Simulation of Cellular Traction Force Based Deflection of PDMS Micropillars

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Introduction

Cells are complex entities which not only passively sense external stimuli (viz. chemical, optical or mechanical) but also interact with extracellular matrix (ECM) by regulating cellular behaviours such as growth, proliferation, migration, etc [1]. Monitoring growth and migration of adherent cells becomes a crucial factor in determining cell-cell and cell-substrate interaction, which is important for formation of tissues, signal transduction pathways and body's defence system.

Polydimethylsiloxane (PDMS) micropillars arrays were used to study the deflection of the tips of the micro pillars which is directly proportional to cell-generated traction forces during cell migration and contraction [2]. Present study discusses the effect of cellular traction force over different micropillars geometries with different PDMS compositions which varies the elasticity of micropillars.

Computational Methods

- Solid mechanics physics based on Hooke's law in COMSOL Multiphysics® was used to model the micropillars structures having different circular shaped pillars of diameter 5, 10, 20, 30, 40 and 50 μm with constant gap of 10 μm.

- Variation in Young's modulus of PDMS corresponding to different PDMS base and curing agent ratio of 5:1, 10:1, 15:1 and 20:1 (as shown in Table 1) were also employed for the above geometries.

- Distributed force in pN range corresponding to epithelial cells was applied near top edges of the micropillars.

$$\rho \frac{\partial^2 u}{\partial t^2} - \nabla.\sigma = F_v$$

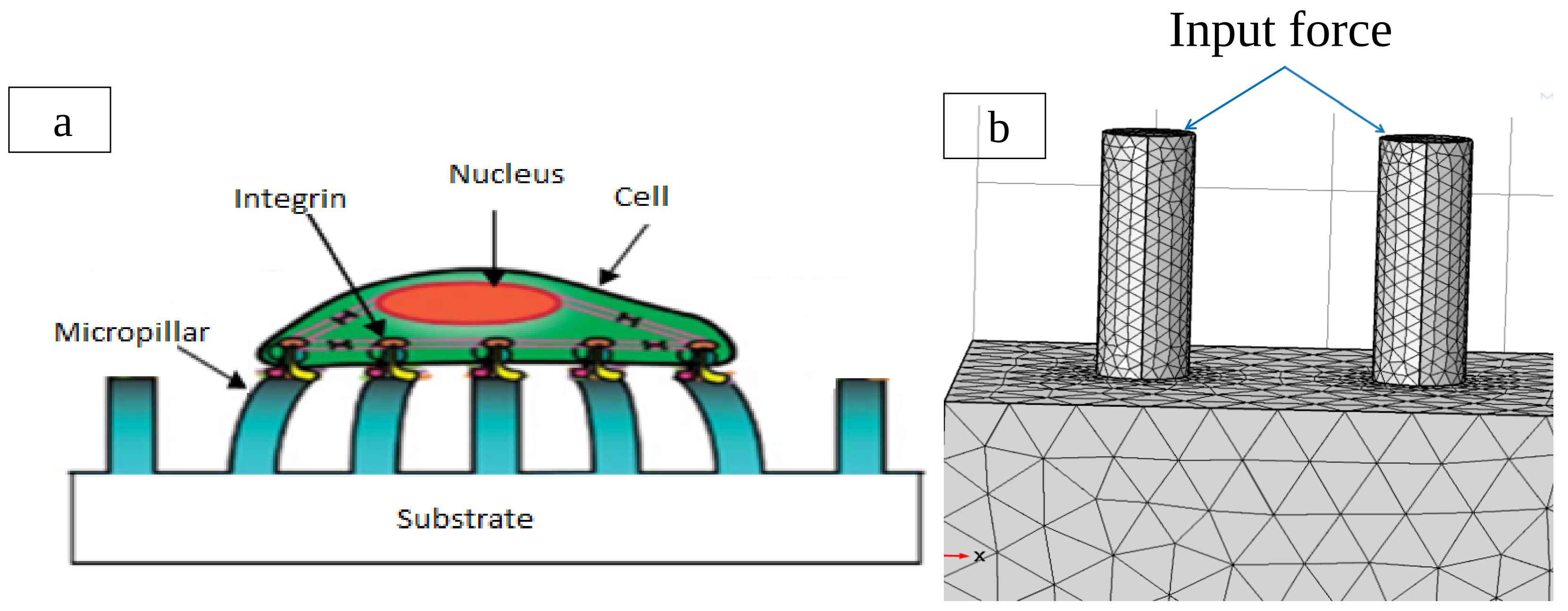

Figure 1 (a) Schematic representation of pillar bending during cell growth and, (b) Mesh diagram of micropillar using COMSOL

Results

- Figure 2 depicts the images of PDMS micropillar deflection and stress for pillar diameter 5, 10, 20 and 30 μm simulated with higher Young's modulus of 3.72 MPa and lowest Young's modulus of 0.47 MPa of corresponding to 5:1 and 20:1 PDMS composition, respectively.

- The micropillars of diameter 5 and 10 μm with PDMS composition 20:1 generate maximum deflection leading to adequate condition for the study of cellular biomechanics as shown in Figure 3.

Table 1. Parameter value for simulation

Variable	*Value*	*Units*
PDMS Density	970	Kg/m^3
Young's Modulus	0.47-3.72	MPa
Poison ratio	0.49	1
Force	150	pN

Surface stress N/m^2

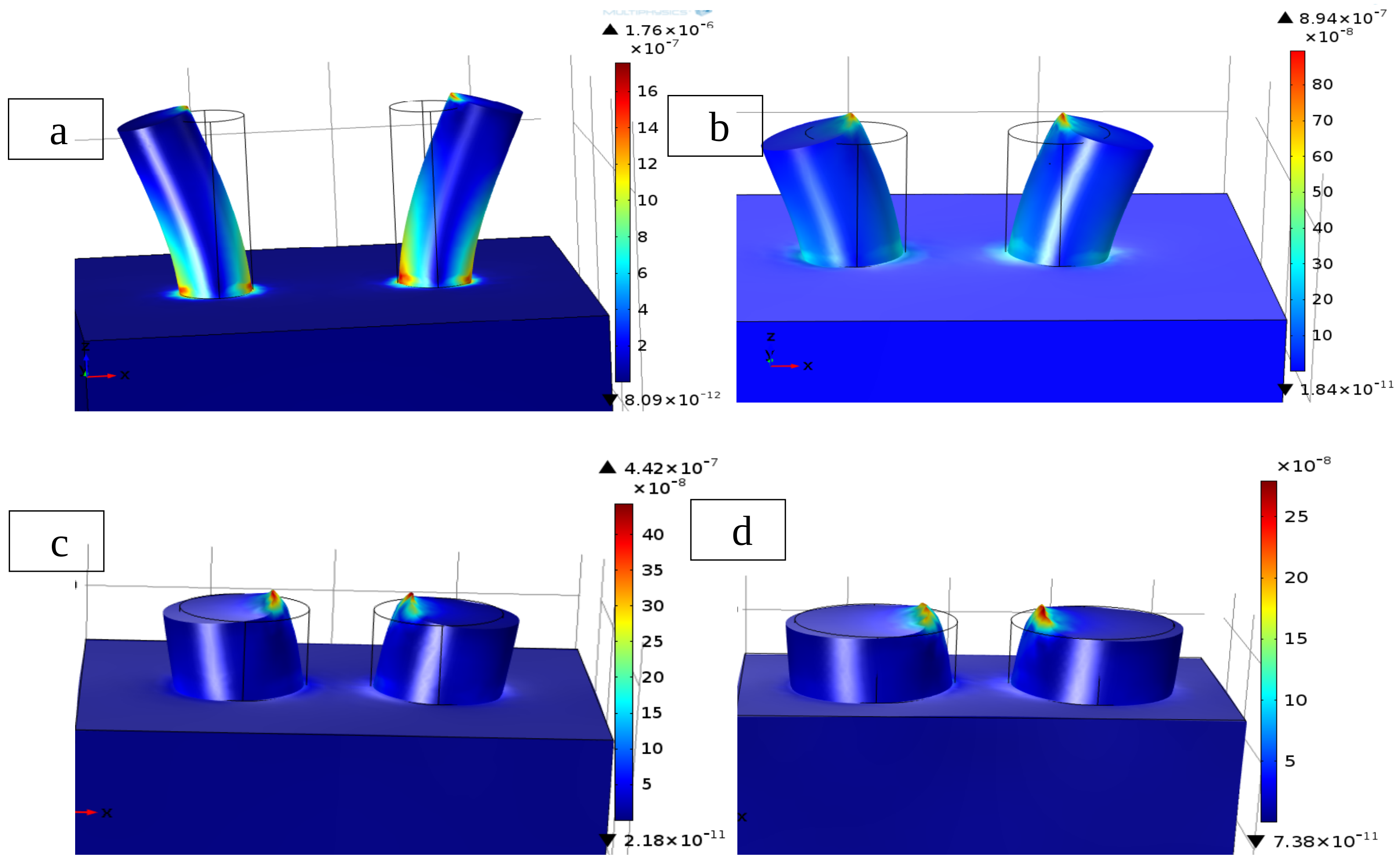

Figure 2. Deflection and stress distribution of PDMS micropillar having composition for diameter (a) 5, (b) 10, (c) 20 and, (d) 30 μm.

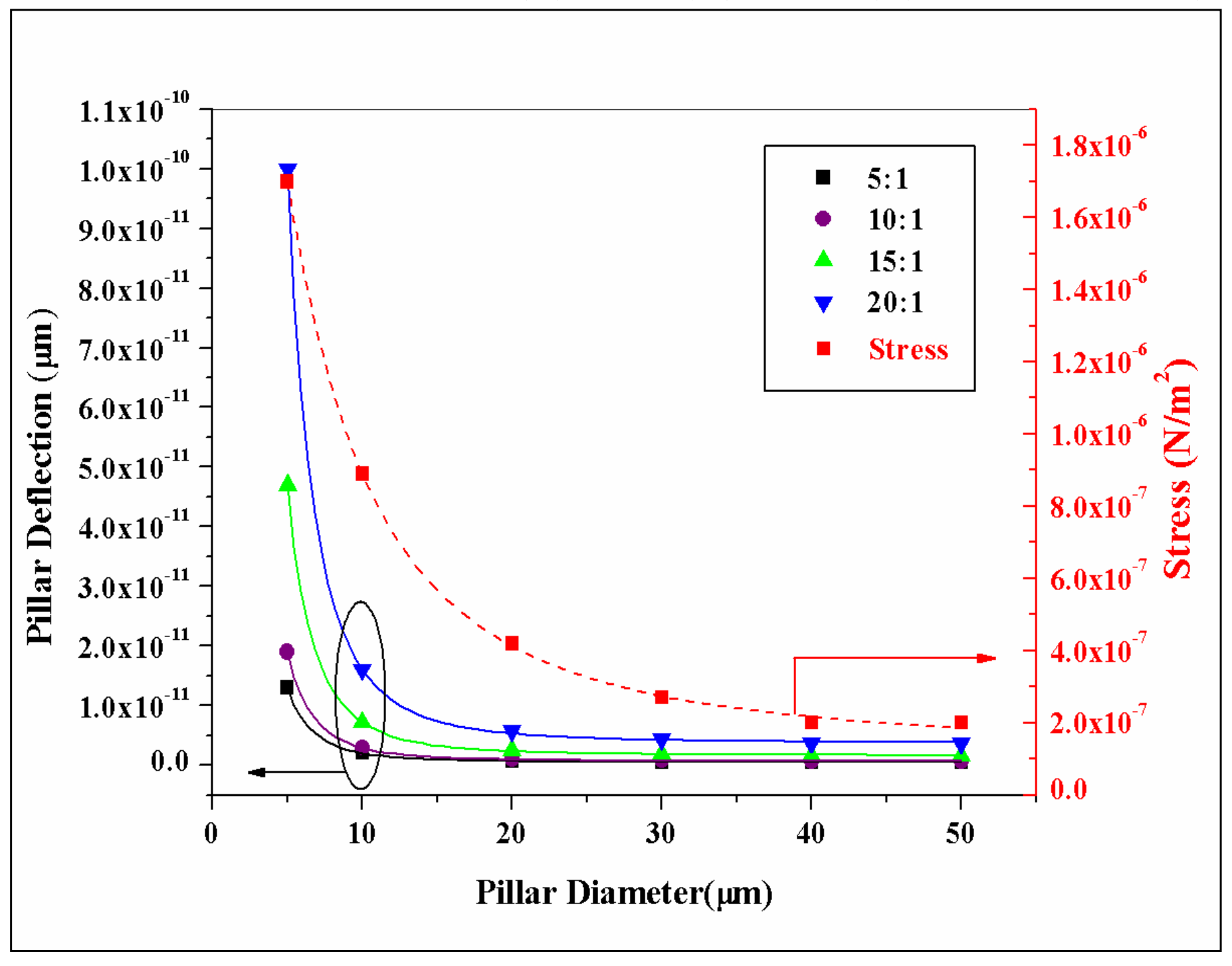

Figure 3. Variation in pillar deflection and stress distribution with different PDMS geometries for various PDMS compositions.

Conclusions

- COMSOL Multiphysics® was successfully used to study the deflection of tips of PDMS micropillars induced due to cell-generated traction force.
- Smaller micropillar geometries with 5 and 10 μm diameter produces larger deflection as compared to higher geometries.
- PDMS composition of 20:1 showed maximum deflection due to lower young's modulus.
- The present work would help in further designing of actual PDMS based micropillar arrays for actual measurement of micropillar deflection to study cellular biomechanics.

References

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