COMPARISON OF CARBON FIBRE PEEK LAMINATES, TITANIUM AND UNREINFORCED PEEK AS MATERIALS FOR DISTAL RADIUS FRATURE FIXATION PLATES

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Introduction

Polyetheretherketone (PEEK) is becoming increasing more attractive as a biomaterial for use in orthopaedic applications [Kurtz, S.M., 2007]. The addition of continuous unidirectional carbon fibres to PEEK allows for the design of laminates with customised anisotropic properties, providing mechanical advantages over homogenous metal plates for fracture fixation applications (e.g. decreasing the potential for stress shielding). This study analyses the response of CF/PEEK laminates to forces induced during everyday physiological loading of the distal radius. Results are compared with homogenous titanium and unreinforced PEEK plates.

Methods

Two composite plate designs are considered, with different layups and ply orientations:

Lam. 1: [0°/0°/90°/0°/90°/0°/90°/-45°/45°]s

Lam. 2: [90°/0°/90°/45°/90°/0°/-45°/0°/0°]s.

Idealised plate geometries are subjected to the physiological loading experienced in the radius, i.e. combined bending (4.9Nm) and torsion (0.68Nm) [Christen, P., 2012; Hirahara, H., 2003] (Fig. 2A).

Results

Figure 1 shows the longitudinal stresses through the thickness of the laminates for a bending load of 4.9Nm. In the case of laminate 1, the high proportion of 0° plies towards the outer edges of the laminate allows for a greater resistance to the applied bending.

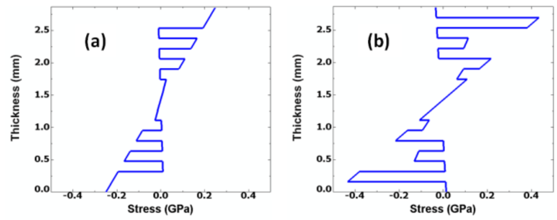

***Fig. 1:** Longitudinal stresses through the thickness of the laminates under a 4.9Nm bending moment **a)** laminate 1 and **b)** laminate 2.*

The longitudinal and transverse stress distributions in the most highly stressed ply in laminate 1 (ply1, 0°) and laminate 2 (ply2, 0°) under the combined bending/torsion load are shown in Fig. 2B. Peak stresses are lower in laminate 1, with a significant stress concentration being computed in the region of the screw thread in laminate 2.

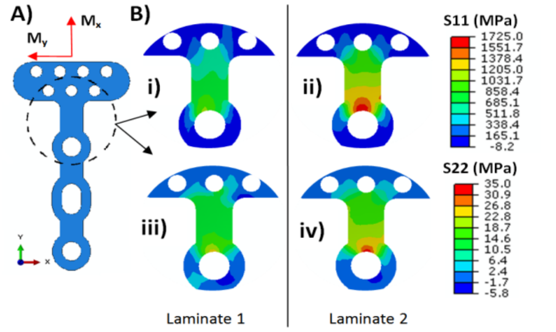

***Fig. 2:** **A)** Plate geometry and applied loading; **B)** Longitudinal (top) and transverse (bottom) stress distributions in laminate 1 and laminate 2.*

As shown in Table 1, the design factor of safety (FoS) of laminate 1 is comparable to that of a titanium plate with the same thickness (2.85mm). The importance of ply orientation highlighted by the reduced FoS of laminate 2. An unreinforced PEEK plate is shown to be unsafe for the specified physiological loading.

	Factor of Safety
Titanium	5.57
Laminate 1	4.72
Laminate 2	2.84
Unreinforced PEEK	0.51

Table 1: Design factor of safety calculated for 2.85mm thick plates under the combined bending/torsion loading.

Discussion

Clearly the introduction of continuous carbon fibres into PEEK polymer allows laminates to be manufactured with a similar thickness to titanium plates, with the advantage of reduced stiffness, thus decreasing the potential for bone resorption due to stress shielding. The importance of ply orientation in the reduction of stress concentrations is demonstrated; optimal laminate design is of critical importance in the use of CF/PEEK as an alternative to titanium for fracture fixation plates.

References

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Hirahara, H., *et al*, J Hand Surg-Am, 28: 614-621, 2003

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