FORMLABS WHITE PAPER:

A Guide to Post-Curing Formlabs Resins

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Abstract

Each Formlabs Resin is formulated with advanced, light-sensitive polymer chemistries. The Form 2 stereolithography (SLA) 3D printer uses a 405 nm laser to cure the liquid resin, producing a highly accurate solid part.

When an SLA part finishes printing, it remains on the build platform in a “green state.” This means that while parts have reached their final form, polymerization is not yet fully completed and the part has yet to attain maximum mechanical properties. Post-curing with light and heat is key to unlocking this last mile of material properties for SLA 3D prints. Achieving optimal properties is especially essential when using functional or specialty resins.

Form Cure, the first post-curing solution from Formlabs, is designed to post-cure parts parts printed in Formlabs Resins with speed and consistency. Our engineers developed Form Cure specifically to work with Formlabs Resins, using the same 405 nm light as the Form 2 laser. Parts are convection heated and automatically rotated in Form Cure’s reflective chamber to ensure an even and consistent post-cure.

This guide will help you understand how post-curing affects the key properties of each Formlabs material. We’ll cover post-curing recommendations for material-specific applications, as well as strategies for avoiding common issues.

This guide was last updated in March 2018, and will be periodically updated as resin versions change and new materials are released.

Methodology

Formlabs developed an in-house post-cure study to identify optimized settings for each individual Formlabs resin[1]. Using the ASTM method, our materials scientists tested a variety of mechanical properties at various temperatures for each material.

Castable and Dental SG resins were also validated externally; third party jewelry casting tested the Castable post-cure setting and quality of customer experience through the casting process and third party biocompatibility testing ensured the safety and dimensional accuracy of Dental SG.

We've also broadly explored how wavelength, luminous flux, temperature, and time affect post-curing in the white paper ***How Mechanical Properties of Stereolithography 3D Prints are Affected by UV Curing***. The conclusions of this study informed the design of a post-curing solution tailored to Formlabs Resin, Form Cure.

PERCENTAGE INCREASE IN MODULUS OF ELASTICITY

Formlabs tested modulus of elasticity, which shows a change in stiffness of a part, for each resin over time in Form Cure. An object with a higher modulus of elasticity will have a greater resistance to changing shape under stress. Modulus of elasticity **is closely related to how completely crosslinked photopolymer chains are within the part**, which is why Formlabs uses modulus to represent overall completeness of post-curing.

The "green" shape of a model is formed by laser-curing the resin during printing, but some potential polymer connections remain unbonded. Cross-linking the remaining polymer proportionally improves strength, stiffness,[2] and temperature resistance. Post-curing also causes some part shrinkage. Formlabs measures accuracy and mechanical properties based on a standard post-cure of parts, and material settings for are tuned to account for shrinkage under the same conditions.

Learn more about the science behind post-curing SLA 3D prints.

The following graphs will help you understand how Formlabs materials respond to post-curing, viewed as a percentage of maximum modulus of elasticity. Familiarity with post-curing behavior saves time and improves accuracy when post-curing parts for your particular application.

[1] Most resins experience an increase in stiffness (modulus of elasticity) during post-cure. An exception is Flexible Resin, which gains elongation (flexibility) with post-curing.

[2] Formlabs regularly updates material formulations, which may result in minor changes to measured properties. Future updates to this document will include major formulation updates. This data reflects Formlabs Resins as of August 2017.

Introduction

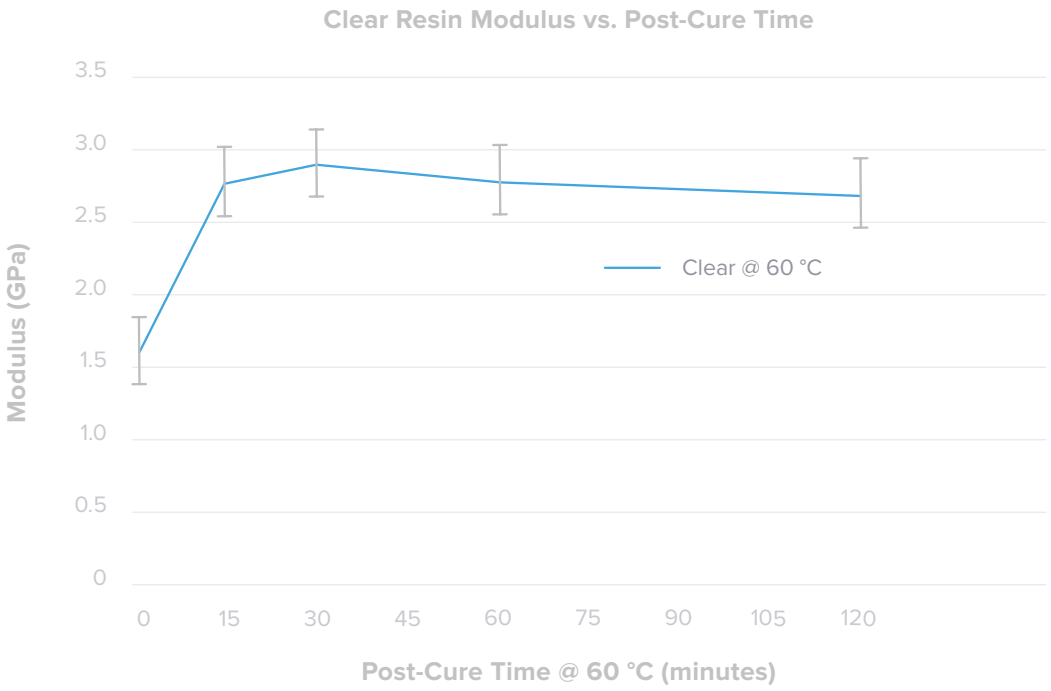
An ideal post-cure setting achieves the properties you need in the shortest amount of time. For Standard Resins (White, Grey, Black, and Clear), this amount may be none at all, or a short 15 minute post-cure. Where strength, rigidity, and temperature resistance are needed, Formlabs Engineering Resins improve with post-cure up to 60 minutes. Biocompatible materials require specific post-curing procedures to qualify as safe in their application.

Depending on your geometry and print material, post-curing can affect the shape of your part. If post-curing is causing warp, we recommend shortening your post-curing plan based on the curves in this resource to reach the best compromise between accuracy and desired mechanical properties.

Use this guide to understand how post-curing affects the key properties of each Formlabs material, and determine the optimum post-curing plan for your application. This guide was last updated in March 2018, and will be periodically updated as resin versions change and new materials are released. Find all **up-to-date recommended post-cure settings** for Form Cure on our website. Specific mechanical properties after the recommended post-cure are available in material **data sheets**.

RECOMMENDED POST-CURE SETTINGS

Clear Resin



Analysis: Post-Curing Optional

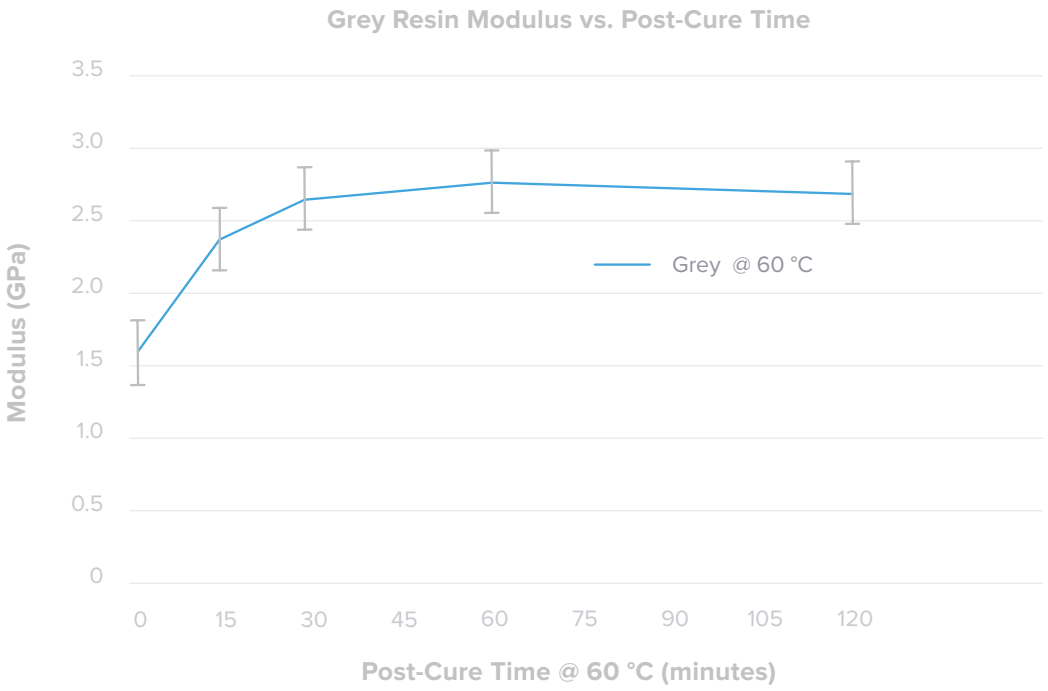
Clear Resin shows a sharp increase to 96 percent of maximum modulus of elasticity in the first 15 minutes of post-cure, which gives way to a gradual increase over the next 15 minutes. Maximum mechanical properties are reached at 30 minutes. Modulus begins to decrease after 30 minutes in Form Cure.

APPLICATIONS GUIDELINE

When used for visual prototypes and models, Standard Clear Resin only requires washing and air drying. A 15 minute post-cure can be helpful to increase surface hardness and improve scratch resistance. If you expect to mechanically stress or heat your part, such as in a fixture or thermoform mold, post-cure to the full 30 minutes to minimize deformation. In order to avoid excessive color change, limit post-curing of Clear Resin to 30 minutes.

RECOMMENDED POST-CURE SETTINGS

White, Grey, & Black Resin



Analysis: Post-Curing Optional

Formlabs opaque Standard Resins (White, Grey, and Black) have similar composition and post-curing characteristics. When post-cured at 60 °C, the modulus of elasticity shows a fast, 15-30 minute initial post-cure phase, followed by a gradual increase up to a maximum modulus at 60 minutes.

APPLICATIONS GUIDELINE

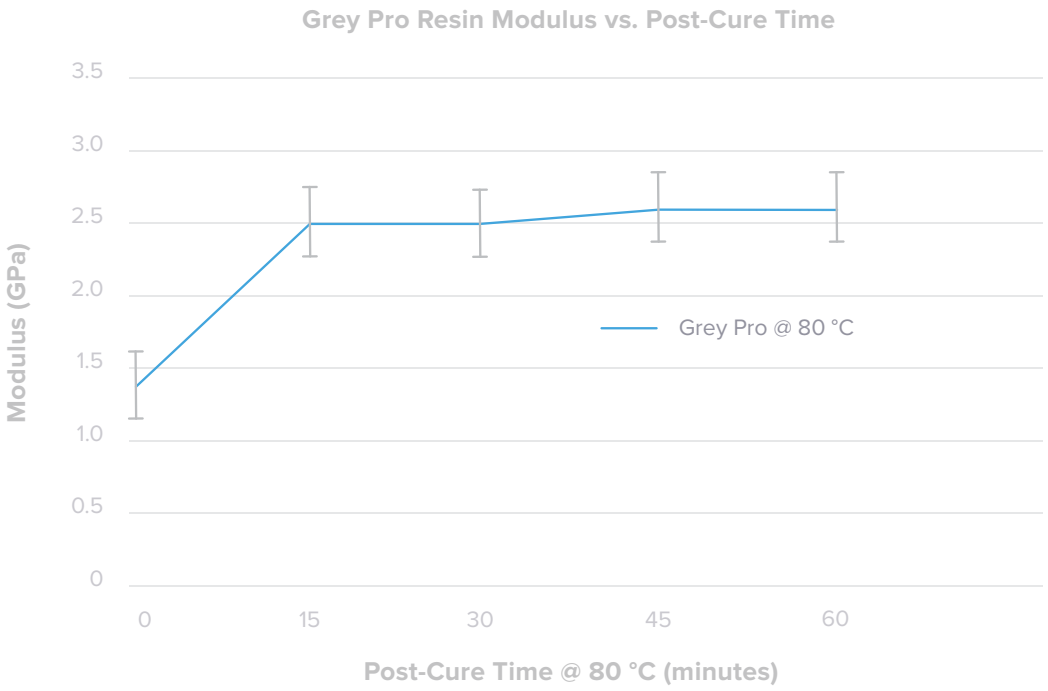
Opaque Standard Resins post-cure slightly slower than Clear Resin. In most cases, Standard Resins only require washing and air drying. A 30 minute post-cure can be helpful to increase surface hardness and improve scratch resistance. If you expect to mechanically stress or heat your part, such as in a fixture or thermoform mold, post-cure opaque Standard Resins for 60 minutes at 60 °C. Post-cure Color Kit with the same procedure as Standard Resins.

FAST POST-CURE

Recommended for display models and static prototypes.

RECOMMENDED POST-CURE SETTINGS

Grey Pro Resin



Analysis: Post-Curing Strongly Recommended

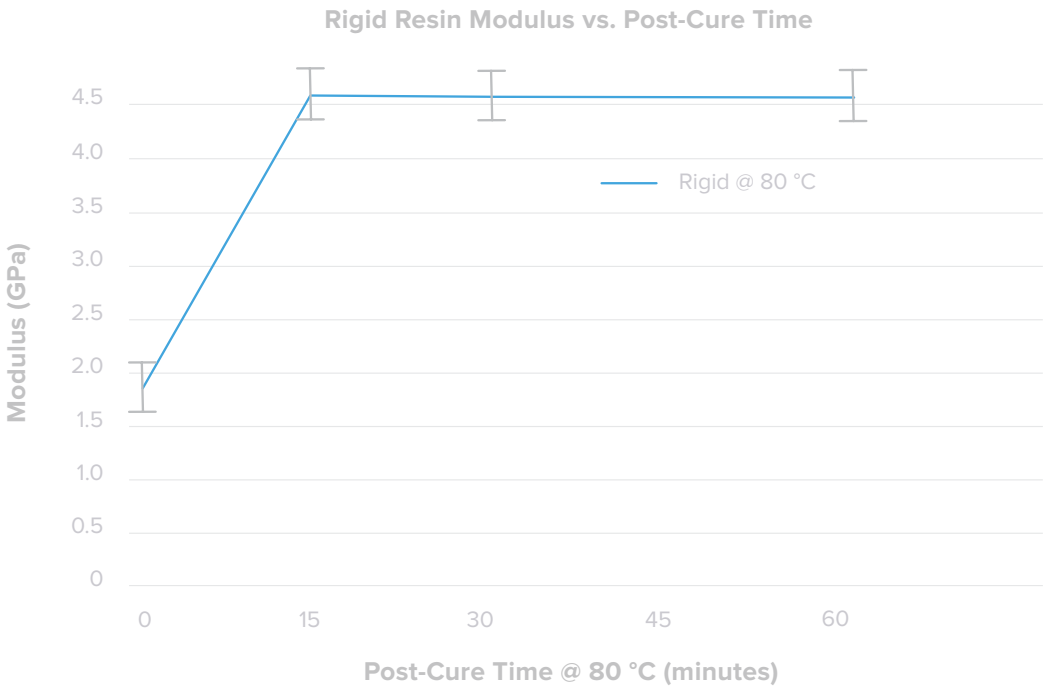
When post-cured at 80° C, Grey Pro gains a substantial 78% increase in modulus of elasticity after 15 minutes. After 15 minutes this reaction is essentially complete, and modulus does not increase except for a small rise between 30 and 45 minutes of exposure.

APPLICATIONS GUIDELINE

Grey Pro Resin should be post-cured for 15 minutes at 80 °C in order to harden the surface and develop expected strength characteristics. While post-curing beyond 15 minutes is generally not needed, thick or bulky parts may benefit from a longer post-cure time in order to ensure that the model has completed the main post-curing reaction throughout.

RECOMMENDED POST-CURE SETTINGS

Rigid Resin



Analysis: Post-Curing Strongly Recommended

Rigid Resin exhibits a sharp rise in modulus of elasticity over the first 15 minutes of post-curing, increasing by 116%. After 15 minutes, no further improvements are observed.

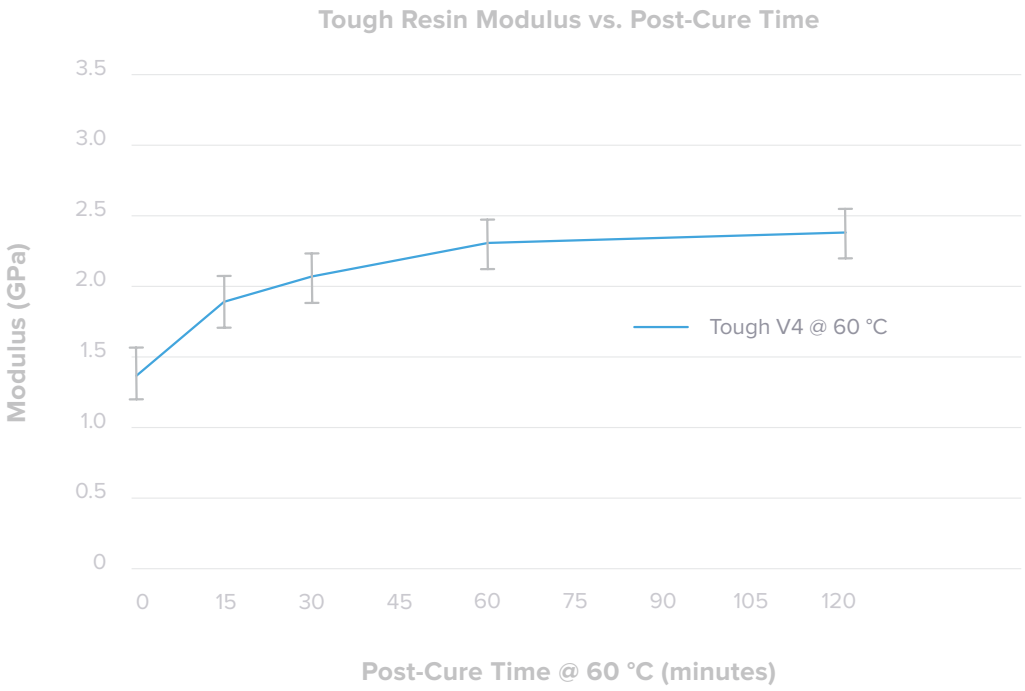
APPLICATIONS GUIDELINE

Rigid Resin is a glass-filled composite material designed for parts requiring high stiffness and strength, as well as low deformation under load. Post-cure directly increases strength and stiffness by further crosslinking the polymer matrix surrounding microparticles of glass, holding them rigidly in place.

Post-cure of Rigid Resin is substantially impacted by temperature. At higher temperatures, a large improvement in modulus of elasticity is gained over a short period of time. Post-curing beyond 15 minutes will not affect properties but will begin to cause cosmetic yellowing, and is not recommended. For most applications of Rigid Resin, post-cure for 15 minutes at 80 °C in Form Cure.

RECOMMENDED POST-CURE SETTINGS

Tough Resin



Analysis: Post-Curing Recommended

Tough Resin shows a gradual increase in modulus of elasticity from 0 to 60 minutes. An increase between 60 and 120 minutes is apparent, but marginal. This indicates a near-linear relationship between post-curing time and mechanical properties until maximum cure.

APPLICATIONS GUIDELINE

Tough Resin balances strength and compliance, making it the ideal choice for prototyping strong, functional parts. Tough excels in mechanical applications where a load is applied over time, such as mounts, fixtures, brackets, and structural enclosures.

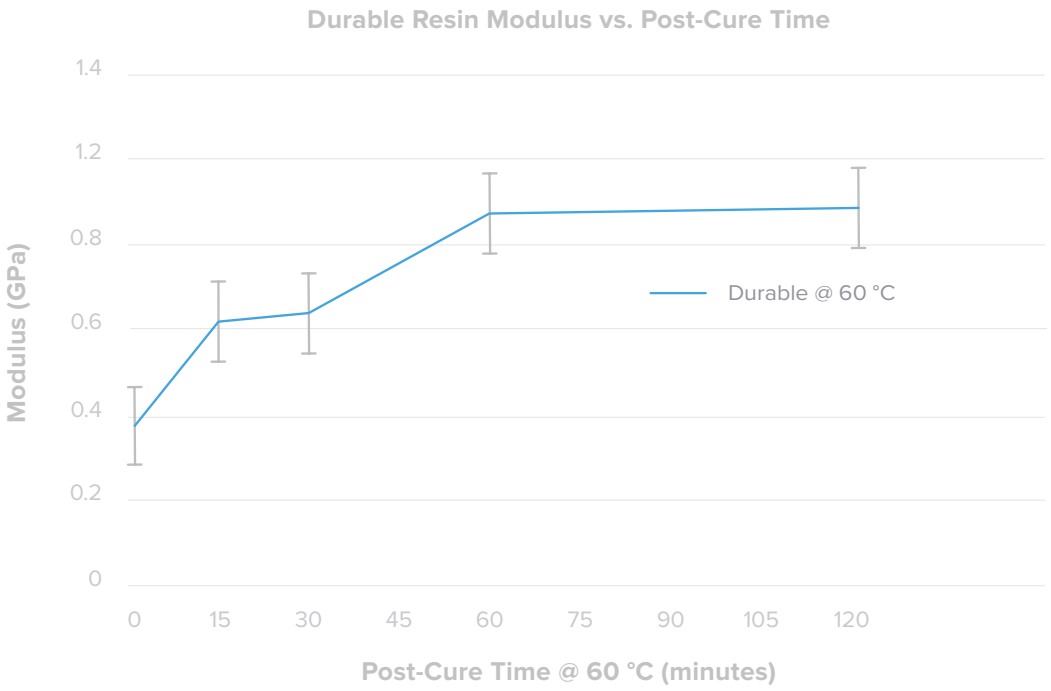
Plastic parts tend to slowly creep under a sustained force. Post-curing is a good way to increase the strength and rigidity of a Tough part beyond what is immediately necessary to carry a load. This margin reduces the rate of creep and increases the lifespan of your parts. The increase in mechanical properties from post-curing is significant: at 60 minutes at 60 °C in Form Cure, the flexural stiffness of Tough Resin more than doubled from 0.6 GPa to 1.6 GPa, and flexural strength nearly tripled from 20.8 MPa to 60.6 MPa. These properties approach the stiffness and strength of injection molded ABS plastic.

For applications where creep over time isn't a concern, Formlabs recommends post-curing Tough Resin for 60 minutes at 60 °C in Form Cure. For maximum resistance to plastic creep, 120 minutes at 60 °C improves stiffness and strength.

> **TIP:** Modifications such as drilling and machining are easier on a softer "green" part. Post-cure Tough Resin after modifications are made.

RECOMMENDED POST-CURE SETTINGS

Durable Resin



Analysis: Post-Curing Recommended

Durable Resin exhibits a two stage post-cure. Modulus of elasticity increases to 68 percent of maximum over 15 minutes, followed by a plateau and a second significant increase occurring between 30 and 60 minutes. Maximum modulus is reached at 60 minutes. Beyond 60 minutes, chances of part deformation increase without an increase in properties.

APPLICATIONS GUIDELINE

Durable Resin produces parts with a smooth, glossy finish and high resistance to deformation. With post-curing, Durable becomes significantly stiffer and stronger, while remaining very resistant to breakage. Higher stiffness and flexural strength allow Durable to perform well for snap fits and flexure features, where a part is subject to cyclic loading and unloading. Applications such as joints and bushings require excellent surface durability. A fully cured surface helps reduce tribological wear and maintains better tolerances over time.

For most applications of Durable, Formlabs recommends a full 60 minute post-cure.

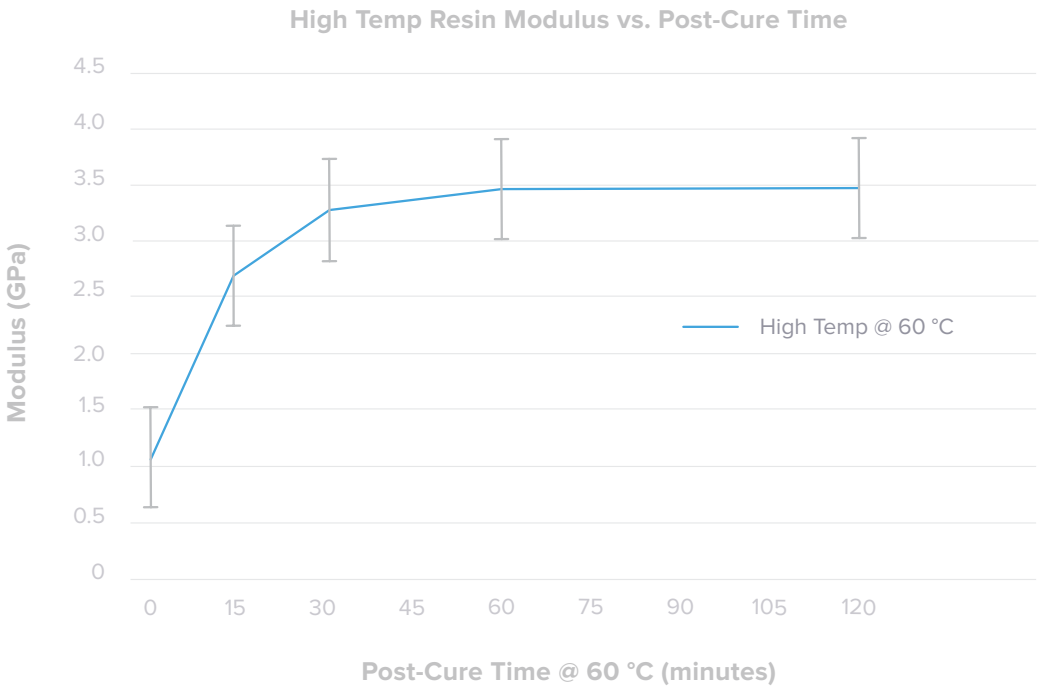
FAST POST-CURE

If engineering requirements demand only flexibility and impact strength, a short 15 minute cure may be a smart compromise to simulate a softer, impact-modified polypropylene. A clean isopropyl alcohol (IPA) wash will help improve surface durability and reduce tackiness when using a shorter post-cure.

> **WARNING:** Durable parts that are not fully cured have lower heat resistance, and will be more likely to creep or deform over time.

RECOMMENDED POST-CURE SETTINGS

High Temp Resin



Analysis: Post-Curing Strongly Recommended

High Temp Resin shows a rapid increase in modulus of elasticity with post-curing, which tapers at 30 minutes of post-cure time. We observed a gradual increase in modulus from 30 to 60 minutes. The part is fully cured at 60 minutes, at which point modulus no longer increases.

APPLICATIONS GUIDELINE

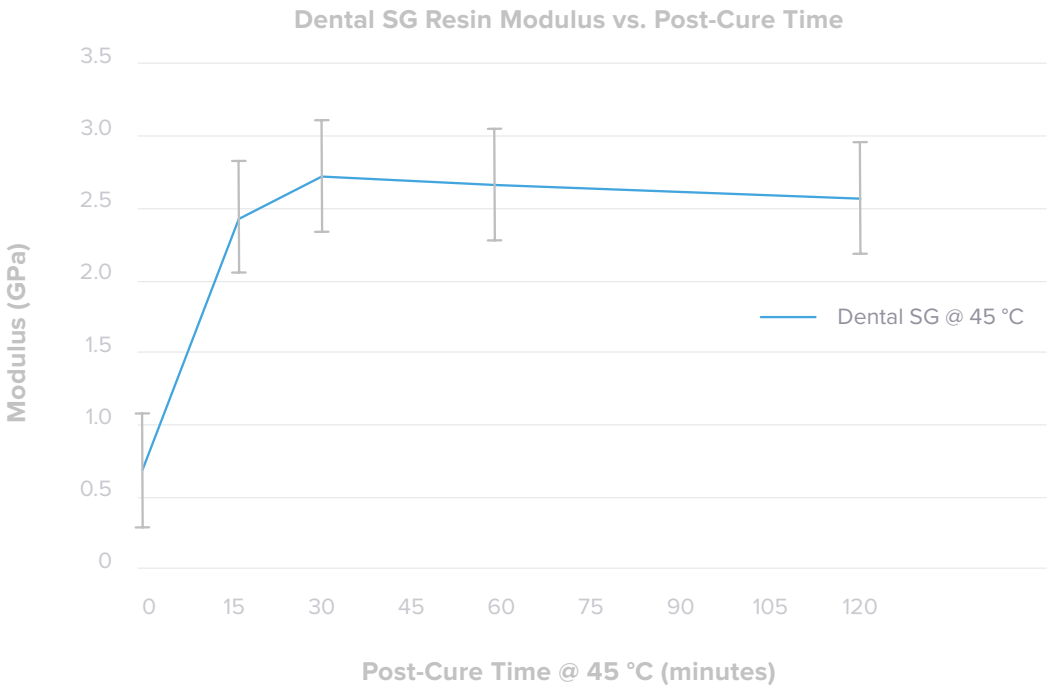
High Temp Resin is intended for low-impact, high-temperature applications such as heater ducts, high temperature millifluidics, and thermoforming. Post-curing is essential for High Temp; the heat deflection temperature of High Temp starts at 55.9 °C and climbs to 289 °C with a complete post-cure. While many resins show signs of thermal shock when placed in sudden direct contact with hot materials such as gas or molten plastic, post-cured High Temp Resin can withstand temperatures near its HDT without degradation.

Formlabs recommends fully post-curing High Temp Resin for 60 minutes at 60 °C to avoid thermal damage to parts.

> **TIP:** High Temp Resin will change color from a light yellow to orange to indicate the extent of post-curing.

RECOMMENDED POST-CURE SETTINGS

Dental SG Resin



Analysis: Post-Curing Mandatory

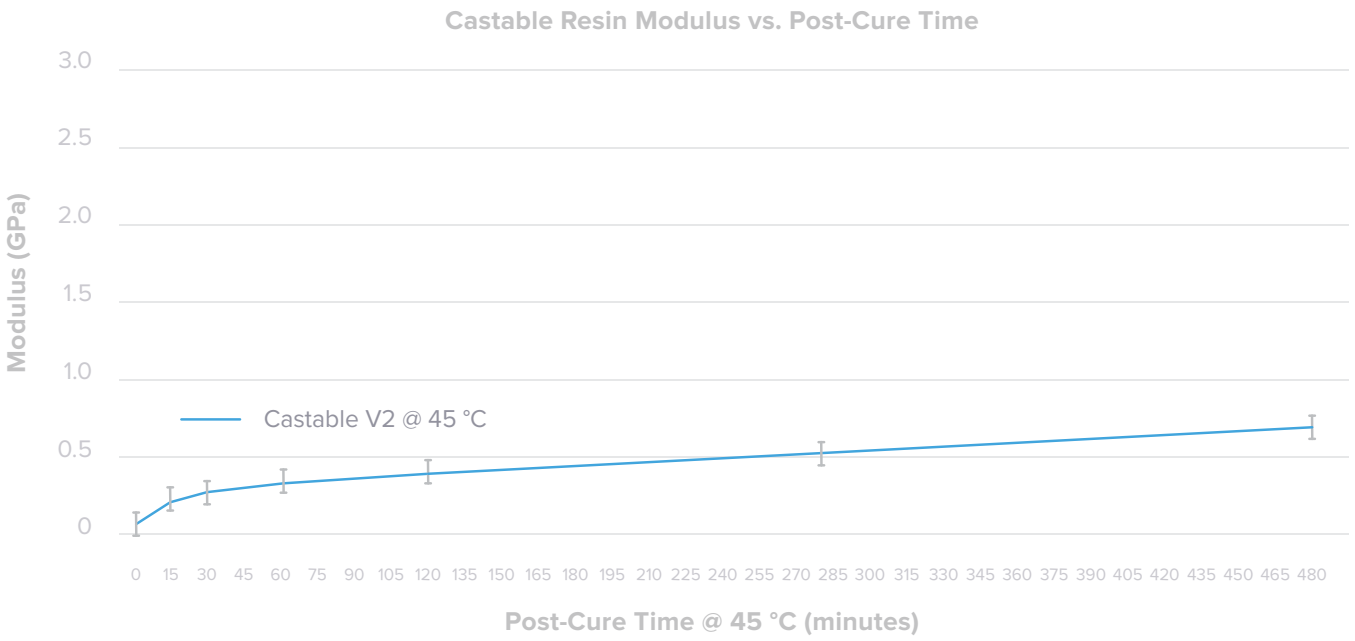
Dental SG Resin shows a peak modulus at 30 minutes of post-curing at 45 °C, indicating a complete cure.

APPLICATIONS GUIDELINE

Dental SG Resin must be fully post-cured to be considered biocompatible. Post-curing ensures that any remaining monomers and oligomers are bonded to the part, preventing them from traveling into the body. Based on the location of the peak modulus of elasticity, we can see that that Dental SG Resin is fully cured at 30 minutes at 45 °C. Formlabs has calibrated Dental SG Resin to account for the small amount of shrinkage that typically occurs when post-curing Dental SG for this duration.

RECOMMENDED POST-CURE SETTINGS

Castable Resin



Analysis: Post-Curing Mandatory

Castable Resin exhibits a gradual increase of modulus of elasticity over the first 480 minutes of post-curing. After 480 minutes, modulus decreased.

APPLICATIONS GUIDELINE

Formlabs internal testing shows that casting success may be improved by increasing part strength. Good part geometry and casting technique were more influential than increasing post-cure time, but testing results showed no disadvantages for increasing post-cure time. Formlabs recommends post-curing Castable Resin parts for 280 minutes at 45 °C.

Follow the **Recommended Burnout Guide** for best jewelry casting results.

Post-Cure Troubleshooting

The most common issues encountered when post-curing parts are **under-curing** and **warp**.

If parts seem weaker or less rigid than expected, they may be insufficiently post-cured. Under-curing can occur when a part is particularly thick or large, as larger parts take longer to heat. Light alone cannot post-cure much beyond the surface of a part, which is why Form Cure applies both heat and light. If a part is significantly larger or thicker than Formlabs' test geometries, it may require a longer post-curing time or higher temperatures to reach a full internal post-cure.

Warping during post-cure may occur if a part is especially thin, and is not equally exposed to light on all sides. Form Cure helps prevent warp by rotating the part on a turntable during postcuring, and by exposing the part to light from all directions—including underneath the turntable.

Post-cured parts also tend to be more brittle than green parts. While the graphs in this white paper focus on changes in modulus, typically, as modulus increases elongation will decrease. Because of this, over-cured parts can be undesirably brittle.

Conclusion

This guide was last updated in March 2018, and will be periodically updated as resin versions change and new materials are released. Visit the Formlabs website for **up-to-date recommended post-cure settings** for using Form Cure. Specific mechanical properties after the recommended post-cure are available in material **data sheets**.

Learn more about post-curing with Form Cure on our **website**.

Learn More About Form Cure →

Contact Formlabs to learn more about advanced post-processing solutions.

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