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The crooked rod sign: a new radiological sign to detect deformed threads in the distraction mechanism of magnetically controlled growing rods and a mode of distraction failure

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Abstract

Study Design: Case report

Objective: To report a unique mechanical failure of magnetically controlled growing rods (MCGR) that is related to continuous rod slippage.

Summary of Background Data: Despite the growing popularity of MCGR in the management of patients with early onset scoliosis, postoperative complications and reoperations are not uncommon. Unique complications or unplanned reoperations are observed in patients with MCGRs that are not seen in traditional growing rods. The complications include rod slippage, mismatch between targeted and achieved distraction length, metallosis and actuator pin fracture. We have identified an unreported failure mechanism whereby deformed threads occur in the internal distraction mechanism of the MCGR. This phenomenon may indicate increased MCGR internal screw friction and increased distraction resistance. This complication ultimately led to distraction failure and revision surgery.

Methods: A girl with early onset scoliosis (EOS) was treated by dual MCGRs. She developed proximal junctional kyphosis (PJK) and continuous rod slippage. Distractions in the out-patient clinic and under sedation did not achieve successful rod lengthening. A tell-tale “crooked rod” radiological sign was identified by angulation between the actuator and the extendable portion of the rod.

Results: Rod exchange was performed and she is now 2 years after revision surgery with successful lengthening episodes. Upon review of the extracted MCGR, distraction was not possible even after rod removal and was only resumed after the screw was manually reinserted along its correct threads.

Conclusions: Deformed threads is a complication that cannot be reverted without rod removal and exchange. Users should be aware of this potential failure mechanism and proceed to early rod exchange rather than attempting any further distractions.

Key Words: Magnetically controlled growing rod; complication; distraction failure mechanism; rod slippage, deformed threads

Level of Evidence: 4

Key Points

1. Continuous distractions in the background of rod slippage is not recommended.
2. Increased rod internal screw friction and resistance to distraction can cause thread deformation.
3. With deformation, the magnetically controlled growing rod is unable to lengthen.
4. A “crooked rod” sign identified on radiographs represents an angulation in the rod resulting from dislodgement of the internal screw.

Background

Magnetically controlled growing rods (MCGRs) has become one of the mainstay treatment options for EOS. It allows more frequent non-surgical outpatient distractions to mimic physiological growth.[1] More regular monitoring can be performed with ultrasound examinations which has no radiation exposure.[2,3] Clinical and radiological efficacy are on par with other methods.[4-7] Its applicability can also be extended to surgical correction of severe deformities.[8] Recent long-term results and study of graduate cases report consistent spine and rod lengthening throughout growth and avoids autofusion of the spine.[9]

Despite these benefits, complications and unplanned reoperations are not uncommon. Teoh *et al*[7] reported a 50% failure rate and Kwan *et al*[10] indicated that 40% of patients develop distraction failure and proximal anchor loosening. Recently, several unique complications including rod slippage, mismatches between targeted and achieved distraction length, metallosis and actuator pin fracture were also reported.[5,9,11,12] The current understanding of rod slippage, also known as clunking or stalling, is limited. We know that rod slippage indicates a failed rotation of the magnets within the actuator in response to the external magnetic controller, leading to failed distraction of the rod.[11] It demonstrates as a "clunking" sound in comparison to the usual smooth "wobble" sensation and continuous rotation of the magnet. This phenomenon is associated with older and larger-sized patients.[5] However, we do not have established protocols for appropriate interventions, and it remains uncertain whether distractions should continue and whether complications may arise from rod slippage.

A newly-identified failure mechanism where deformed threads occur within the internal distraction mechanism of the MCGR is reported. It is suspected to be caused by continuous rod slippage. This event leads to distraction failure and ultimately revision surgery.

Clinical Presentation

A girl diagnosed with Sotos syndrome presented at age of 3 years with a double major curve of 41° from T6-11 and 44° from T11-L4. MRI showed no intraspinal pathology. Despite good compliance to bracing, there was progression of the deformity to 54° at T11-L4 (**Figure 1AB**). Dual MCGRs in standard and offset configuration were implanted at T5-L4 (**Figure 2AB**) with claw construct at the proximal foundation (T5-T6) and pedicle screws at the distal foundation (L3-L4). Postoperatively she was given a corset with shoulder straps for 3 months before monthly outpatient distractions were performed.

Despite the finding of proximal junctional kyphosis (PJK) 5 months after the surgery, early distractions were smooth and successful monthly 2mm lengthening achieved on both rods as confirmed by ultrasound. At the 11th distraction, 1.5 years after rod implantation, rod slippage occurred in both rods and no lengthening was observed (**Figure 3AB**). Targeted 2mm distraction was continued at the next two clinics despite continuous rod slippage and failed lengthening. The difficulties were initially contributed to the uncooperative patient who became irritable during distraction sessions. Subsequently, a distraction session under sedation was performed to eliminate the soft tissue resistance contributed by muscle contraction. Despite successful distraction on the left rod, continuous slippage was still observed on the right rod. As further lengthening was unsuccessful, rod exchange was performed with proximal extension to T3-T4 to control the proximal junctional kyphosis. Intraoperatively metallosis was observed around the screw-rod junction. After rod exchange, smooth distractions were again observed for both rods. The patient is now two years after the rod exchange with monthly successful lengthenings.

Retrospective examination of the radiographs acquired prior to the sedation procedure revealed rod angulation between the actuator and the extendable portion of the rod (**Figure 4AB**). Upon review of other patients in our series who have experienced distraction failures and continuous rod slippage (n=8), none observed similar crooked rod sign on follow-up radiographs. The extracted MCGRs were studied in our mechanical laboratory. Externally there was no rod fracture but there were many wearing marks at the junction between the extended portion of the rod and the actuator (**Figure 5A**). Rod angulation was also observed by placing the rod next to a straight bench edge (**Figure 5B**). After the extended portion and the actuator were dissected, it was revealed that the threads of the internal screw providing the distraction were no longer in-line with such deformation (**Figure 6**) and thus the screw refused to rotate with external magnetic force due to the increased resistance. After the screw was dislodged and re-inserted along the correct threads, the screw was able to rotate manually under external force and the distraction resumed.

Discussion

This is a new failure mechanism of MCGRs related to the increased rod internal screw friction and resistance to distraction caused by the deformation of the threads. This is another mechanical failure in addition to others reported including pin fractures, corrosive debris and metallosis.[13-16] This complication may be identified with meticulous scrutiny of the radiographs during the period of interest. It is prudent for MCGRs users to keep a close eye on radiographs for subtle angulations between the actuator and the extendable portion of the rod, especially when rod slippage occurs. Although the immediate x-ray (**Figure 3**) prior to the continuous slippage showed no obvious abnormality, the next radiograph taken (**Figure 4**) during the distraction under sedation showed an angulation at the MCGR which should not be present in any functional MCGR. This is a very subtle finding that is only apparent to us with assessment of the rod at the laboratory (**Figure 5B**) and of the radiographs on retrospective review. Nevertheless, this is one visible sign that can be identified on plain radiographs that warrants revision surgery. This finding is perhaps more obvious with projection of a line drawn along the border of the actuator and another along the border of the extended portion of the rod. If these lines intersect then a deformed thread complication may be present. Due to the overlap of the dual rods on lateral radiographs, this may only be apparent on the posteroanterior radiographs.

The rationale for the failed distraction can be comprehended as increased resistance from the deformed thread preventing the rotation of the internal screw under the magnetic driving force of the external controller, and thus preventing extension of the rod. It should be noted that the patient did not have any significant axial growth during the months where rod slippage occurred. Hence, soft tissue tension is significant and is likely the main reason for failed lengthening. The continuous rod slippage may be considered as a warning to avoid forcing further distraction. The PJK may have also contributed to the series of events as increased kyphosis may apply extra anterior loading to the proximal end of the MCGR. The relationship between rod alignment, increased anterior loading and deformed threads require further study.

Based on what we have observed with this complication, we recommend MCGR users to avoid distraction attempts if continuous rod slippage occurs as this may jeopardize the longevity of the MCGR. The relationship between continuous rod slippage and this deformed thread phenomenon requires further testing to reproduce and to understand its underlying mechanism. Radiographic images should be scrutinized for the "crooked rod sign" which represents angulation between the extended portion and the actuator. This sign is indicative of deformed threads in the internal distraction mechanism. Once it occurs, revision surgery with rod exchange is inevitable. Similar findings should be explored in other MCGR failures to determine its frequency of occurrence.

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Figure legends

Figure 1: Posteroanterior (A) and lateral (B) radiographs pre-MCGR implantation.

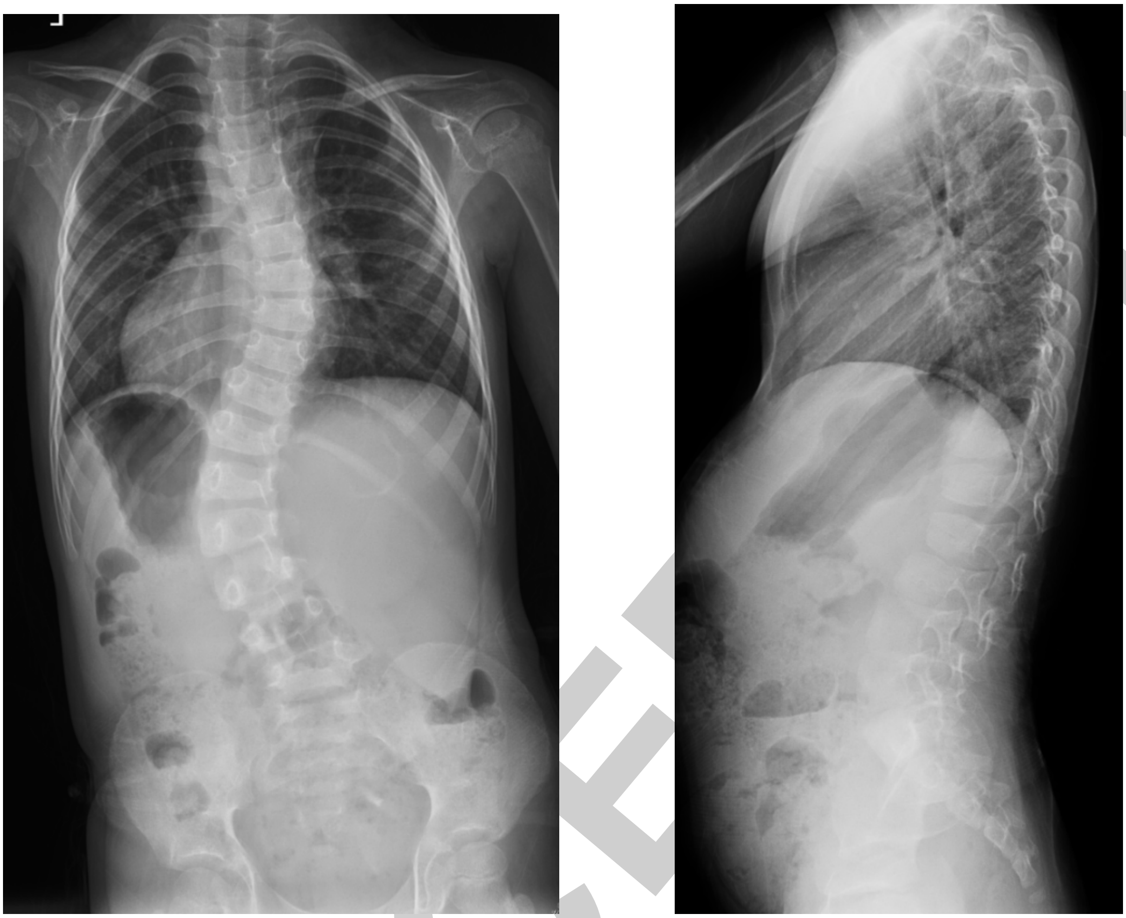

Figure 2: Posteroanterior (A) and lateral (B) radiographs post-MCGR implantation.

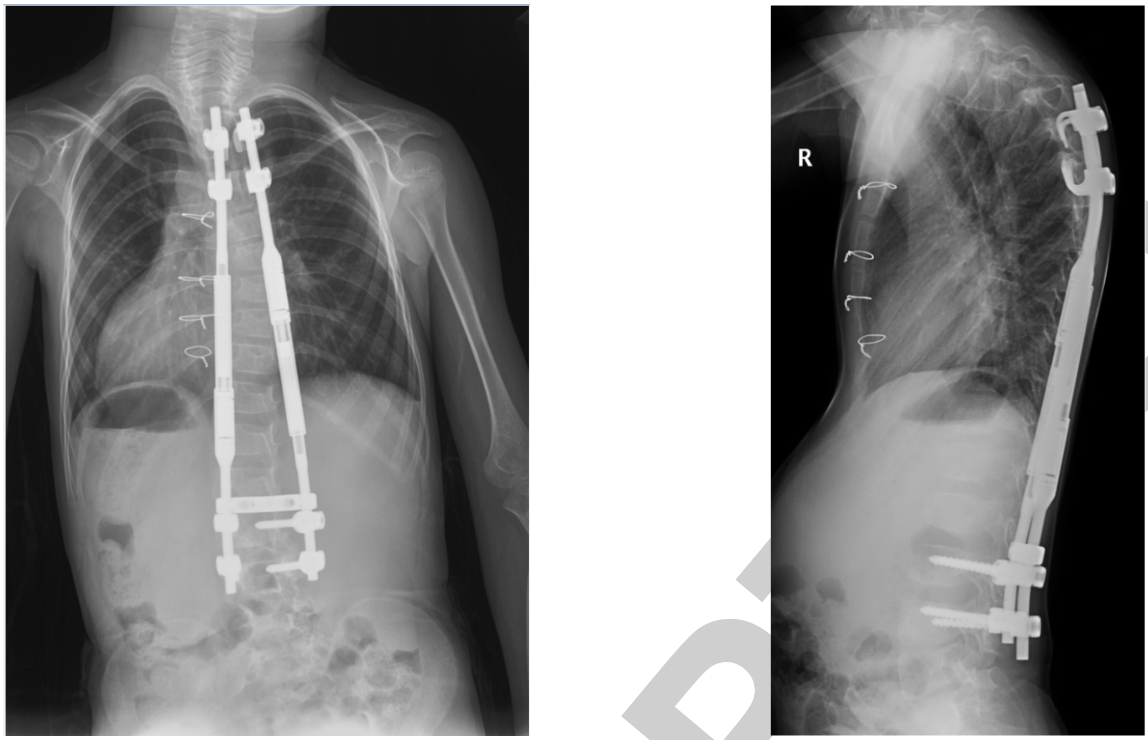

Figure 3: Posteroanterior (A) and lateral (B) radiographs immediately prior to continuous rod slippage showed no rod angulation (marked by lines).

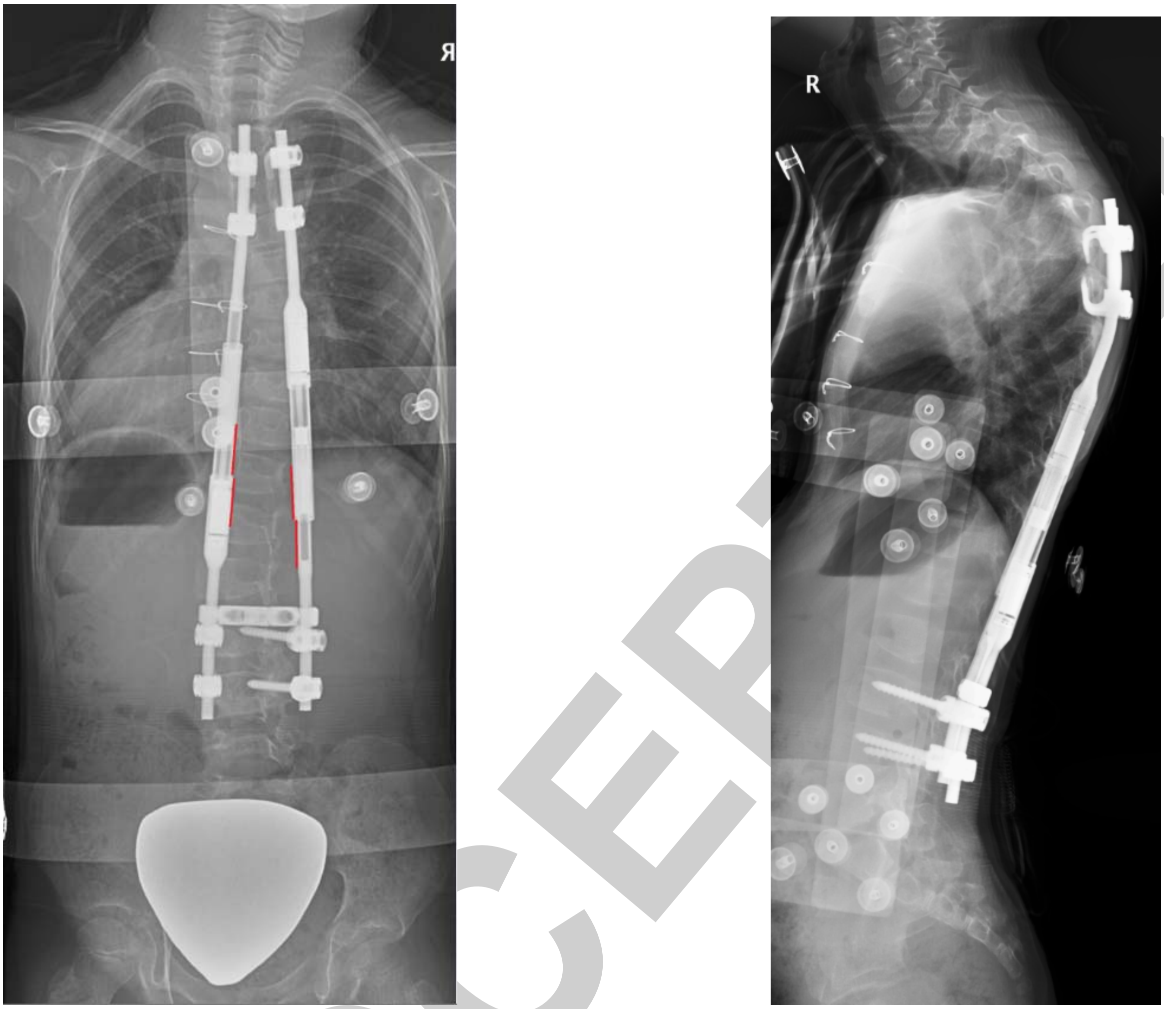

Figure 4: Posteroanterior (A) and lateral (B) radiographs obtained during the admission for distraction under sedation showing rod angulation at the right rod (marked by lines).

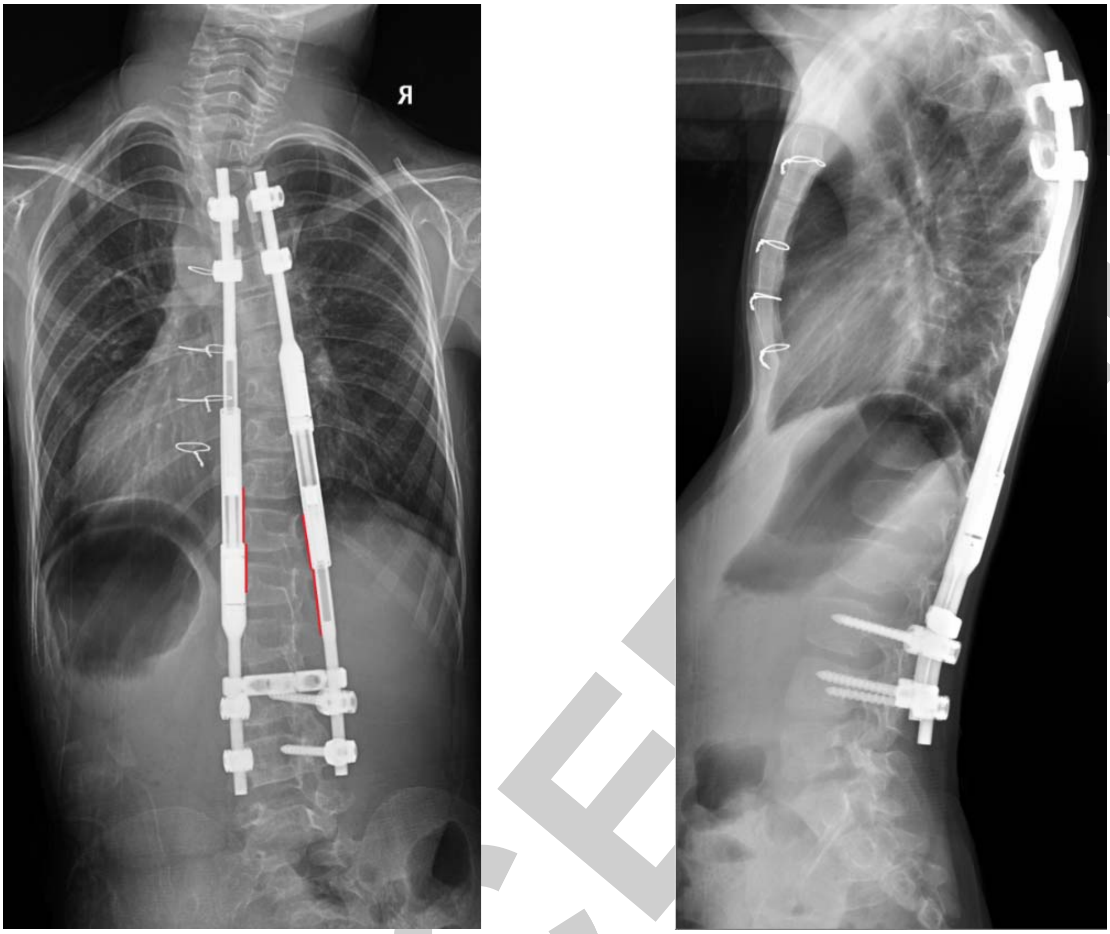

Figure 5: The explanted rod appearance with wearing marks (A) and rod angulation (B).

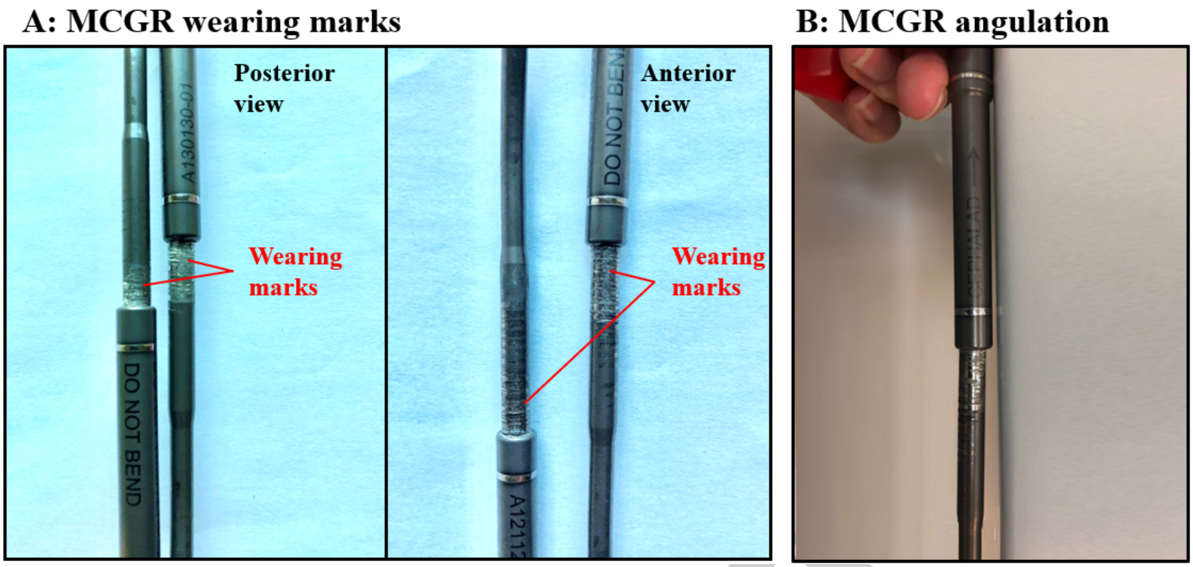

Figure 6: The explanted rod after dissection with indications of the thread design and deformed threads. Microscopic analysis of the deformed threads with deformations shown by changes in the color.