INTRODUCTION: Transdermal drug delivery using microneedles has been recognized as an effective method, and a potential alternative for hypodermis needle injection. Despite significant advances in microfabrication techniques for high-precision manufacturing of microneedle arrays, less is known about the effect of various geometrical parameters on overall mechanical performance of microneedles. This study aims to systematically study the effect of various geometrical design parameters on mechanical performance of microneedles.

COMPUTATIONAL METHODS: Structural Mechanics Module from COMSOL Multiphysics® V 5.3 in conjunction with Material Library was employed. A parametric study was performed using the results of more than 2100 simulations performed by parametric sweep feature. Critical buckling load factor (\(\lambda\)), maximum deflection and von Misses stress under bending and axial loading, as well as maximum deliverable drug volume were multi-objectively optimized using the following equations:

\[
\lambda = \frac{P_{\text{critical}}}{P_{\text{appplied}}} \\
P_{\text{critical}} = \frac{E^2I}{KL^2} \\
\sigma_{\text{bending}} = \frac{MP}{I} \\
L_P(x) = \sum_{i=1}^{k} \left[ \frac{P^i f_i(x) - P^i f_i^\text{max}}{f_i^\text{max} - f_i} \right]^{1/p}
\]

Considered Design parameters are illustrated in Figure 1 with the Boundary conditions shown in Figure 2. The microneedle was considered solid, made form PMMA.

RESULTS: Effect of each design parameter on maximum stress and deflection under bending and axial loadings as well as critical buckling load factor were examined.

CONCLUSIONS: In this study, parametric sweep feature was used to establish an extensive database for performing single-variable, multi-objective optimization, and ANOVA analyses. Results provided insight into effect of each design parameter on overall mechanical stability of microneedle. Also, it was revealed that microneedle dimeter is the most important design factor.

REFERENCES:
2. (2012).

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Table 1. Considered levels for each design parameter.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter value</th>
<th>Parameter unit</th>
</tr>
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<tbody>
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<td>(\alpha)</td>
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<td>0.292</td>
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<tr>
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<td>(\delta)</td>
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<tr>
<td>(\lambda)</td>
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<td>0.292</td>
</tr>
</tbody>
</table>

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Figure 1. Illustration of the design parameters considered in this study.

Figure 2. Specified boundary conditions for each type of analysis.

Figure 3. Effect of parameter alpha on (A) maximum stresses, and (B) maximum deflection under bending and axial loading. Contours of von Misses stress for different designs, under (C) axial, and (E) bending, and maximum deflection for different designs under (D) axial, (F) bending loading (D).

Table 2. Result of ANOVA with (left) and without (right) consideration of maximum deliverable drug volume as an objective function. ANOVA was performed using software Minitab.

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