High Rate of Corrosion of Retrieved 316L Stainless Steel Plates Used in Posterior Thoracolumbar Fixation
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Surgical placement of a plate and screw system assists in the fusion between vertebrae by imparting mechanical rigidity. Typically, these devices are manufactured of stainless steel or titanium. Stainless steel is used because of its mechanical properties (higher modulus of elasticity and fatigue strength); however, stainless steel is more susceptible to corrosion than titanium, making it potentially more harmful to the body and patient.

Electrochemical attack of metal occurs in the form of a series of reduction and oxidation reactions, which results in ion release and structural degradation. Fretting and crevice corrosion are two common mechanisms of corrosion observed in retrieved stainless steel spine devices. Fretting corrosion occurs due to unintended micromotion between two surfaces, which removes the passive oxide layer. The removal of this layer, which acts as both a kinetic and thermodynamic barrier to corrosion, leaves the material susceptible to electrochemical attack until it can be spontaneously reformed (repassivated). Stainless steel has a lower repassivation rate in vivo due to physiological fluids containing proteins and complexing agents. This lower repassivation rate allows for additional corrosion when the oxide layer is removed. Both the mechanical and electrochemical nature of fretting corrosion favor the release of particulate and metal ion debris. Crevice corrosion occurs when a small gap between the plate and screw allows for an environment depleted in oxygen and highly concentrated in chloride ions. Chemical reactions that occur in this crevice result in metal ion release from the material and the formation of pits.

Previous studies have found stainless steel spine devices show evidence of mild to severe corrosion; fretting and crevice corrosion were the most commonly reported types. Studies have also demonstrated the toxicity of metal ions released from stainless steel corrosion and how the ions may adversely affect bone formation and/or induce granulomatous foreign body responses. In this study, 118 retrieved 316L stainless steel thoracolumbar plates, of three different designs, used for fusion in 60 patients were examined for evidence of corrosion. A medical record review and statistical analysis were also performed. This study aims to identify types of corrosion and examine preferential metal ion release and the possibility of statistical correlation to clinical effects.

The retrieved plates were visually inspected and graded based on the degree of corrosion. The plates were then analyzed with optical microscopy, scanning electron microscopy (SEM), and energy dispersive X-ray spectroscopy (EDX). A retrospective medical record review was performed and statistical analysis was performed to determine any correlations between experimental findings and patient data. More than 70 percent of the plates exhibited some degree of corrosion.
Both fretting and crevice corrosion mechanisms were observed, primarily at the screw plate interface. EDX analysis indicated reductions in nickel content in corroded areas, suggestive of nickel ion release to the surrounding biological environment. The incidence and severity of corrosion was significantly correlated with the design of the implant.

Corrosion on stainless steel lumbar plates was observed upon gross inspection. Plates graded as mild corrosion had less than 10 percent corrosion in the area proximal to the screws and washers (A), moderate corrosion was defined as 10 – 50 percent corrosion (B), and severe corrosion encompassed greater than 50 percent of the area (C). Percentage was defined as the ratio between surface area in the defined region affected with respect to total surface area.

Scanning electron micrographs of fretting corrosion (A,D) and crevice corrosion (B,C) illustrating characteristic pitting of fretting corrosion (D) and the scalloping of crevice corrosion (C).