강도를 비교하고자 하였다. 모든 나사못은 Universal Material Test Machine(Mini Bionix 858)을 이용하여 나사못의 장축 방향으로 인장력을 가하여 뽑힘 강도를 측정하고자 하였다. 각 두 군간의 뽑힘 강도의 차이는 non-parametric paired test (Wilcoxon's signed rank test)를 이용하여 분석하였다.

결과: 나사못 삽입과 관련된 crack이나 fracture는 발견되지 않았다. 나사못 삽입군과 나사못 재삽입군의 비교에서 pull-out strength의 유의한 차이는 보이지 않았으며(p=0.753), 나사못 재삽입군과 rescue screw 삽입군 비교에서도 pull-out strength의 유의한 차이는 보이지 않았다(p=0.646).

결론: 외측괴 나사못을 재삽입하는 경우에도 pull-out strength의 유의한 저하는 관찰되지 않으며 rescue screw 를 삽입하는 경우에도 기존 screw를 재삽입하는 것에 비하여 유의한 고정 강도의 향상을 기대할 수 없었다. 따라서 외측괴 나사못을 수술 중 제거한 후 재삽입해야 하는 경우 동일한 나사못을 재삽입하는 것이 추천된다.

색인 단어: 경추, 외측괴 나사못, 구조 나사못, 생역학, 인발 강도