Transient polymer networks are found throughout biological systems, both intracellularly and extracellularly. Hydrogels with dynamic linkers have garnered intense interest as extracellular matrix (ECM) mimics and injectable delivery vehicles due to their tailorable viscoelasticity, stress relaxation, and self-healing behavior. However, to fully enable these applications, there remains a need to understand how linking chemistry affects gelation and nonlinear rheological properties. In this context, we have developed synthetic multi-arm poly(ethylene glycol) (PEG) hydrogels with three different dynamic covalent linking chemistries. This suite of dynamic covalent linkages allows control over the bond exchange kinetics across three orders of magnitude, which dictates hydrogel viscoelasticity under small amplitude oscillatory shear. Interestingly, the hydrogel moduli demonstrate unique scaling behavior at low concentrations, indicating heterogeneous networks. Furthermore, they exhibit non-monotonic flow curves under steady shear, with shear thickening behavior that depends on the crosslinking bond exchange kinetics and polymer concentration. At high shear, the dynamic hydrogels are injectable, with faster bond exchange kinetics leading to lower injection forces. Overall, these results provide insight to the molecular and structural characteristics that govern dynamic covalent PEG gelation, mechanics, and flow, while also expanding the types of scaffolds applicable to tissue engineering and therapeutic delivery.