The Effects of E-Cigarettes on Fracture Healing

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INTRODUCTION: It is well-established that cigarette smoking causing delayed healing of fractures, and results in higher rates of non-unions. Nicotine exposure itself has been shown to adversely affect fracture healing in clinical trials[1,2]and in studies using animal models[3,4]. Nicotine exposure through smoking cigarettes may be more harmful than nicotine exposure through oral administration or nicotine patches due to other harmful chemicals in the smoke. Little is known concerning the effects of electronic-cigarettes that also contain nicotine on fracture healing, despite the growing popularity of these devices. The aim of this study was to compare the effects of traditional cigarette smoke to e-cigarettes on fracture healing using a rodent model.

METHODS: Forty-eight adult male Sprague Dawley rats were randomly allocated to either exposure to ambient air (control), regular cigarettes or e-cigarettes by placing them in a smoking chamber (TE-2, Teague Enterprises) for 20 minutes twice daily. After one week of exposure, all animals were anesthetized and underwent surgery to create transverse osteotomy in the midshaft of one femur with a Gigli saw which was then stabilized surgically with an intramedullary k-wire. All animals were treated with buprenorphine to reduce pain after surgery. Half of the animals were euthanized 3 weeks after fracture surgery, and the remaining animals were euthanized 6 weeks after surgery. Serum obtained at the time of euthanasia was used to measure continine levels, a nicotine metabolite. Bilateral femurs were harvested and imaged using contact radiographs and microCT. An orthopaedic traumatologist used a modified RUST scoring system to evaluate both the contact radiographs and the microCT images of the fractured femur in a blinded fashion. This surgeon also made an assessment of whether each femur was healed. The microCT images were segmented into 3 density ranges (unmineralized callus, mineralized callus, and cortical bone) and analyzed using BoneJ to determine the volume of tissue present in the 3 density ranges.

RESULTS: Five animals (2 in the control group, 1 in the cigarette group, and 2 in the e-cigarette group) were removed from analysis due to either inadequate fracture fixation or non-transverse fracture. Cotinine levels in the animals from the cigarette group were nearly twice the level of those in the e-cigarette group. The mRUST scores from contact radiographs correlated modestly but significantly with most measures from the microCT image analysis (r values ranged from 0.312 for cross-sectional area moment of inertia to 0.570 for medium density tissue volume). After 3 weeks, there were significantly more animals in the control group (42.9%) who were assessed on microCT as healed than either the cigarette (0%) or e-cigarette groups (0%). At 6 weeks, there were no differences among the 3 groups in terms of healing assessment, but the e-cigarette group had significantly higher measures of low-density tissue, indicating persistent soft callus volumes.

DISCUSSION AND CONCLUSION: Electronic-cigarette use is increasing, especially among younger Americans. The effects of e-cigarette use has not been studied previously in terms of bone healing, but has been demonstrated to have adverse effects on the healing of soft-tissue flaps5. In this study we attempted to equalize the amount of time animals were exposed to cigarette smoke or vapers from electronic cigarettes. Despite the lower level of cotinine in the group exposed to e-cigarettes, the bone healing in this group was still compromised compared to the control group.