Corning® Matribot® Bioprinter Parameters

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Introduction

The Corning Matribot Bioprinter is a 3D bioprinter that can dispense and print bioinks as well as extracellular matrices such as Corning Matrigel® matrix and Collagen. Corning DNA Studio software enables the user to adjust several parameters in order to optimize dispensed volumes and printed structures for their particular application. These parameters, which are located in the Printhead tab in Corning DNA Studio, are explained in detail below for both Droplet Dispensing and Bioprinting projects. This document also includes illustrations to demonstrate how adjusting these parameters can resolve common printing issues.

Parameters in Droplet Dispensing Mode in Corning DNA Studio

Basic Parameters

Basic Parameters	Description	Printing Impact
Temperature	The temperature of the printhead.	Changing the temperature of some materials can alter their viscosity. Check which temperature the material prints best at. Certain materials, such as Corning Matrigel matrix and Collagen, require a cooled printhead to keep from premature polymerization.
Extrusion rate	The rate at which the bioink flows from the nozzle with respect to µL per seconds.	Increasing the extrusion rate will increase the flow of the bioink from the nozzle. Decrease if the droplet size is inconsistent. It is recommended to set the extrusion rate between 0.5 to 60 µL/s.
Extrusion volume	The volume of the bioink that flows from the nozzle.	The extrusion volume can range from 1 to 2500 µL. If a droplet array is selected in the Surface tab, the maximum volume will be dependent upon the plate type and number of droplets per well.
Retract volume	The volume of bioink which is drawn into the nozzle after dispensing a droplet before the printhead moves to the next location.	Increase the retract volume if material continues to extrude after completing a droplet or if droplet size is inconsistent. It is recommended to set the retract volume between 5 to 20 µL for droplet volumes above 10 µL and to set it between 2 to 5 µL for droplet volumes below 10 µL. Set the retract volume at least 1 µL lower than the extrusion volume.
Droplet volume	The net volume of bioink dispensed for each droplet. This is equal to the extrusion volume minus the retract volume.	The droplet volume is automatically calculated by the software. It can be changed by adjusting the extrusion volume or retract volume.
Z-offset	The distance the nozzle is offset above the calibrated reference point.	Increase the z-offset if the nozzle is calibrated too close to the surface. It is recommended to set 0.2 to 0.4 mm as default.

Advanced Parameters

Advanced Parameters	Description	Printing Impact
Extra preflow volume	The amount of bioink that is extruded at the start of the very first droplet.	Increase the extra preflow volume if the first droplet is too small. This can occur if the nozzle is not fully primed at the start of the print. Decrease this setting if the first droplet is too large. It is recommended to set between 0 to 4 µL.
Retract rate	The speed at which the bioink is retracted back into the nozzle with respect to µL per seconds.	Increase the retract rate if experiencing a delay in printhead movement due to waiting for the retract move to finish. It is recommended to use a retract rate of 3 to 25 µL/s.
Postflow stop time	The time the print movement is delayed after each droplet.	Increase the postflow stop time if viscous materials are oozing between droplets. It is recommended to use 0.3 s as default.
Z-lift between wells	The lowering of the printbed when moving between wells.	Increase the z-lift for deep well plates. Decrease to speed up the process in 384-well micro plates.

Parameters in Bioprinting and Generate Modes in Corning® DNA Studio

Basic Parameters

Basic Parameters	Description	Printing Impact
Nozzle	The size of the nozzle inner diameter.	Select the nozzle size that corresponds to the nozzle loaded on the syringe. Changing the nozzle size will result in thinner or thicker printed lines. It is recommended to use a nozzle size between 20 to 27G.
Speed	The speed of the printhead during printing moves.	Increasing the printing speed will result in a shorter printing time, while decreasing the speed can give higher resolution of the printed structures. It is not recommended to use a speed higher than 40 mm/s.
Temperature	The temperature of the printhead.	Changing the temperature of some materials can alter their viscosity. Check which temperature the material prints best at. Certain materials, such as Corning Matrigel® matrix and Collagen, require a cooled printhead to keep from premature polymerization.
Preflow volume	The amount of bioink that is extruded before starting a new filament.	Increase the preflow volume if the bioink is not extruding at the start point of each new filament. Decrease the preflow if there is an accumulation of bioink at the start point. It is recommended to set between 2 to 50 µL.
Extrusion rate	The rate at which the bioink flows from the nozzle with respect to µL/s.	Increasing the extrusion rate will increase the flow of the bioink from the nozzle. Decrease if the filament is too thick or overflowing. It is recommended to set between 0.5 to 60 µL/s.
Retract volume	The volume of bioink which is drawn into the nozzle during a non-print move.	Increase the retract volume if material continues to extrude after completing an extrusion move. It is recommended to set between 2 to 30 µL.
Z-offset	The distance the nozzle is offset in the z direction from the calibrated reference point.	Increase the z-offset if the nozzle is calibrated too close to the surface. It is recommended to set 0.2 to 0.4 mm as default.

Advanced Parameters

Advanced Parameters	Description	Printing Impact
Extra preflow volume	The amount of bioink that is extruded at the start of the very first filament.	Increase the extra preflow volume if the bioink is not extruding at the start point. This can occur if the nozzle is not fully primed at the start of the print. Decrease this setting if there is an accumulation of bioink at the starting point. It is recommended to set between 0.5 to 4 µL.
Infill extrusion multiplier	A scaling factor of the extrusion rate with respect to the infill verses the perimeter paths.	Increase the infill extrusion multiplier if the perimeter is as desired but the infill is too thin.
Retract rate	The speed at which the bioink is retracted back into the nozzle with respect to µL per seconds.	Increase the retract rate if experiencing a delay in printhead movement due to waiting for the retract move to finish. It is recommended to use a retract rate of 3 to 25 µL/s.
Extra retract	The volume of bioink drawn into the nozzle after the print is complete.	If printing with temperature sensitive materials, increase the extra retract to protect the bioink from heat until the start of a new print. It is recommended to use 30 µL to prevent gelation at the nozzle tip between prints. If not using a temperature-sensitive material, this value can be set to 0 µL.
Postflow stop time	The time the print movement is delayed after each filament.	Increase the postflow stop time if the end of the filament is not complete due to the next move starting before the bioink is properly extruded. It is recommended to use 0.3 s as default.
Z-lift	The lowering of the printbed when performing non-print moves.	Increase the z-lift if the nozzle is dragging in a previously printed filament during a non-print move. It is recommended to use 1 mm as default.

Common Bioprinting Issues that can be Resolved by Parameter Adjustment

The Basic Bioprinting parameters include nozzle size, print speed, printhead temperature, preflow volume, extrusion rate, retract volume, and z-offset. By modifying these values, improvements to the shape of your print can be made. The parameters in the Advanced settings bar can be adjusted to improve the structures even further. These advanced parameters include extra preflow volume, infill extrusion multiplier, retract rate, extra retract, postflow stop time, and z-lift parameters.

Below you can find common printing issues and how adjusting these parameters can influence your print.

NOTE: Some parameters are closely connected and can be adjusted in relation to one another. For example, if the filament thickness is as desired, but the speed is reduced by half, combine this change with reducing the extrusion rate by half to maintain the same filament thickness when printing at the lower speed.

Issue	Resolution
1. The resolution of the print is too low.	By decreasing the print speed, a higher resolution in corners can be achieved. Adjust the print speed in direct relation to the extrusion rate. Liquids with low viscosity can also overflow (see No. 12 for more details).

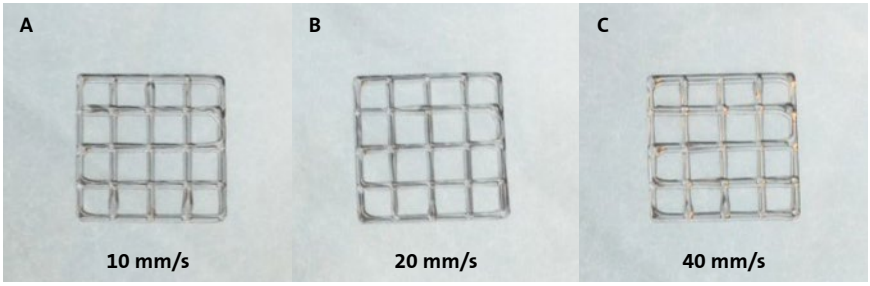

Figure 1. Adjusting the print speed, and in relation changing extrusion rate. The extrusion rate was doubled each time the print speed was doubled.

2. The filaments of a temperature sensitive bioink like Collagen and Corning Matrigel matrix, are uneven.	Certain materials require a cooled printhead to keep from premature gelation, such as Corning® Matrigel® matrix and Collagen. **NOTE:** Make sure that the printhead is already cooled when inserting a temperature sensitive material to prevent premature gelation in the nozzle. At 2°C the Matrigel matrix is completely liquid which can result in the filaments overflowing. Increasing the printhead temperature to 12°C results in a more viscous material making the filament thicker. At 20°C the Matrigel matrix polymerizes and will print unevenly. Changing the temperature of other materials can also alter their viscosity, so it is best to verify at which temperature the material prints best.

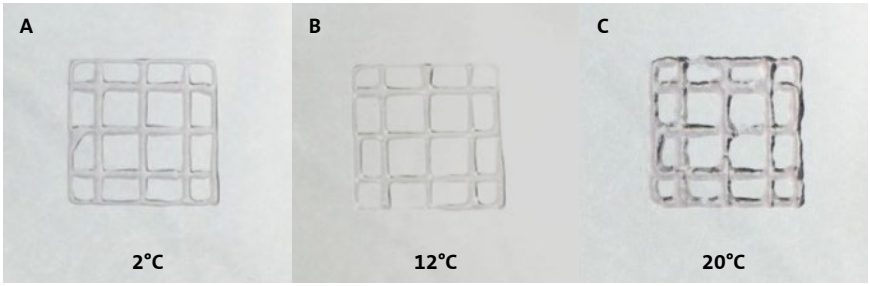

Figure 2. Adjusting the printhead temperature.

3. The filaments are broken.	Broken filaments can be due to a low extrusion rate. Try increasing the extrusion rate to compensate for this effect. If the broken lines are at the start of each new filament in the infill, increase the preflow volume. If the filament is broken at the very start of a new print, change the extra preflow volume (see No. 6). Bubbles in the material can also cause breaks in the print. To get rid of bubbles in the material when preparing the bioink, centrifuge the syringe at 1600 x g for 2 to 3 min.

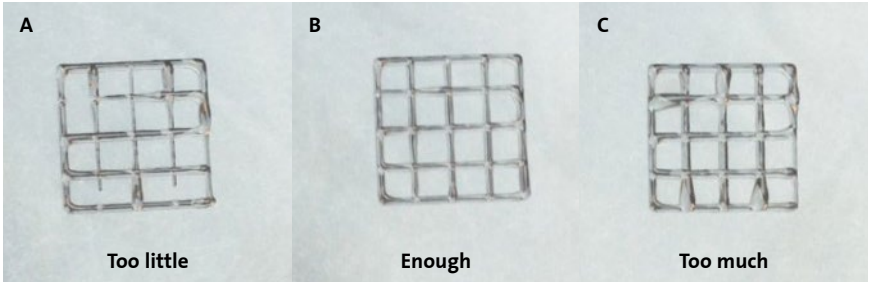

Figure 3. Adjusting preflow volume.

Issue	Resolution
4. The filaments are too thick.	Try to decrease the extrusion rate and/or increase the printing speed. A smaller nozzle can also help to get thinner filaments. If the filaments in the perimeter or in the infill are too thick in relation to one another, change the infill extrusion multiplier (see No. 7).

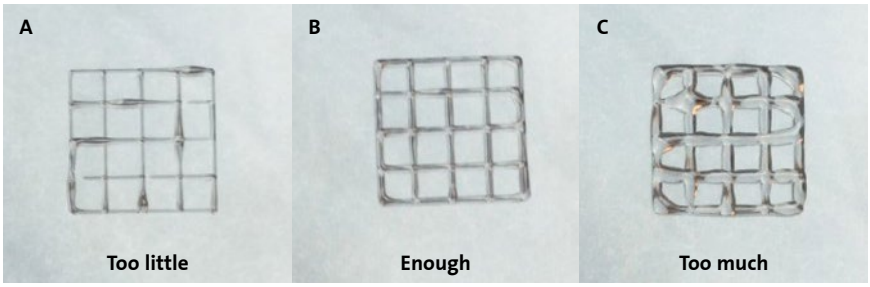

Figure 4. Adjusting extrusion rate.

5. The material continues to extrude out of the nozzle during non-print moves.	Highly viscous materials tend to continue extruding from the nozzle even after the extrusion move is finished. Increase the retract volume and/or rate to minimize this effect. Increasing the postflow stop time can also aid in preventing this problem by allowing the extrusion to fully extrude.

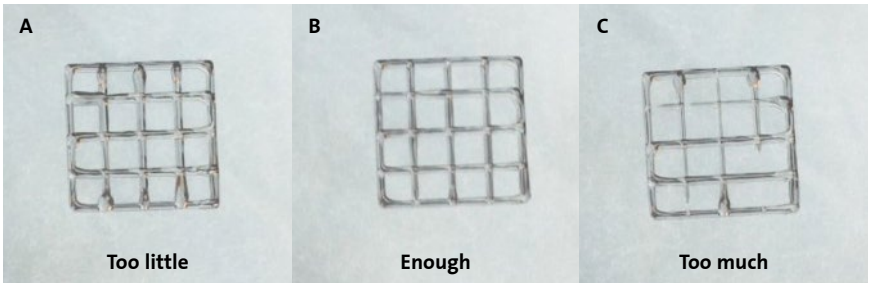

Figure 5. Adjusting retract volume.

6. The material does not extrude at the starting point of the print.	Ensure that the nozzle is fully primed before starting a print. Increase the extra preflow volume if the bioink is not extruding at the starting point of the print. Decrease the extra preflow volume if there is an accumulation of bioink at the starting point.

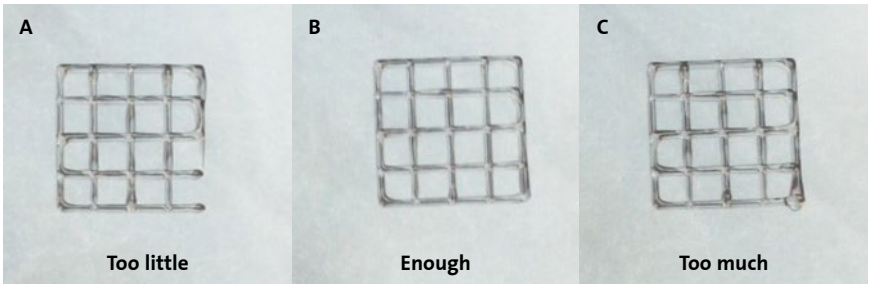

Figure 6. Adjusting extra preflow volume.

7. The infill is too thin while the perimeter is as desired.	Increase the infill extrusion multiplier if the perimeter is as desired, but the infill is too thin. Decrease the infill extrusion multiplier if the perimeter is as desired, but the infill is too thick.

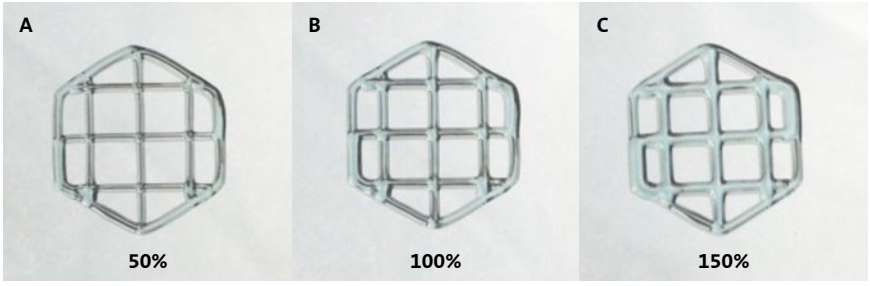

Figure 7. Adjusting infill extrusion multiplier.

Issue	Resolution
8. There is a pause in the print after each filament.	This can be due to a low retract rate value. The printer will stop after each filament in the infill to allow for the plunger to retract. Adjusting the retract rate has little impact on the printed structure, however, too slow of a retract rate can extended the print time, which can be stressful for cells.

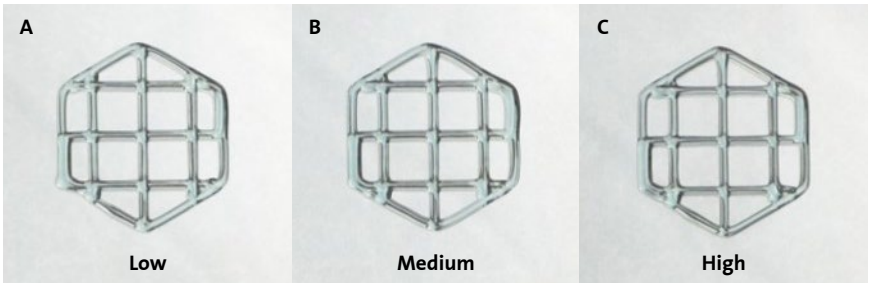

Figure 8. Adjusting retract rate.

9. There is gelated/dried bioink in the nozzle between each print.	The bioink in the nozzle tip can gelate or dry if left idle for a time. To try to avoid this issue, use a higher extra retract volume to retract the bioink up into the nozzle after a finished print. Keep in mind to fully prime the nozzle before starting the next print.
10. There is a gap at the end of the filament.	If the end of the filament does not completely extrude before the start of the next move, increase the postflow stop time. Adjusting the postflow stop time has little impact on the printed structure, however, a long postflow stop time can extend the print time, which can be stressful for the cells.

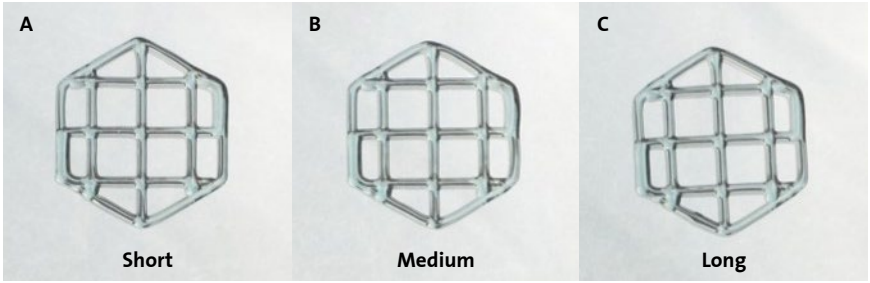

Figure 9. Adjusting the postflow stop time.

11. The nozzle is dragging in the printed structure.	If the nozzle is dragging in a previously printed filament during a non-print move, increase the z-lift. Generally, set z-lift to at least 1 mm. This can also happen if the layer height is set lower than the extruded filament height, if the actual nozzle size is larger than the set value, or if the extrusion rate is too high.
12. The filaments are overflowing.	This can be a material property. Certain materials with low viscosity have problems holding their shape after extrusion. If printing with Corning Matrigel matrix or Collagen, which can thermally gel, try heating the printbed to 37°C for the material to polymerize. **NOTE:** Adjusting the printbed temperature to above 37°C has little impact on the printed structure but can stress cells. Avoid printing tall constructs if the material has poor shape fidelity. Using lower printing speeds can facilitate in obtaining higher print resolution.

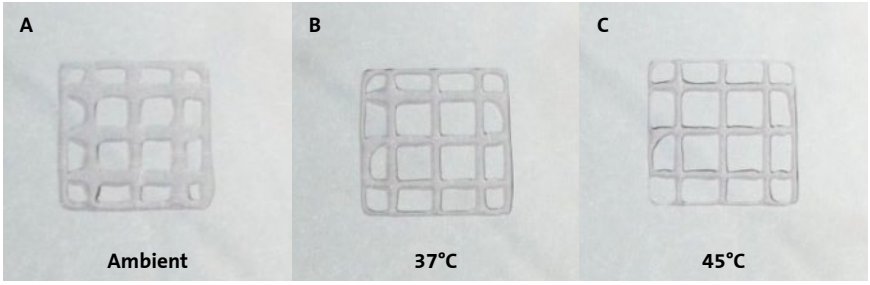

Figure 10. Adjusting the printbed temperature.

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