A Appendix

A.1 Genesis Multi-Object Dataset Physical Parameters

Fig. 6 shows a sample from the Genesis Multi-Object dataset. We parameterize each material by a set of physical attributes, and assign every object the parameter values associated with its material label. Some of these parameters are selected uniformly at random from a range to increase variation in the dataset, and not all parameters are used by each material. The numerical details are shown below.

	Young's Modulus $(E)^\dagger$	Poisson's Ratio $(\nu)^\dagger$	Density $(\rho)^\dagger$
Elastic	$[4.75 \times 10^4, 5.25 \times 10^4]$	$[20, 30]$	$[800, 1200]$
Elastoplastic	$[4.75 \times 10^4, 5.25 \times 10^4]$	$[20, 30]$	$[800, 1200]$
Sand	$[4.75 \times 10^4, 5.25 \times 10^4]$	$[20, 30]$	$[800, 1200]$
Snow	$[4.75 \times 10^4, 5.25 \times 10^4]$	$[20, 30]$	$[800, 1200]$
Liquid	$[4.75 \times 10^4, 5.25 \times 10^4]$	$[20, 30]$	$[800, 1200]$

	Shear Modulus $(\mu)^\dagger$	Yield Stress Range (τ_Y)	Friction Angle (θ)
Elastic	–	–	–
Elastoplastic	–	$[2.5 \times 10^{-2}, 4.5 \times 10^{-2}]$	–
Sand	–	–	45°
Snow	–	$[2.5 \times 10^{-2}, 4.5 \times 10^{-2}]$	–
Liquid	$[2.4 \times 10^6, 3.6 \times 10^6]$	–	–

Table 4: Physical parameter values for objects in the Genesis Multi-Object Dataset. † indicates that the value is selected uniformly at random from the given range

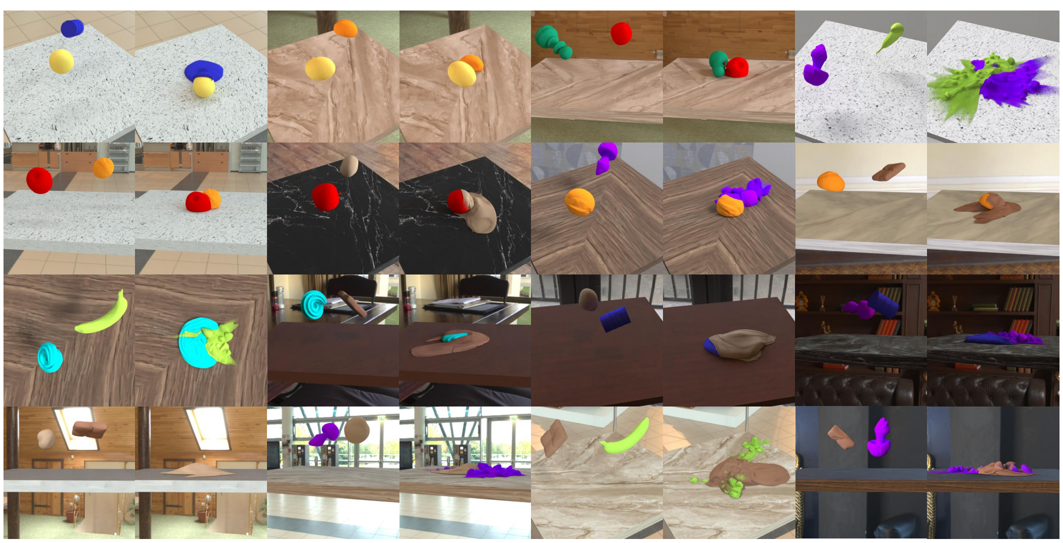

Figure 6: **Multi-Object Dataset Example.**

A.2 Material Point Method

The Material Point Method (MPM) (Jiang et al., 2016) is a hybrid Eulerian-Lagrangian method for simulation the behavior of continuum materials, based on its physical parameters. MPM represents continuum as particles, each with its own physical parameters, interacting with a background grid from which governing physics laws are solved to obtain an update, and then the updates at grid locations propagate back to the particles. Although (Jiang et al., 2016) covers the mathematical derivations in detail, we provide a brief overview of the method and the most relevant equations.

A.2.1 Initialization

The continuum is first represented by a set of discrete particles. We enumerate the particles as $\mathcal{P} = \{1, 2, ..., P\}$ where P is the total number of particles. Each particle $p \in \mathcal{P}$, is initialized with starting position x_p^0, velocity v_p^0, mass m_p^0, volume V_p^0, deformation gradient F_p^0, and material parameters. Each particle also stores an affine matrix B_p^0. The grid is also initialized with grid points $\mathcal{G} = \{1, 2, ..., G\}$ where G is the total number of grid locations.

A.2.2 Particle to Grid Transfer

At this stage, particle properties are transferred to grid locations to perform physics calculations. Each grid point stores a mass and momentum. At timestep t, grid point i has mass:

$$m_i^t = \sum_{p \in \mathcal{P}} w_{ip}^t m_p^t$$

and momentum

$$m_i^t v_i^t = \sum_{p \in \mathcal{P}} w_{ip}^t m_p^t \left(v_p^t + B_p^t (D_p^t)^{-1} (x_i^t - x_p^t) \right)$$

where

$$D_p^t = \sum_{i \in \mathcal{G}} w_{ip}^t (x_i^t - x_p^t)(x_i^t - x_p^t)^\top$$

Grid velocities are calculated by dividing momentum by mass. In the case that the mass is zero, the velocity is instead set to 0.

A.2.3 Computing Grid Forces and Velocity Update

Now, the force acting upon each grid point as a result of elastic stresses from nearby particles is calculated for grid point i at timestep t as:

$$f_i^t = -\sum_{p \in \mathcal{P}} V_p^0 \left(\frac{\partial \Psi_p}{\partial F}(F_p^t) \right) (F_p^t)^\top \nabla w_{ip}^t$$

Here, F_p^t is the deformation gradient at time t for particle p and $\frac{\partial \Psi_p}{\partial F}$ represents the first Piola-Kirchhoff stress tensor at that particle. Now, we can update the velocity at each grid point with:

$$v_i^{t+1} = v_i t + \Delta t f_i^t(x_i^t)/m_i$$

In this step, boundary conditions and collisions are also taken into account and resolved.

A.2.4 Grid to Particle Transfer

Now that the relevant values have been computed at the grid points, we can propagate these changes back to the particles by updating their deformation gradients as follows for particle p at timestep t:

$$F_p^{t+1} = \left(\mathbf{I} + \Delta t \sum_{i \in \mathcal{G}} v_i^{t+1} (\nabla w_{ip}^t)^\top \right) F_p^t$$

At this stage, updates to each particle's velocity and B affine matrix are also calculated. The velocity is calculated as:

$$v_p^{t+1} = \sum_{i \in \mathcal{G}} w_{ip}^t v_i^t$$

The affine matrix is updated as:

$$B_p^{t+1} = \sum_{i \in \mathcal{G}} w_{ip}^t v_i^t (x_i^t - x_p^t)^\top$$

A.2.5 Particle Update

Finally, with the updated velocities, the particle locations can now also be updated as follows for particle p at timestep t:

$$x_p^{t+1} = x_p^t + \Delta t v_p^{t+1}$$

Finally, with the updated velocities, the particle locations can now also be updated as follows for particle p at timestep t:

$$x_p^{t+1} = x_p^t + \Delta t v_p^{t+1}$$

A.3 More Qualitative Results

We conduct extra qualitative comparison of multi-material interaction, showing the results of OmniphysGS (Lin et al., 2025), OmniphysGS w/ Oracle (Lin et al., 2025), and our MOSIV in Figs. 7 to 16. Each figure compares the results of both observed and predicted frames and MOSIV shows finer deformations with greater accuracy, demonstrating superior adaptability to diverse materials interactions.

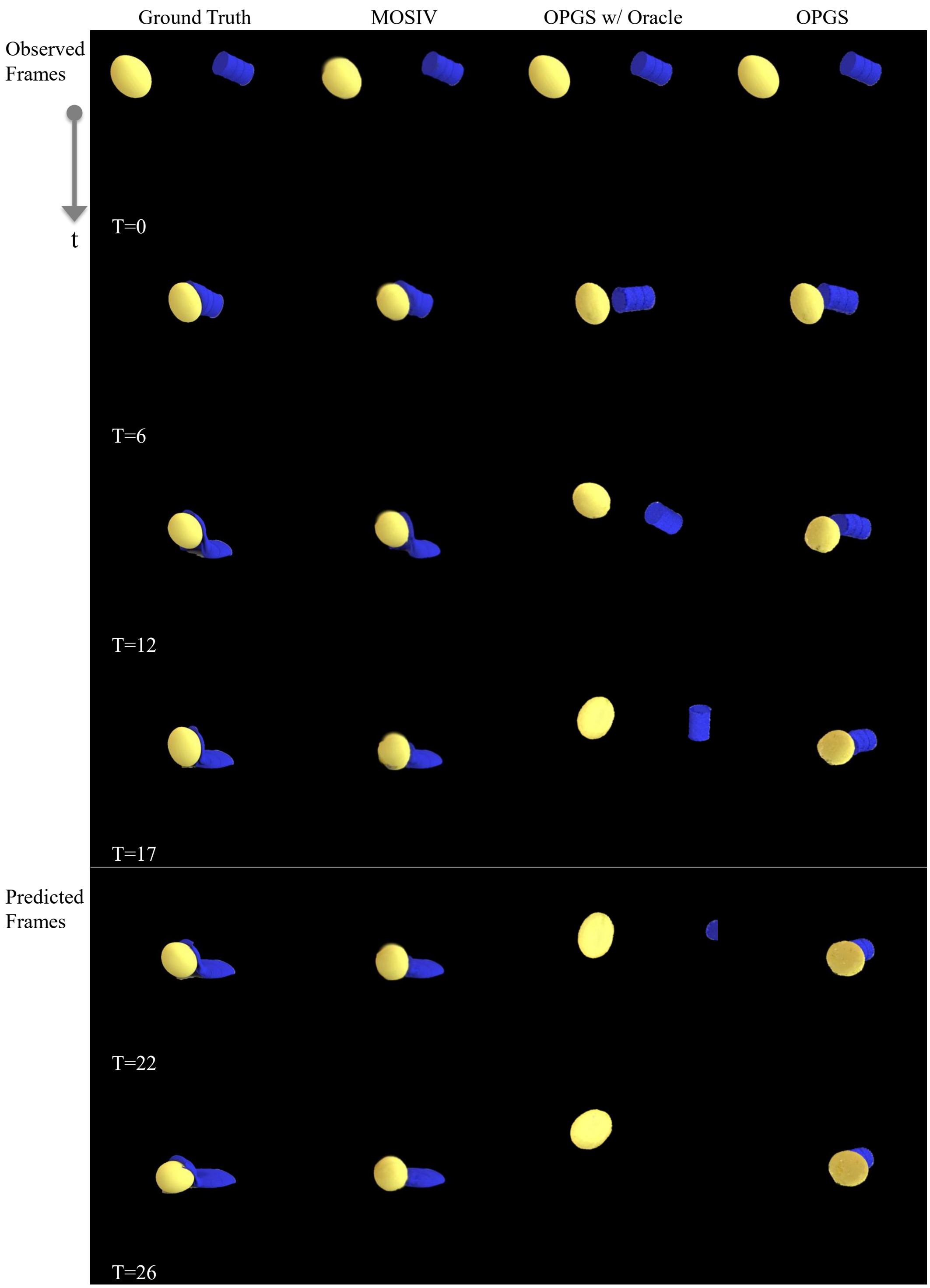

Figure 7: **Qualitative Comparison with material type elastic/fluid (E/F).**

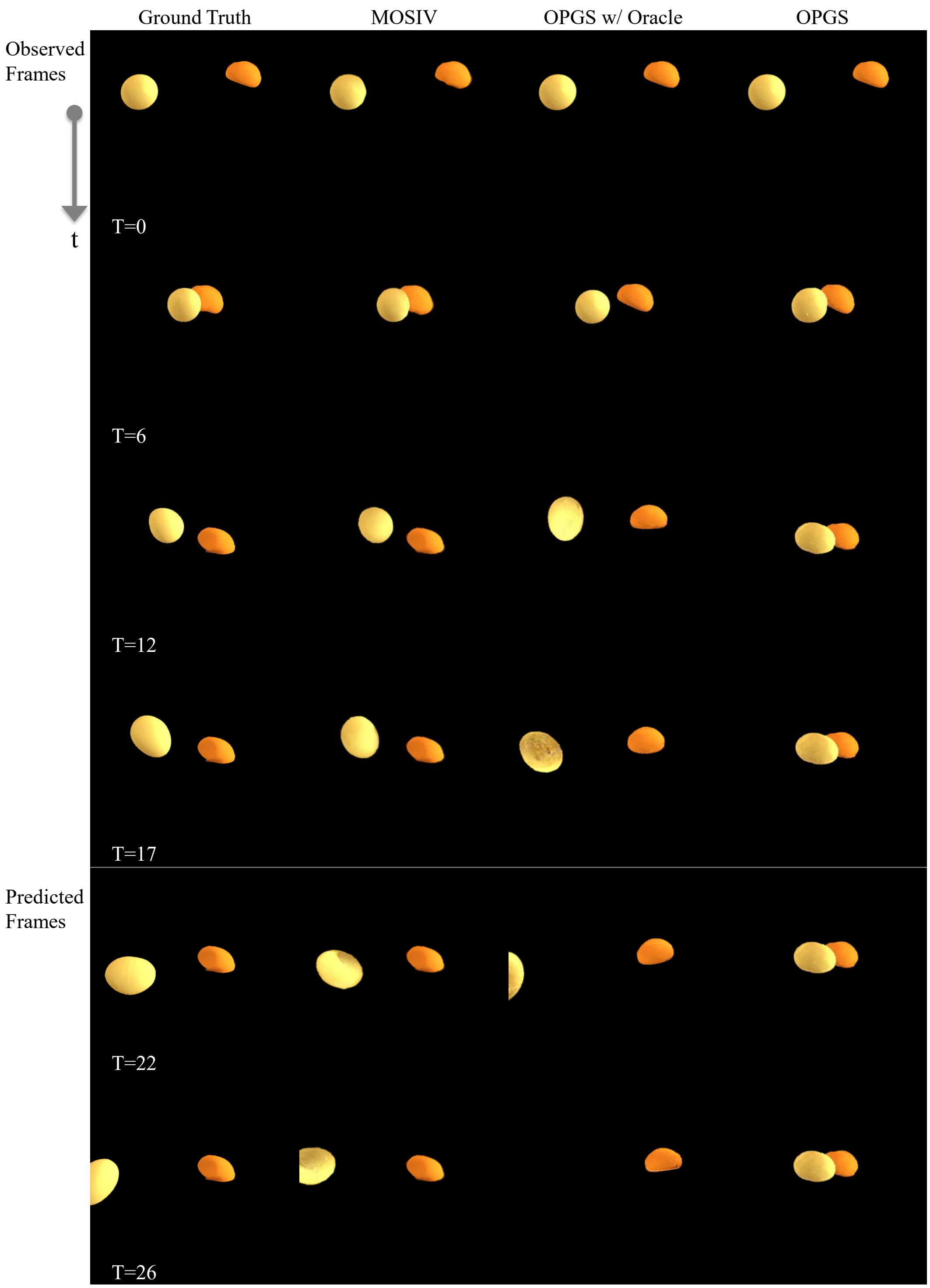

Figure 8: **Qualitative Comparison with material type elastic/plasticine (E/P).**

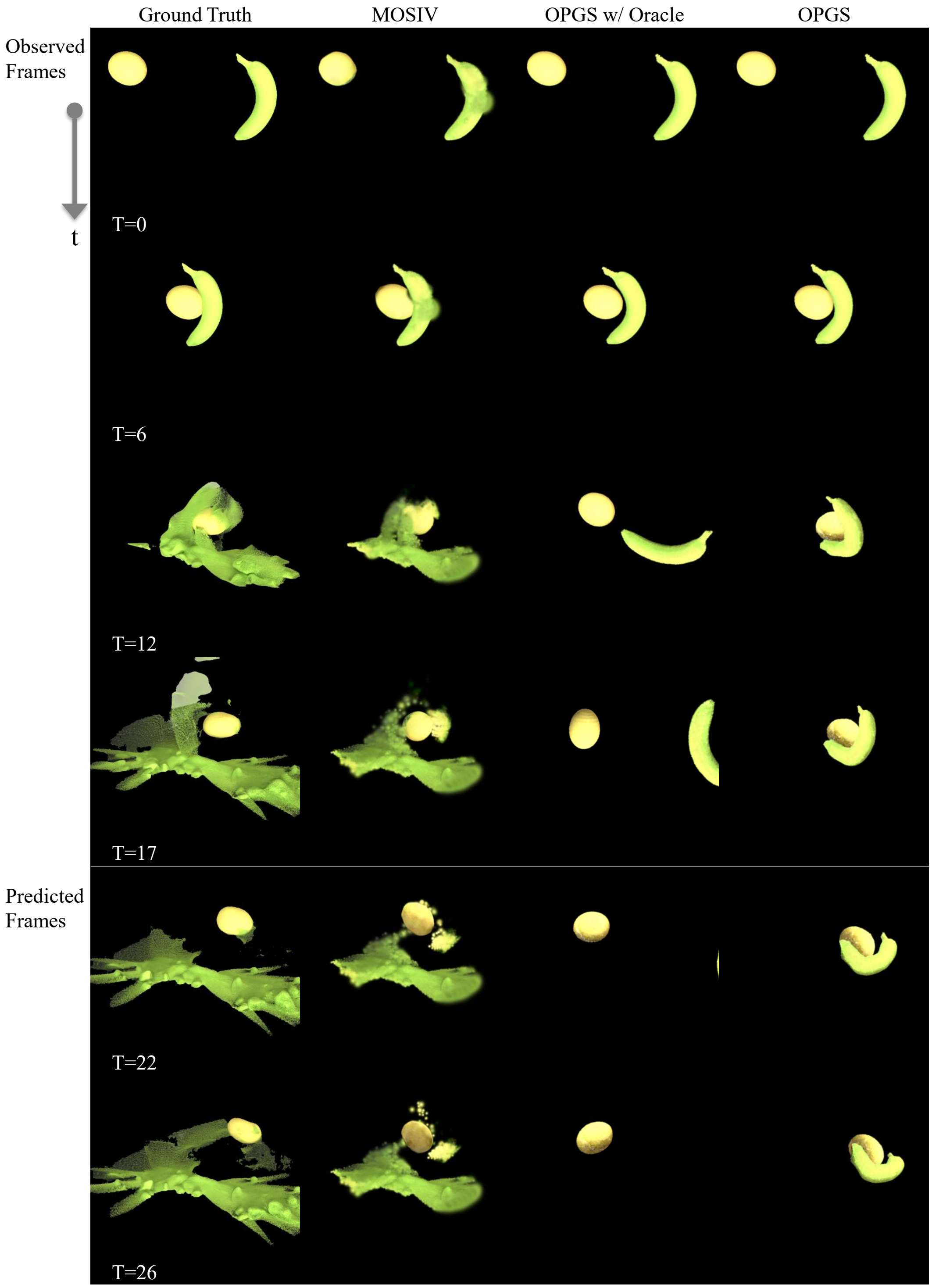

Figure 9: **Qualitative Comparison with material type elastic/sand (E/S).**

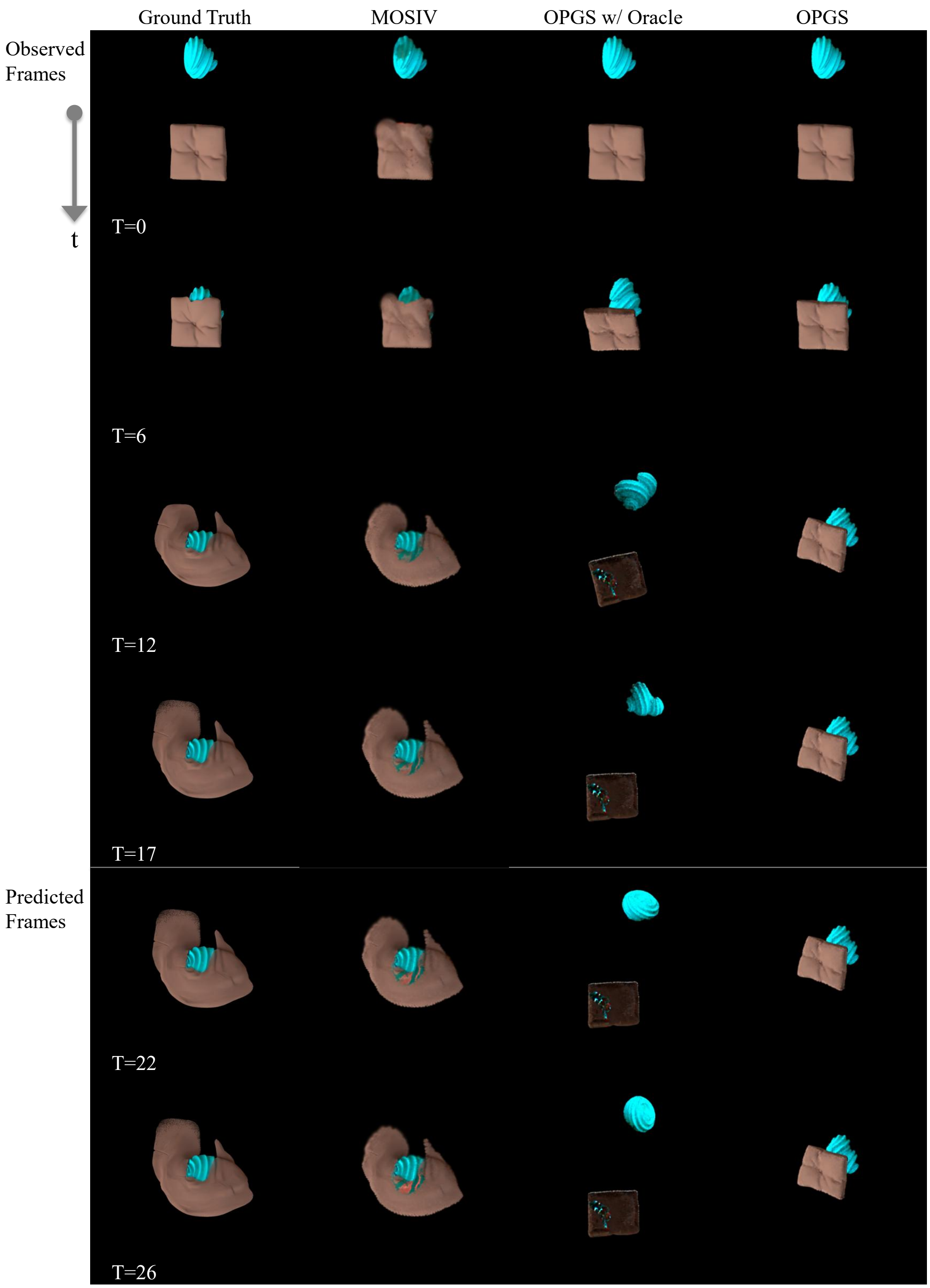

Figure 10: **Qualitative Comparison with material type fluid/sand (F/S).**

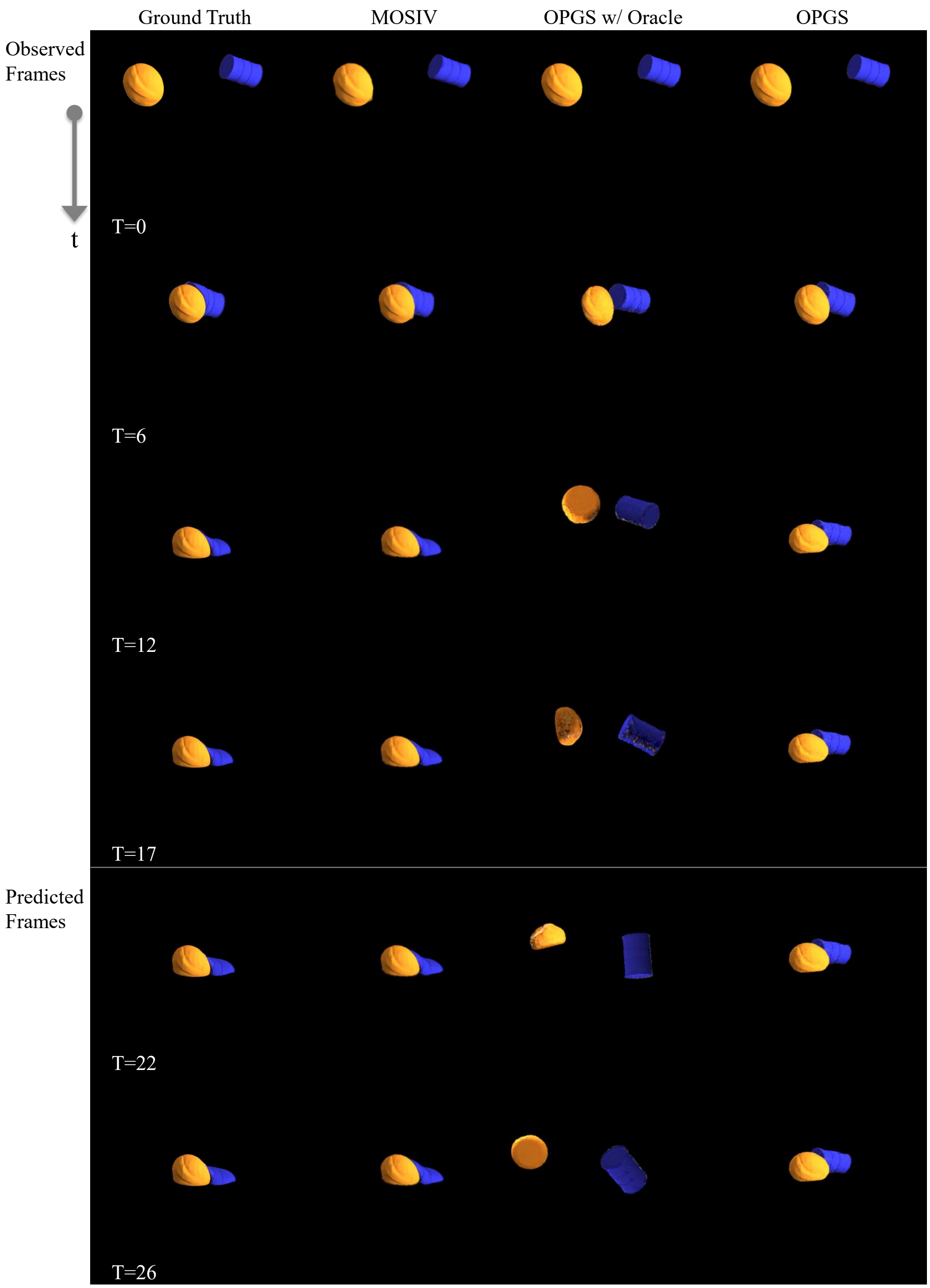

Figure 11: **Qualitative Comparison with material type plasticine/fluid (P/F).**

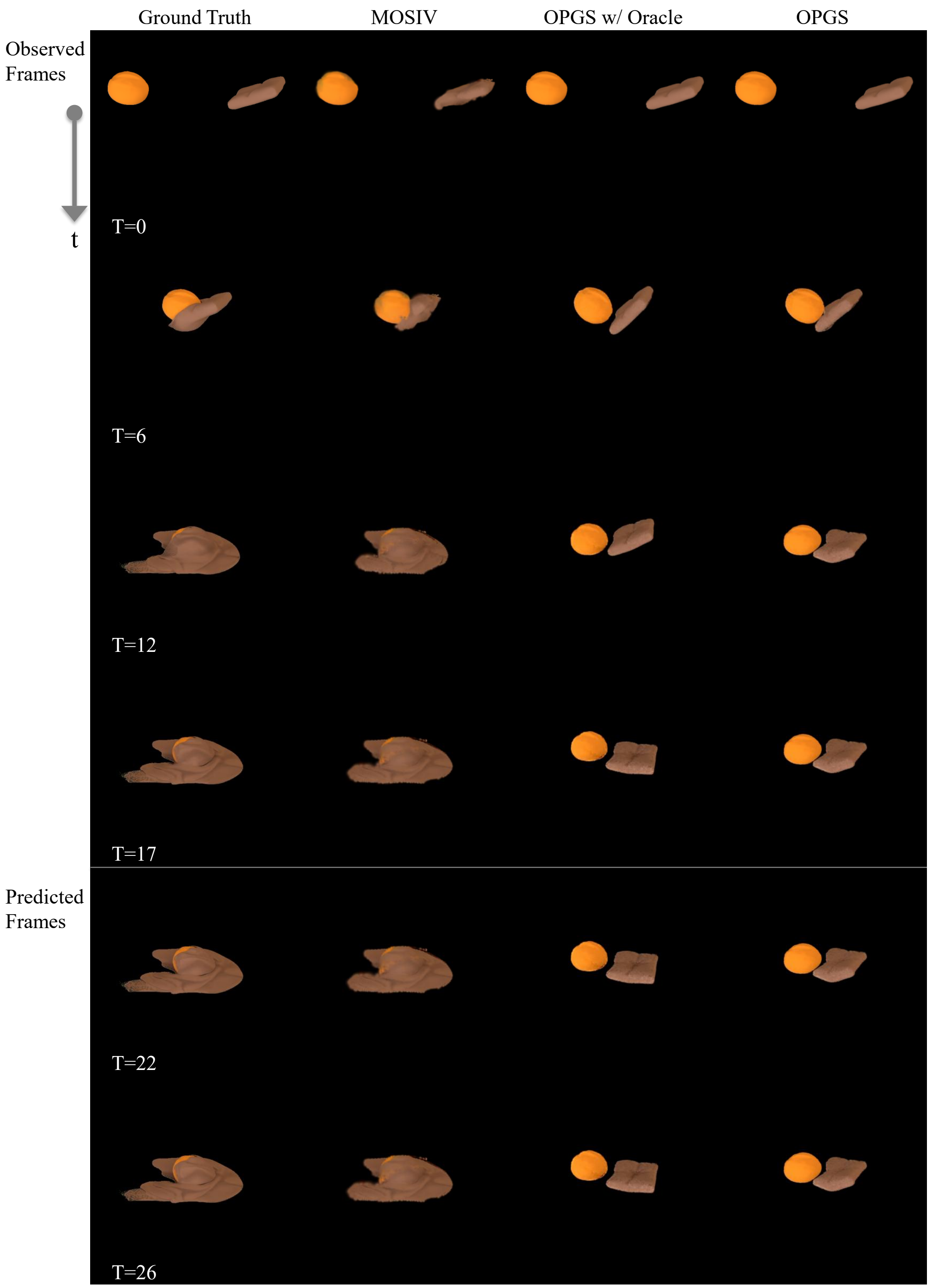

Figure 12: **Qualitative Comparison with material type sand/plasticine (S/P).**

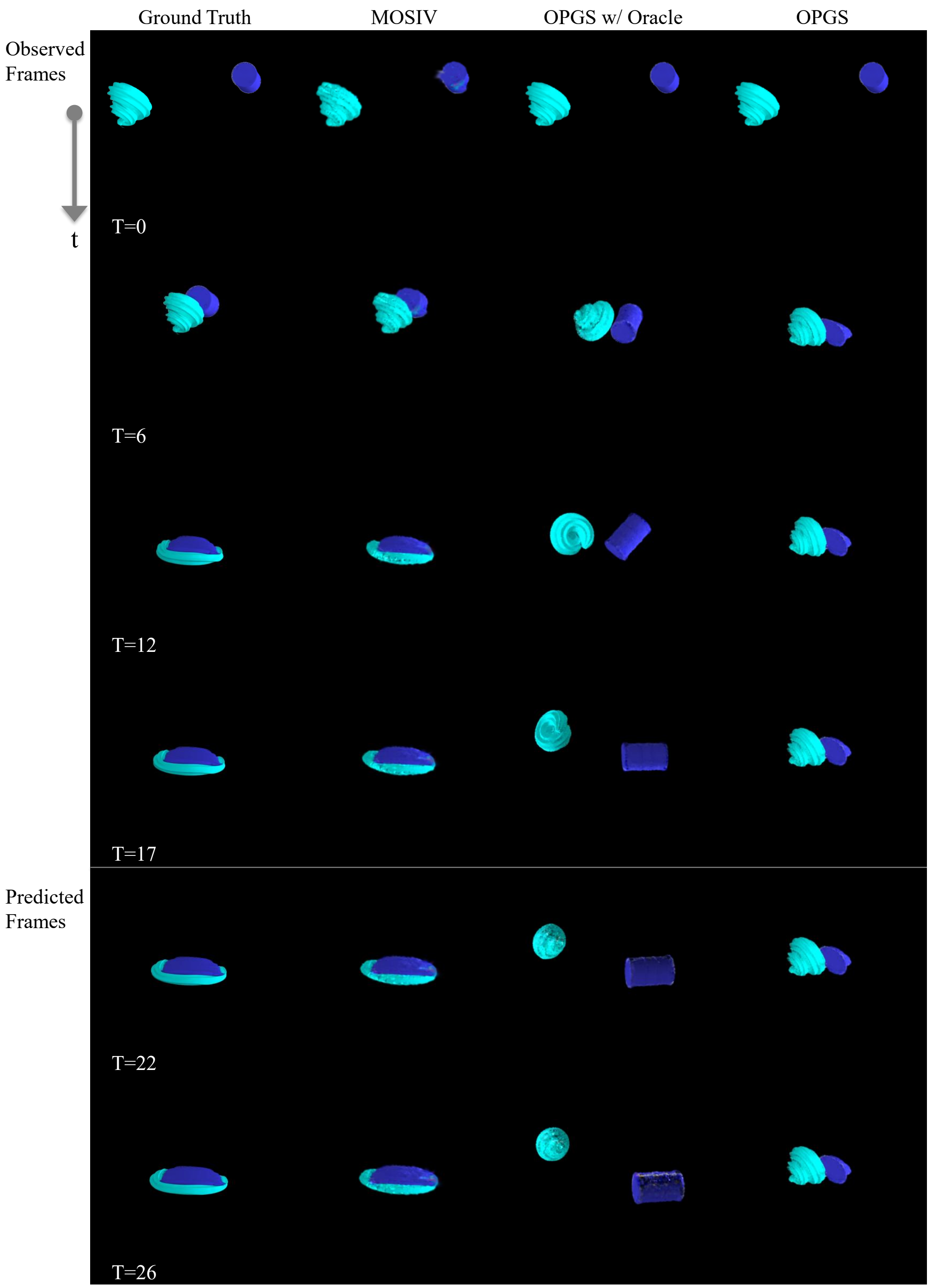

Figure 13: **Qualitative Comparison with material type fluid/fluid (F/F).**

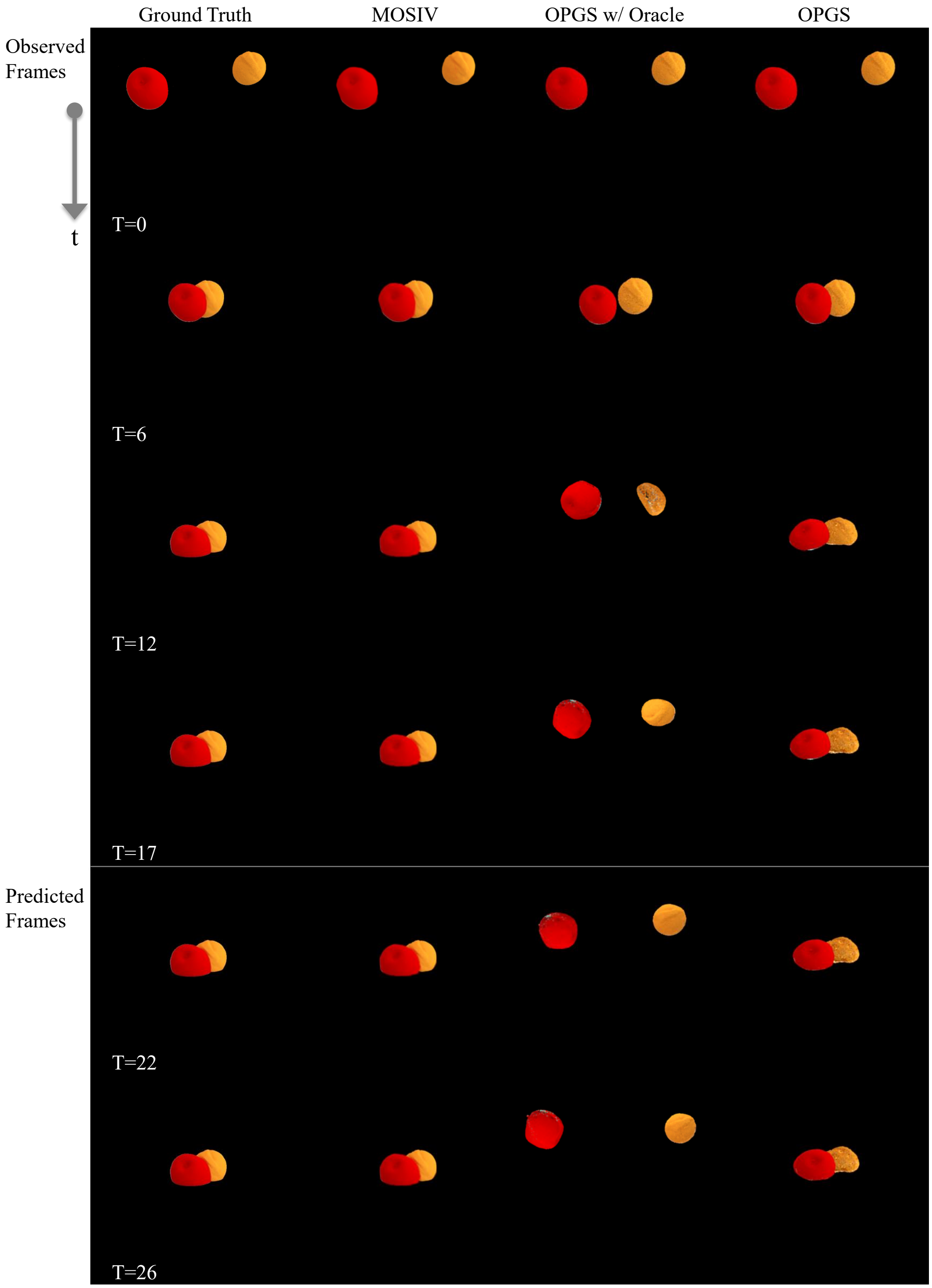

Figure 14: **Qualitative Comparison with material type plasticine/plasticine (P/P).**

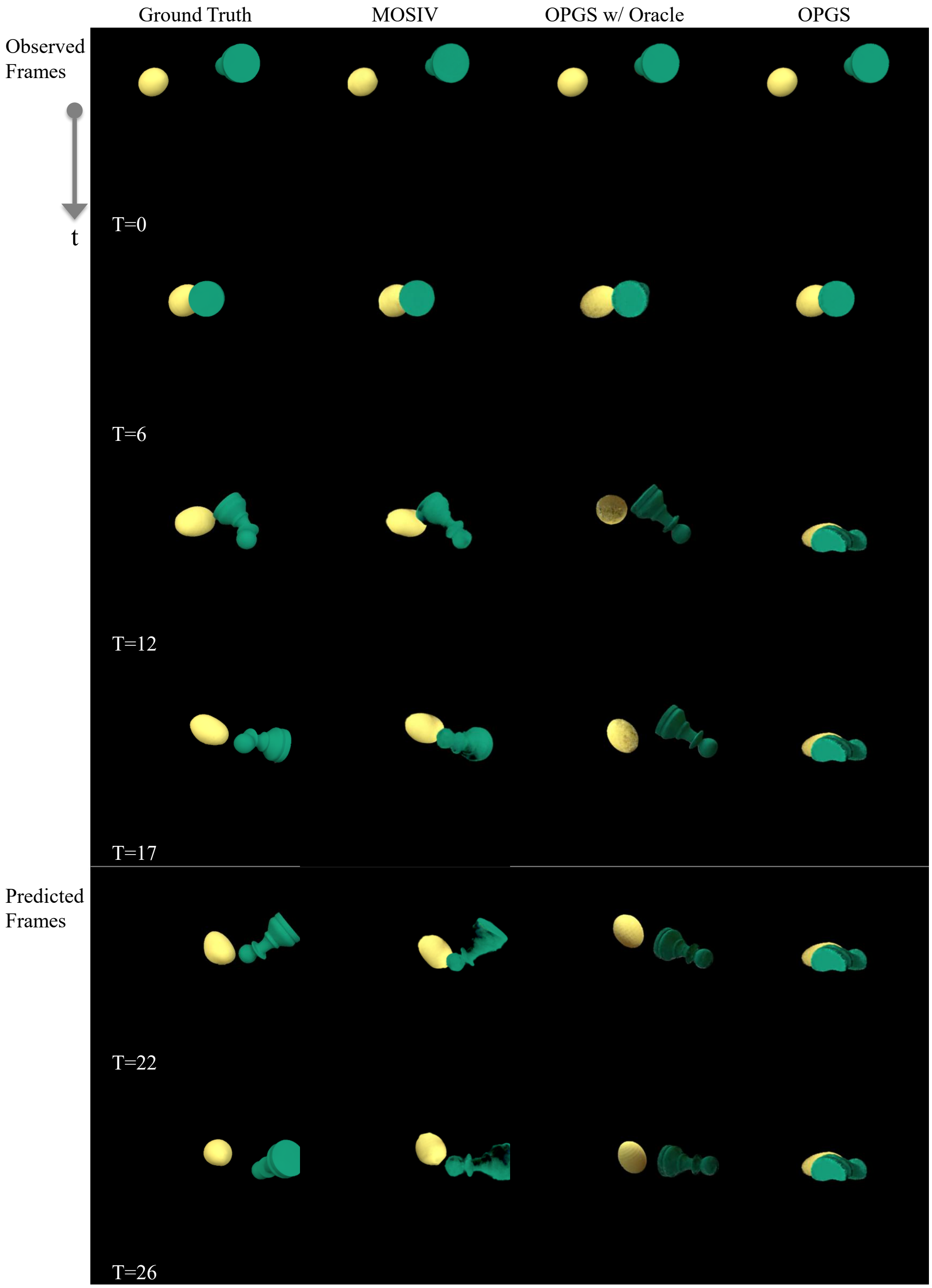

Figure 15: **Qualitative Comparison with material type elastic/elastic (E/E).**

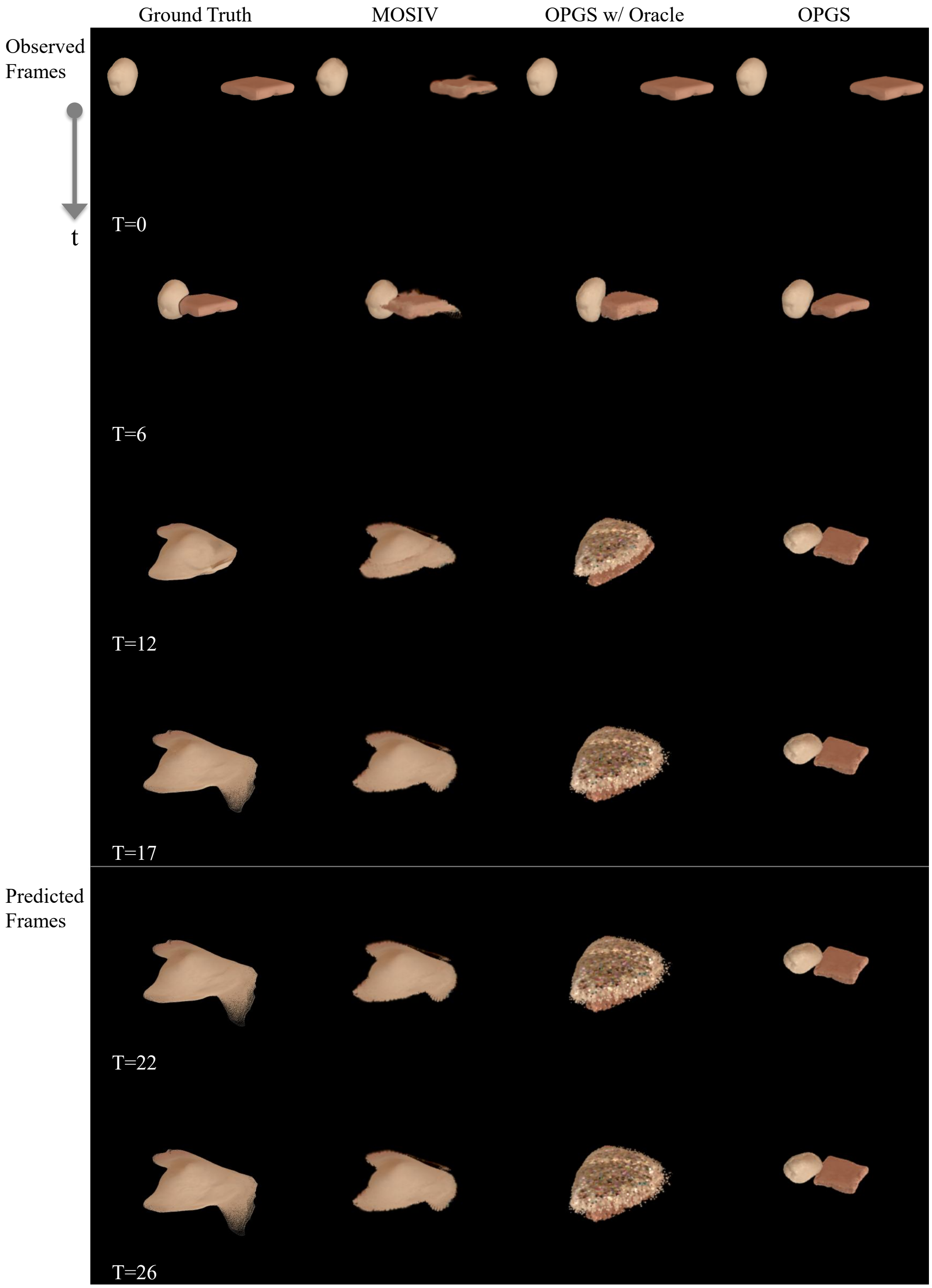

Figure 16: **Qualitative Comparison with material type sand/sand (S/S).**