Red blood cell (RBC) hemolysis is a critical concern in the design of artificial devices implanted into the circulatory system, such as heart valves. The new stresses imposed on RBCs by the presence of these devices can accelerate their breakdown in comparison to what is observed through the pristine circulatory system. To date a few analytical and numerical models have been proposed to relate either RBC stress or strain resulting from the surrounding fluid conditions to the expected degree of hemolysis as a function of time. Here we first present a brief survey of the existing models, which are based on either “lumped” descriptions of stress or analytical-numerical RBC descriptions relying on simple geometrical assumptions, and introduce two additional approaches based on an existing coarse grained particle dynamics method. We then explore the rationale and RBC physics within each method through model virtual experiments. Finally, we apply all models to simulate the expected level of RBC damage using pathlines calculated for a realistic artificial heart valve. Our results shed light on the strengths and weaknesses of each approach and identify the key gaps that should be addressed in the development of new models.