A proof of Lagrange's and Jacobi's four-square theorem due to Hurwitz utilizes orders in a quaternion algebra over the rationals. Seeking a generalization of this technique to orders over number fields, we identify two key components: an order with a good factorization theory and the condition that all orbits under the action of the group of elements of norm 1 acting by multiplication intersect the suborder corresponding to the quadratic form to be studied. We use recent results on class numbers of quaternion orders and then find all suborders satisfying the orbit condition. Subsequently, we obtain universality and formulas for the number of representations by the corresponding quadratic forms. We also present a quaternionic proof of Götzky's four-square theorem.