Recent advancements in microelectronics have increased the need for thermal management systems capable of high heat flux dissipation within significant spatial constraints. One method of increasing local heat fluxes is the fabrication of superhydrophilic materials via micro/nanostructuring of the surface. Superhydrophilic surfaces act in a self-pumping capacity, spreading fluid beyond its intrinsic meniscus length to form thin-films, a process known as “hemiwicking”, with practical applications in evaporative cooling, as well as flow, pool, and thin-film boiling. Of particular interest is anisotropic hemiwicking via asymmetric microstructuring. The microscopic asymmetricity of the design induces a macroscopically preferred direction of wicking, which has the potential to be tailored to specific heating configurations for increased efficiencies. In this study, half-conical asymmetric microstructures have been produced via two-photon polymerization, and anisotropic quality has been characterized through the use of high-speed videography. High-speed thin-film interferometry and microscopic side-angle videography are utilized to study the evolution of meniscus curvature during inter-pillar fluid front propagation, which determines driving force via Laplace pressures. Experimental results show increased meniscus curvature in the preferred direction of wicking, and measurements at later time scales are in agreement with traditional curvature scaling laws. Meniscus stability differences are also observed during initial front propagation. These results can be used to help optimize anisotropic hemiwicking designs for use in next-generation heat sinks.