Treating the glass build-plate of a 3D-printer with salt water improves bonding of PLA-prints

Summary:

This manual describes a new method to achieve a good bonding of **PLA** to a heated glass build-plate of a 3D-printer, by treating that glass plate with **salt water**. When warm, bonding is stronger than with other methods. As a result, models don't lift corners and don't come off while printing anymore. However, after cooling down, the models pop off automatically, without requiring any force at all. This makes glue, tape, hair spray, or any other adhesive aids superfluous for printing PLA. So this might be a good alternative for people who are not totally satisfied with the traditional bonding methods.

This technique requires an FDM/FFF type of 3D-printer with a heated glass build-platform, such as an Ultimaker2, and PLA or PLA/PHA-filament.

(FDM = fused deposition modeling, FFF = fused filament fabrication, which both mean any 3D-printer that operates by melting plastic filament into very thin sausages, similar to how a glue gun works.)

Safety warnings and Disclaimer:

Table salt (chemical formula: NaCl, sodium chloride) is corrosive, and salt water is a very good electrical conductor. Make sure that you do not spill any salt water into the printer electronics and drive mechanisms, as this might cause short circuits, create electric shock hazards, and cause corrosion. Anyone trying this procedure should understand these risks, be careful, and use good common sense. Make sure to educate others (kids, students, collegues,...) on these risks before letting them use this method. It should not be used by people with reduced mental or physical abilities, or who are not sufficiently familiar with this sort of complex equipment and its risks.

This method works very well on our Ultimaker2 printers, when printing PLA. So I expect it to work well for you too. But I can not guarantee it, since all 3D-printers and all environmental circumstances are different. You will have to try this for yourself, using good judgement and common sense. I can not be held responsible for the results, or the lack thereof, nor for any damage or injury you might cause while trying this. It is up to each user to correctly evaluate this method and to take proper safety measures.

Usage and Distribution License:

Build-plate preparation for first time use:

On 3D-printers where this method has never been used before, start with these steps to prepare the build-plate:

• For this technique to work well, all traces of soap, glue, or other chemicals, need to be removed from the build-plate first, by thorough cleaning. You can use whatever cleaning-aid works best for you, e.g.: window cleaner, cleaning alcohol, acetone, ether,... However, these products sometimes leave traces of soap or other (petro)chemicals on the glass plate, which could reduce bonding and need to be removed too.

• So, as the next step, thoroughly rinse the glass plate under pure warm tap water. Do **not** use any soap or cleaning agent now! Wipe the plate dry using a paper tissue, by rubbing hard. Then rinse a second time under pure warm tap water, and wipe dry again by rubbing hard with a fresh paper tissue. Most of the chemical residues and soap should now be removed. Then mount the glass plate back in the printer, and avoid getting fingerprints on the upper side.

• Find a clean glass jar, and rinse it thoroughly with pure warm tap water (**no soap!**). Pour some fresh tap water in it, and dissolve some table salt in it (chemical formula: NaCl, sodium chloride, or natriumchloride in Dutch). The salt-concentration is not critical, just make it "very salt".

Procedure to apply the salt:

(See the photo-section at the end of this manual also.)

• You can leave the glass plate in the printer, if you like.

• Using a pipette, put a few drops of pure tap water on a paper tissue (**pure** tap water, **no salt**). The tissue should be moist, not dripping wet. Then gently wipe the glass plate. The goal is to remove any dust, fingerprints, and any excess salt that might be present from a previous print, and to redistribute any remaining salt (if any) from a previous print evenly on the plate again.

• Inspect the plate: if there is still a thin, even mist of salt on the plate now, you can start the next print right away and skip the next two steps.

• Else, using a pipette, put a few drops of **salt water** on the paper tissue. Then gently wipe the glass plate, first from left to right, then from back to front. Keep wiping gently until the water evaporates, leaving a very thin mist of salt stuck to the glass plate. The trick is to keep wiping very gently and very lightly, so that you spread the salt water into always finer and finer drops, until it dries evenly. But do not rub off the salt.

• Inspect the glass for a thin, even salt coverage (in the area you want to print on).

• Start the print, using **PLA filament**, with the **build-plate heated to 60°C**. The plate has to be heated, it will not work at all on a cold plate. The 3D-model should now print well, without corners lifting and for sure without coming loose totally.

• After completion of the print, let the build-plate **cool down to ca. 25°C**. The models will then pop off automatically, and can be removed without any force at all.

• Cycle through these steps for each next print. That is all. It takes a lot more time to read this than to do it. Cleaning the build-plate and applying salt takes only a minute.

Miscellaneous tips & tricks:

• Make sure the build-plate is calibrated correctly. If it is too far off, the first layer would be printed into thin air, instead of onto the build-plate, and no bonding will occur. Air is not the best glue.

• It is safest to apply the (salt) water drops to a paper tissue first, and then use that tissue to wipe the glass plate. This minimizes the risk of spilling water into the printer. However, sometimes I put the salt water drops directly on the center of the glass plate, using a pipette. In this case you will notice that the drops tend to stay quite round, and tend to regroup, instead of spreading out into a thin layer. This is due to the high surface tension.

• Always be careful not to spill any salt water into the printer electronics and drive systems. If you want to be safe, you can always remove the build-plate from the printer to apply the salt water, but that creates other risks such as dropping and shattering the glass. I prefer to leave it in the printer.

• Prevent any build-up of salt in the printer. Between prints, regularly use a bit of clean tap water (instead of salt water) to remove any excess salt.

• Often, I re-use the same paper tissue several times to wipe the glass plate. The first times I use salt water. The next times enough salt is still on the plate and in the paper tissue, so I use clean tap water only, just to dissolve and redistribute the remaining salt again into a thin, even layer. Usually I do one treatment with salt water, and the next treatment with clean tap water only. This prevents build-up of too much salt.

• The salt water can be applied when the glass is cold, while warming up for the next print, or while still luke-warm from a previous print. All work well, although on a slightly warm plate it dries faster.

• After completion, do not force the prints off when the plate is still warm. This may damage the models, or warp them, or it may decalibrate the build plate. Even not when the printer says that it is safe to remove the models, usually at 40°C. This temperature may be safe to handle without risk of skin burns. But it is still too hot for removing fragile prints undamaged. Wait until the temperature drops to about 25°C and the prints will come off automatically, without any force at all. They are just sitting loose on the bed. That aspect - very good bonding when hot, but no bonding at all when cold - is the beauty of this method, together with the ease of application.

• The precise salt concentration of the water is not important. It should be salt enough to leave a thin mist of salt on the build plate after gently wiping, but not so much that the salt does not dissolve in the water anymore or crystallizes again. Anything in between should be okay.

• At this time (summer 2016), I have printed about 1000 parts with success, using this method. Even difficult and long parts with 100% infill do print well.

• I had only a few failures: one when the build plate callibration was way off after fooling around with it, so that the first layer printed into thin air. But that is a user error and does not count. Further, an upside-down prism (especially designed for warptests) also failed: it came loose due to warping. See the photo section. Obviously, its wide top and chamfers exerted too much warping force on its very small base.

And then I got to careless and designed a model without realising that its feet were exactly modeled like inverted pyramids: a very small contact area, followed by very big, massive overhangs. So one of those feet lifted too, and I had to abort the print and re-desing the feet a little bit. Apart from these, no models ever came off and no corners ever lifted severely.

Only at very sharp corners of 100% filled objects, sometimes a small edge of about 0.3mm typically lifts a little bit. Thus while not perfect, for me this technique works best of all methods I tried. In real life, this method gives great peace of mind, and I do not have to worry about models coming off anymore.

• I have used this method **succesfully with various colors of Ultimaker PLA and colorFabb PLA/PHA,** which all worked equally well. But it does **not** work with ABS and ABS+ (an ABS optimised for 3D-printing), where even simple models do warp and fail. I have not tried any highly filled PLA yet, such as wood-filled, stone-filled, or metal-filled, nor any other printing materials such as PET, Nylon,..., nor any other build plate materials than glass. If you would try them, I would welcome any feedback.

• I would suggest using the name "**the salt method**" for this technique. This in analogy with other names like "the glue stick method" and the "ABS-juice method".

Background and observations:

This chapter gives some additional background data and observations, which might be of interest to people who want to develop this method further. But if you are in a hurry, you can safely skip it, since it does not contain any information required to apply the method.

When searching for a better glue, table salt is usually not the first thing that comes into mind. So, how did I come up with this method? And how does it work technically?

Although the well known "glue stick method" worked reasonably well for bonding PLA to glass, it was not perfect: I found the glue difficult to spread evenly; it requires removing the build plate for cleaning; very thin and fragile prints sometimes got stuck and were damaged when trying to remove them; corners still did lift; and difficult objects sometimes came loose due to warping. So, although usable, I wasn't totally satisfied with it.

(Later I learned that other people use wood glue (10%) dilluted in water, and they spread that in a very thin layer on the glass, so it dries almost invisibly. Or they spread the glue of the glue-stick with water after applying it to the glass plate. Some others use "3DLAC" spray. In this way, they all seem to get better results than by just wiping the glass plate with the glue stick. But at that time I did not know this yet. So, on any filament where my salt method would not work, such as ABS, you could try one of these.)

As an alternative to the glue stick, I considered using blue painter's tape. But that leaves ridges on the bottom of the prints, where the tape strokes meet. These ridges would hinder the precise sliding mechanisms in my models, similar to those used in vernier callipers.

Using ABS-acetone juice as adhesive seemed too unhealthy and too dangerous, because it could easily explode due to the sparks of electric motor drills, ceramic cutter disks, or switches in the neighbourhood. Also, acetone is aggressive towards most plastics, so the vapors might attack sensitive printer components, if applied to the glass plate while it is still in the printer. Plus, the ABS-acetone might not work with PLA, or it might cause prints to stick too well and be too hard to remove without damage. (On the internet I found contradictory data about this ABS-juice method, but I haven't tried it myself, so I don't know which is true. Or maybe both are true depending on the exact technique, the concentration and the PLA-brand used?)

Removing the build-plate after every print might disturb its calibration. And it adds to the risk of dropping the glass. Thus I wanted a method where I could leave the glass in the printer.

Further, I wanted a method where applying the bonding-aid, removing the finished prints, and cleaning the plate would require no force at all.

And I wanted it to be a very clean and fast method too.

So I tried to print directly on the bare glass plate, without any adhesive aids at all. This would have been ideal, if it worked. However, it gave very variable results. Sometimes the prints stuck reasonably well to the glass. Sometimes they were even quite difficult to get off. But at other times the models came loose very soon while printing and I had to abort the prints. Sometimes the first layer wouldn't even stick at all, and it would curl up immediately. And unfortunately, corners of difficult models kept lifting always: at best a little bit, but often severely. The reasons for these wild variations were not obvious, since I always tried to do everything exactly the same.

Further tests and observations lead to more or less repeatable results:

• After cleaning the glass plate with window cleaner, alcohol, or acetone, the bonding of PLA was always very poor. Always. The models came off almost immediately. To me, it appears that these cleaning-aids leave traces of soap, detergents, or petrochemicals on the plate, which reduce bonding.

• After cleaning the glass plate with pure tap water only (no soap, no solvents), bonding was better, and it improved further after a few cycles. It was acceptable for normal 3D-models, but still not good enough for our long and difficult models, 100% filled: corners kept lifting too much.

• When cleaning the glass plate with pure tap water, if the water re-grouped into a few big round drops, bonding of the next print would be acceptable. However, if the water spread out into a very thin layer, bonding of the next print would be miserable. Thus, surface tension seemed to play a role.

• When cleaning the glass plate with pure tap water only, on very cold and dry winter days, bonding of PLA was better. However, on warm wet days, bonding was far worse, and often the first layer wouldn't even stick at all. Thus, air humidity and static electric charge seemed to play a role too. (Freezing cold winter days are known for "charging up" everything.)

• On a cold glass plate, below 30°C, bonding was non-existent. On a warm plate at 60°C, bonding was best for PLA. Both lower and higher temperatures gave a worse bonding. At 50°C bonding is weaker, and corners of difficult objects occasionally start lifting. At 40°C warping forces could cause the models to pop off suddenly while printing. At 70°C, while bonding itself is stronger, the models became too flexible, so that warping forces could make corners curl up and peel the model off the glass plate. Thus the default build-plate temperature of 60°C for PLA seems to be an excellent balance.

• I had the idea that in identical circumstances, bonding would be better by using hard tap water to wipe the glass (=calcium rich water, which feels hard to the hands), than by using soft tap water (=demineralised, which feels soft to the hands). But that is rather a feeling, not a scientific observation. Anyway, in our area we have very hard and calcium rich tap water, with a distinct smell of chlorine. Yours could be different.

In conclusion, a higher surface tension and/or higher electrical charge seemed to improve bonding of PLA, while air moisture, or any traces of soap, detergent or petrochemicals, seemed to reduce bonding.

So I started researching further into this direction.

From what I already knew about electricity, physics and chemistry, and from what I found on the internet, it appeared that:

• To make any liquid glue work well, the substrate (=thing to glue) needs to have a higher surface tension than the glue itself. Otherwise, the glue can not spread onto the substrate and can not "wet" it (=penetrate into all pores and give good molecular contact). It would curl up into a ball instead. Thus, if I understood that correctly, translated to 3D-printing this would mean that the glass plate needs to have a higher surface tension than molten PLA, in order for the PLA to stick to it.

• Charged surfaces do attract oppositely charged surfaces, and charged surfaces do re-orient polar liquid molecules such as water. If PLA-molecules would be polar, a charged glass plate might affect bonding.

• Most plastics do have a high electrical insulation, and can be electrostatically charged easily. If this would also apply to PLA (which seems to be the case since grinding-debris of PLA is often difficult to shake off the hands), PLA might stick better to an electrostatically charged glass plate.

• Oils and fats prevent bonding, obviously. That is why they exist after all: to lubricate things and prevent sticking. So these have to be avoided at all.

• Some materials have a natural affinity for each other, and some do repel each other (e.g. like silicone tubing does repel water). This affinity might be aided or disturbed by environmental or chemical circumstances. This effect might also play a role in the bonding.

• It is well known that soap reduces surface tension. And soap also reduces bonding of PLA, as I experienced.

So, if soap makes things worse, I reasoned that I would need the opposite of soap: something that would increase surface tension and the electrostatical charge of the glass plate. Upon research, table salt (NaCl) seemed to be one of the very few chemicals that would increases surface tension of water. Maybe that could help? That is how I got the idea of using salt water to treat the glass plate.

I don't know whether my reasoning is correct or not (it could even be totally wrong), but obviously this method works well, at least for PLA. And that is what is most important.

So I still don't know the exact molecular mechanism. Is it because of the surface tension? Or is it the ionisation or static electrical charge of the salt and glass plate? Is it the rubbing which charges up the salt and glass plate? Or is it due to the chemical composition of salt itself? Does the hot and molten PLA chemically bond to the salt (but then only when hot, which doesn't seem likely)? Do PLA molecules have an electrical polarity, and thus get oriented and bond to any surface with an electrical charge? Does PLA have a natural affinity for salt? Does the surface-roughness of the salt play a role, similar to grinding or etching a surface to increase bonding of paint or glue? Or maybe a bit of all of these? I don't know for sure. So, if anyone could explain the precise chemical or physical phenomena, I would like to know. Then I could add it to this manual, which in turn may help other people finding similar solutions for other materials.

Feedback:

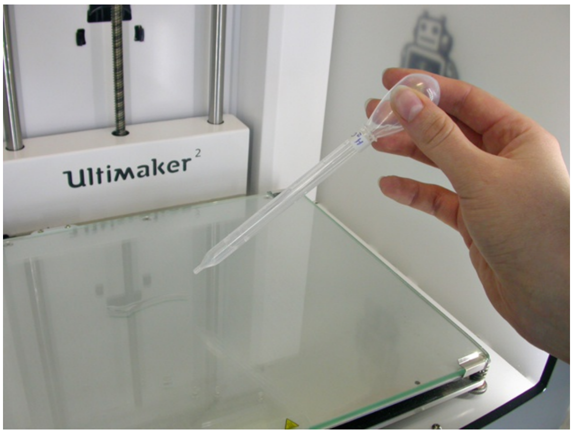
To give feedback on which filament materials other than PLA or which build-plates other than glass do work well on your system, or which don't work at all, you can reach me at: "**geert . keteleer @ uantwerpen . be**" (remove all spaces). Please give your e-mails an appropriate and descriptive title, and avoid attachments other than JPG-pictures, so that they don't get eaten up by our spam filters and anti-virus. You can write in Dutch and English. I can read German too, but can not write it.

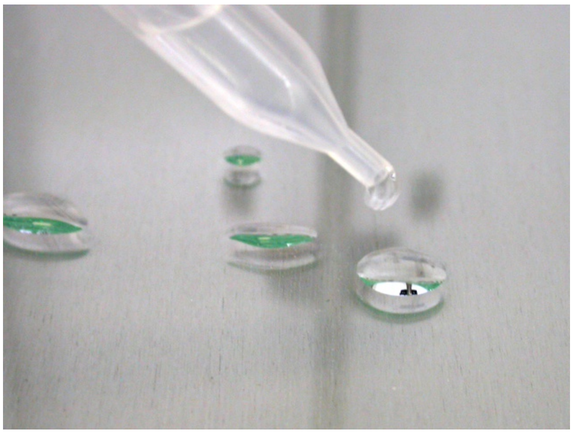
Photo illustrations of "the salt method":

All 3D-models shown in this manual for illustration are designed by myself from scratch. All non-dental models are my personal intellectual property and may be used under the same CC BY-SA license as this text itself. However, any dental appliances are intellectual property of the Lab Dental Materials of the University of Antwerp (Belgium) and should not be used without written permission. Thanks for respecting this.

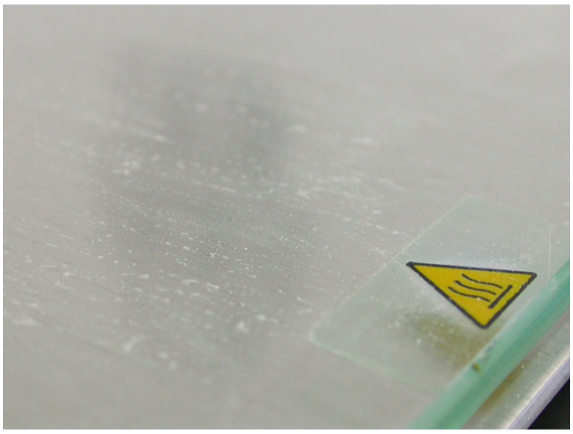
All blue PLA shown in these photos is Ultimaker standard blue PLA (I don't know the official name); and the grey, white and orange materials are colorFabb PLA/PHA-blends.

*This is all you need for "**the salt method**": paper tissue, glass jar, salt, tap water, and two cheap pipettes: one for salt water and one for pure tap water. I labeled my pipettes with **H_2O** for the pure tap water and **NaCl** for the salt water so I can easily recognise them.*

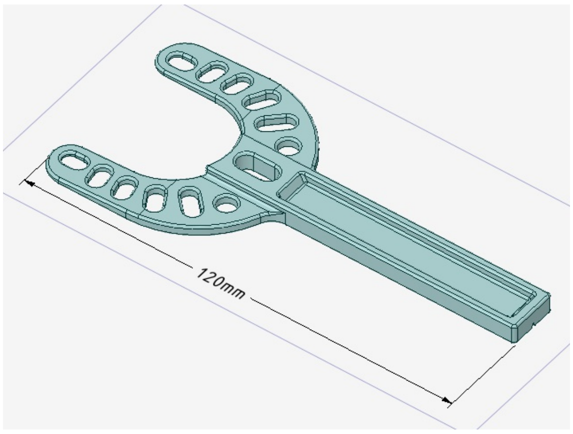


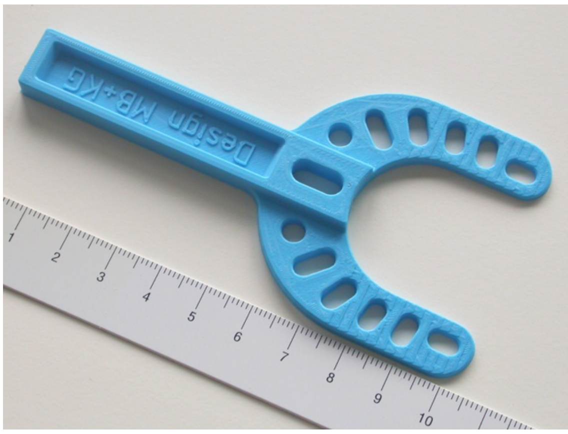


Applying a few drops of salt water: these drops usually stay quite round, and tend to regroup, instead of spreading out into a thin layer. This is a good sign. Instead of applying the drops directly to the glass plate, it is safer to apply them to a paper tissue first, and then use the moist tissue to wipe the glass plate. That reduces the risk of spilling water into the printer electronics.



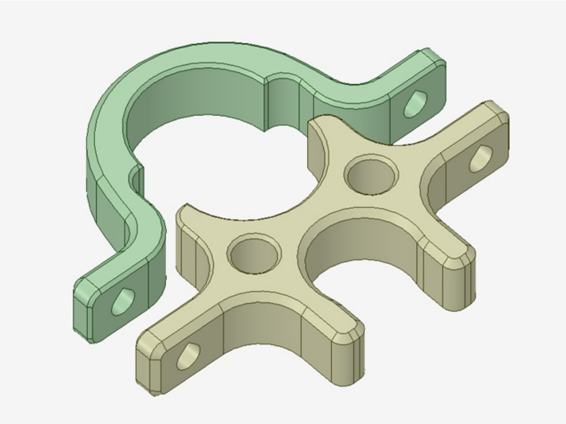
Keep wiping the glass plate very gently and lightly: first from left to right, then from back to front until the water evaporates. This leaves an even, thin mist of salt stuck to the plate. On the close-up photo, contrast is artificially enhanced in Photoshop, otherwise the salt would be very hard to see. In reality the glass plate just looks somewhat matt and dusty.



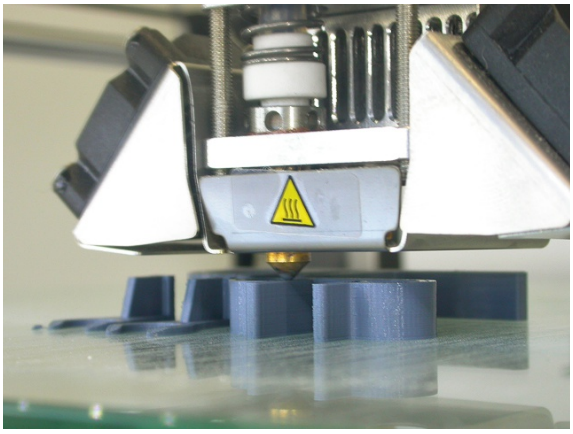
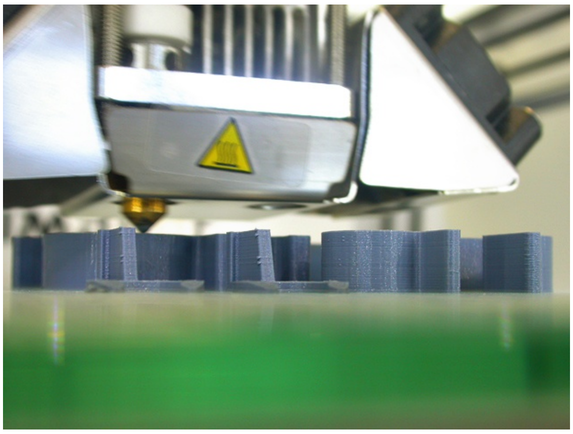


Even difficult models such as these dental appliances do stick very well while printing, without corners lifting. I have printed more than 500 parts similar to these ones, in various editions and lengths, usually between 100 and 140mm long, about 50mm wide, and between 3 and 10mm high. All 100% filled. When using the glue stick method, these models were hard to get off the glass plate due to their big contact surface, but corners still did keep lifting too much. Since using the salt water method, no corners ever lifted. Thus bonding is much better while hot, but after cooling down, models allways come off easily.

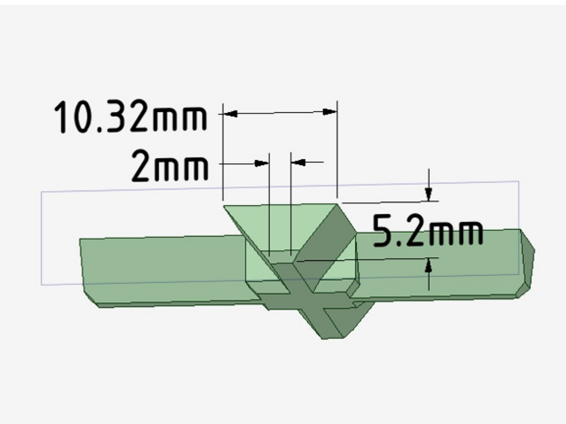
(These models are intellectual property of Lab Dental Materials, University of Antwerp.)

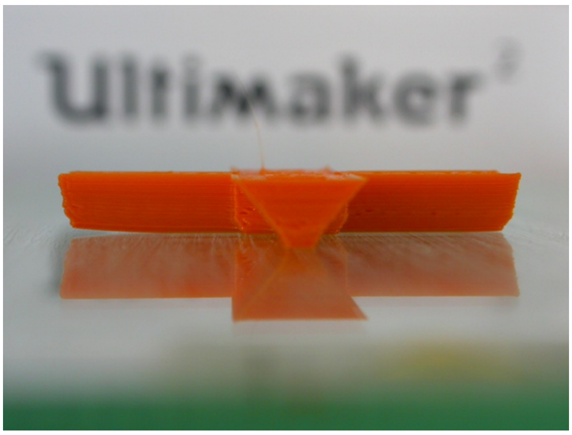
 

Clamps like these can be printed well too. This one was particularly difficult to print using other bonding methods, due to its small base area and its big chamfers that exerted a lot of warping force, and its 100% infill for mechanical strength. On a bare glass plate, I could not print it at all. When using the glue stick method, I had to retry a few times because it still warped and came off. Not so with the salt method.

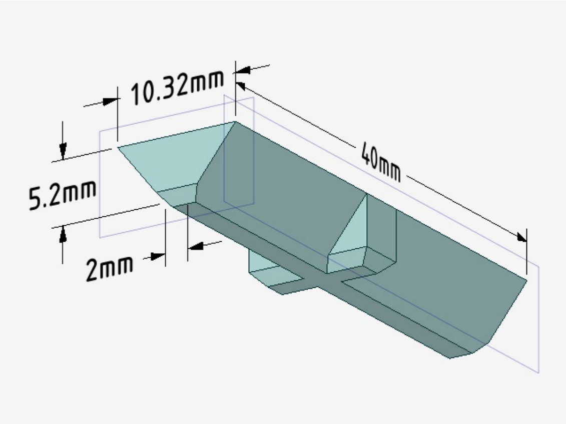
 

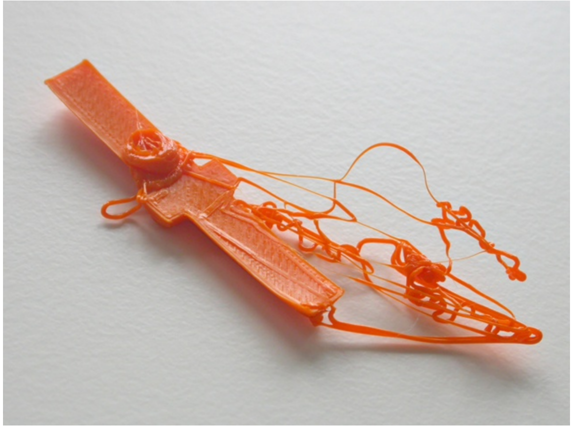
Printing several custom cable clamps in one batch. They show no sign of lifting corners whatsoever. Note that the salt is well visible at this low angle of view, giving a dusty appearance to the glass.





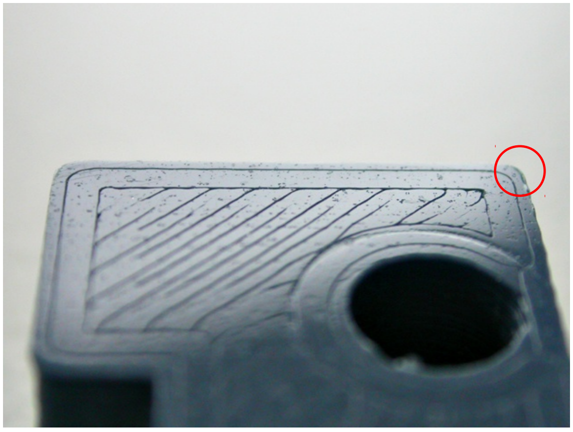
The only items of which corners did lift severely, were these specially designed "warptests": inverted prisms with a very small base (2mm), a very wide top (10mm), and big chamfered corners, which exert a lot of warping stress and tend to pry off the model. It is printed with 100% fill-in, for maximum shrinking- and *warping stress. As you can see in the photo, the left corner lifted about 0.5mm (you need to divide the apparent opening of 1mm by two, since half of that is reflection). The right corner lifted just a little bit, barely visible. But even though corners did lift, this item still could be completed, without coming loose totally. I could not print this at all with the glue stick method or by printing on bare glass).*



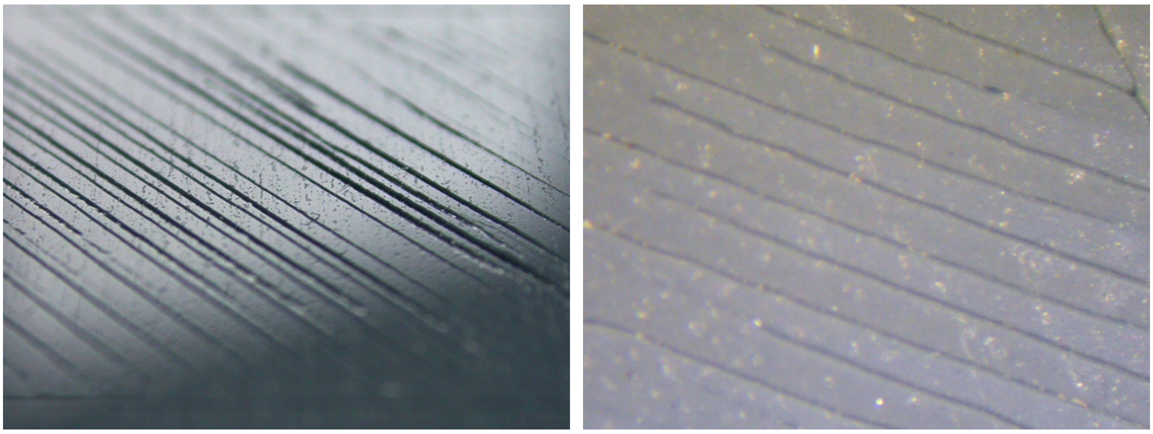


This inverted prism could not be printed anymore: it came off halfway and produced some nice spaghetti before I aborted the print. Corners curled up too much (clearly visible in front), and then the print head hit them hard and knocked the model off the plate. So this model would need brims or a raft to print successfully. This warptest shows the limitations of the salt method: no upside-down prisms or pyramids.

At this time of writing, I have printed about 1000 models in PLA successfully using the salt method. Often very difficult models, such as the dental models similar to the ones shown earlier. Concerning bonding, that is a success rate of far more than 99%. Practically, for all normal designs, this means that I don't have to worry anymore about the models sticking to the glass plate. Gives great peace of mind. Further, I can leave the glass plate in the printer always, there is no need to remove it.



The typical (not) lifting of corners, on typical 3D-models: in a corner, an edge of 0.3mm wide might lift a little bit. That is usually all. See the right corners in both models (although hardly visible, try zooming in). For reference: the round hole in the left photo is 4.5mm diameter. The brick on the right photo is 10mm x 10mm x 5mm. Both are 100% filled. Also notice the tiny pits created by the salt in both samples, which look similar to corrosion-pits in metals.



Close-up photos showing the tiny pits caused by the salt crystals. Try zooming in for a better view. Left picture taken using the camera macro-function, right picture taken through a microscope at 10x magnification: here the white salt stuck in the pits is still visible. For reference: nozzle diameter of our 3D-printers is 0.4mm, so the extrusion lines are about 0.4mm apart also.

*So, for printing PLA, as far as I know, the **salt method** is the best bonding method currently available. It is very easy and quick to apply, and rarely fails. It gives a very strong bonding when hot, but no bonding at all when cold. However, for ABS it is inferior to other methods such as the dilluted wood glue method, the glue stick method, or 3DLAC spray. If you would have any experience with other filament materials, good or bad, please let us know the results.*

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