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Finite Element Analysis of Fatigue Behavior of Stent in Tapered Arteries

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Abstract: In order to open up the blocked lumen and remodel the blood environment, vascular stents were usually used to transplant into narrowed blood vessels. Due to its minimally invasive and highly efficiency, stenting has achieved great success in the treatment of cardiovascular diseases. However, failure of stents due to its fatigue will damage the arterial wall, leading to adverse reactions such as thrombosis and in-stent restenosis (ISR), which severely limited its long-term outcome. Therefore, it was very important to predict the service life of stents, especially in tapered arteries.

FEA was adopted to study the effects of arterial tapering and stent material on the fatigue life of stents. Balloon-stent-plaque-vessel coupling systems were established to simulate the working environment of stents in vivo. Five different tapered vessel models were established to study the vessel tapering level on the fatigue life of stents. Besides, the fatigue life of 316L stainless steel stent and L605 cobalt-chromium (Co-Cr) alloy stent deployed into a 0.43° tapered vessel were analyzed and compared. The Goodman diagram method was adopted to evaluate the fatigue resistance of stents.

Results showed that the stress concentration was found on the inner crown of the strut when the stent was subjected to pulsating blood pressure. It was similar to the stress distribution on the stent after expansion. This also indicated that the crown of the strut played a decisive role in the long-term efficacy of the stent. The maximum average stress of Co-Cr alloy stent was higher than 316L stainless stent. However, the fatigue resistance of stents was improved by simply changing stent material from 316L stainless to L605 cobalt-chromium alloy. So the L605 Co-Cr alloy stent can withstand greater stress without fatigue. In addition, the tapering of the vessel will also affect the fatigue performance of the stent. The stent implantation in tapered vessels could lead to greater residual stress and shorter fatigue life of the stent. With the tapering level gradually increased, the minimum fatigue safety factor of the stent decreased, which indicated the stent was more likely to fatigue. Compared to a straight vessel, the fatigue life of the stent was shortened by 9.8%, when it was deployed in a 1.13° tapered vessel.

The obtained results showed that finite element analysis was an effective tool to predict stent fatigue life. The method that predicted stent fatigue life in tapered vessels can help clinicians select stents that are more suitable for tapered vessels and help stent engineers design stents that are more resistant to fatigue.

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