Objectives

The single tunnel (3 mm) specimens exhibited a stiffness of 19.9 ± 1.55 Nm² and failed at 686 ± 45.2 N through the tunnel. The double tunnel technique exhibited a stiffness of 15.8 ± 1.18 Nm² and failed at 390 ± 31.7 N through the medial tunnel. In FE models of the experiments (Fig. 1), the double tunnel technique has 69% of the strength of the single tunnel (vs 57% in the experiments) and failure was predicted at the medial tunnel. In 200 variations of tunnel configuration, the double tunnel technique exhibited increased stress concentration relative to a single tunnel. Larger tunnels exhibited higher stresses than smaller tunnels. Fig. 1: FE models exhibit greater stress concentration of the double 6 mm tunnel (right) technique compared to the single 3 mm tunnel (left) and technique.

Methods

Composite synthetic clavicles were subjected to four-point bending on a servohydraulic load frame. Two established surgical techniques were compared; a single 3 mm tunnel technique and a double 6 mm tunnel technique. Finite element (FE) models were validated against experimental findings. Subsequent FE models explored a broad range of tunnel parameters to determine their biomechanical consequences.

Fig. 1: Experimental results for load to failure (mean ± standard deviation) testing are revealed in this box-whisker plot for the single 3 mm tunnel and double 6 mm tunnel techniques. Load (A) and moment (B) at failure are shown.

Results

Fig. 2: Using finite element analysis, the stress concentration surrounding tunnels was determined. A right clavicle was modeled and the lateral aspect was evaluated. Superior (A) and inferior (B) views of the stress concentration surrounding a single 3 mm tunnel are shown. Stress concentration surrounding double 6 mm tunnels are also shown with superior (C) and inferior (D) views.

Conclusions

Experimental and FE results demonstrate that the double 6 mm tunnel reconstruction has a higher stress concentration than the single 3 mm tunnel technique when subjected to four-point bending. The validated FE model supports the use of small tunnels and suggests that a double tunnel configuration may have biomechanical disadvantages that must be weighed against the perceived advantages of “anatomic” reconstruction.

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References