ABSTRACT: In 2007, there were approximately 1.7 million people with limb loss in the US with more than 185,000 new amputations each year. The prevalence rate in 1996 was 1 per 200 persons (medical care costs exceed $4.3 billion yearly). The science of socket fitting suffers from inaccurate measurement of kinematics experiences at the residual limb-socket interface. Static Roentgen Stereophotogrammetric Analysis (RSA) has been used to characterize socket and stump motion [2]. These studies are not accurate enough to register dynamic slippage in three dimensions (3D). We present here a new method to assess residual bone-stump-skin-socket interface kinematics of above knee amputees with high accuracy biplane dynamic roentgen stereogrammetric analysis (DRSA).

METHODS: Slippage between transfemoral residuum and its prosthetic socket of ten above knee amputees (two females, eight males, Age: 35±12 years) was measured using DRSA (with IRB approval). DRSA can assess dynamic high speed socket-stump and bone-socket telescoping motion with as much as ±0.1mm accuracy (one order of magnitude higher than current techniques) using the dynamic radiostereography analysis (DRSA) system [3] (Fig. 1a) Tracking of 3D kinematics of tantalum markers rigidly placed on the socket inner wall, the liner, and skin surface (stripes of lead paint in the shape of orthogonal mesh) was performed for amputee walking, running and jumping activities (Fig. 1). Two techniques were used for skeletal kinematics tracking: a) Tantalum markers (0.8 mm beads) embedded in the bone during amputee reconstructive surgery and tracked with DRSA imaging. b) Markerless tracking was also possible using image processing software [4] (Fig. 1b). These techniques involve three dimensional reconstruction of the sequences of biplane stereoradiography data from DRSA and fusion with the patient Computed Tomography data to track the 3D motion of bone, skin, stump and socket.

RESULTS: Our study of above amputee (n=10) socket-stump motion showed an average variation of 10-30mm (±17mm) in the vertical motion (VM) and 0 to 15 mm (±8mm) in the anterior posterior (AP) motion during gait (Fig. 2). In two-legged jumping vertical motion exceeded 40mm in all of the amputee studies. The skin deformed during the support phase of gait and during jumping since we saw a skewness of the skin lead paint mesh (Fig. 1b). The top part of the mesh was displaced 10mm (±12mm) from the bottom part during the support phase of gait (22mm (±19mm) in jumping).

DISCUSSION: The socket telescoping motion of above knee amputees in all 3D translations and rotations was assessed using a new method. Excessive socket–stump vertical and AP motion (up to 40mm) was measured during gait and two legged jumping activities. This excessive motion is of critical importance in the optimization of socket fitting since motion of the residuum (skin, underlying soft tissue) is responsible for its poor adaptation to the high pressures, shear stress, abrasive relative motions, and the other physical irritations encountered at the prosthetic socket interface.

REFERENCES