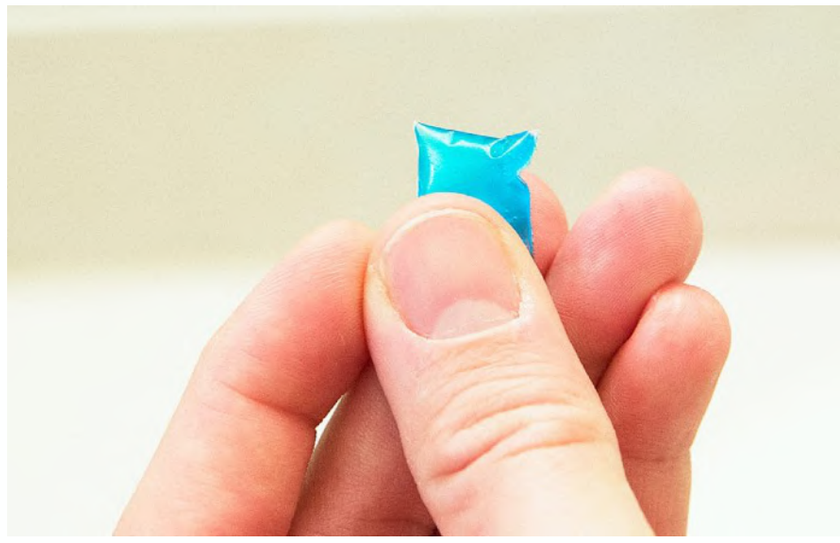
Injection Molding OnePod

Inspiration

Toothbrush moments, but no toothbrush! Has this ever happened to you? You're on a long flight, in a hotel, perhaps just ate lunch and you need a toothbrush, toothpaste or floss — but it's not available?

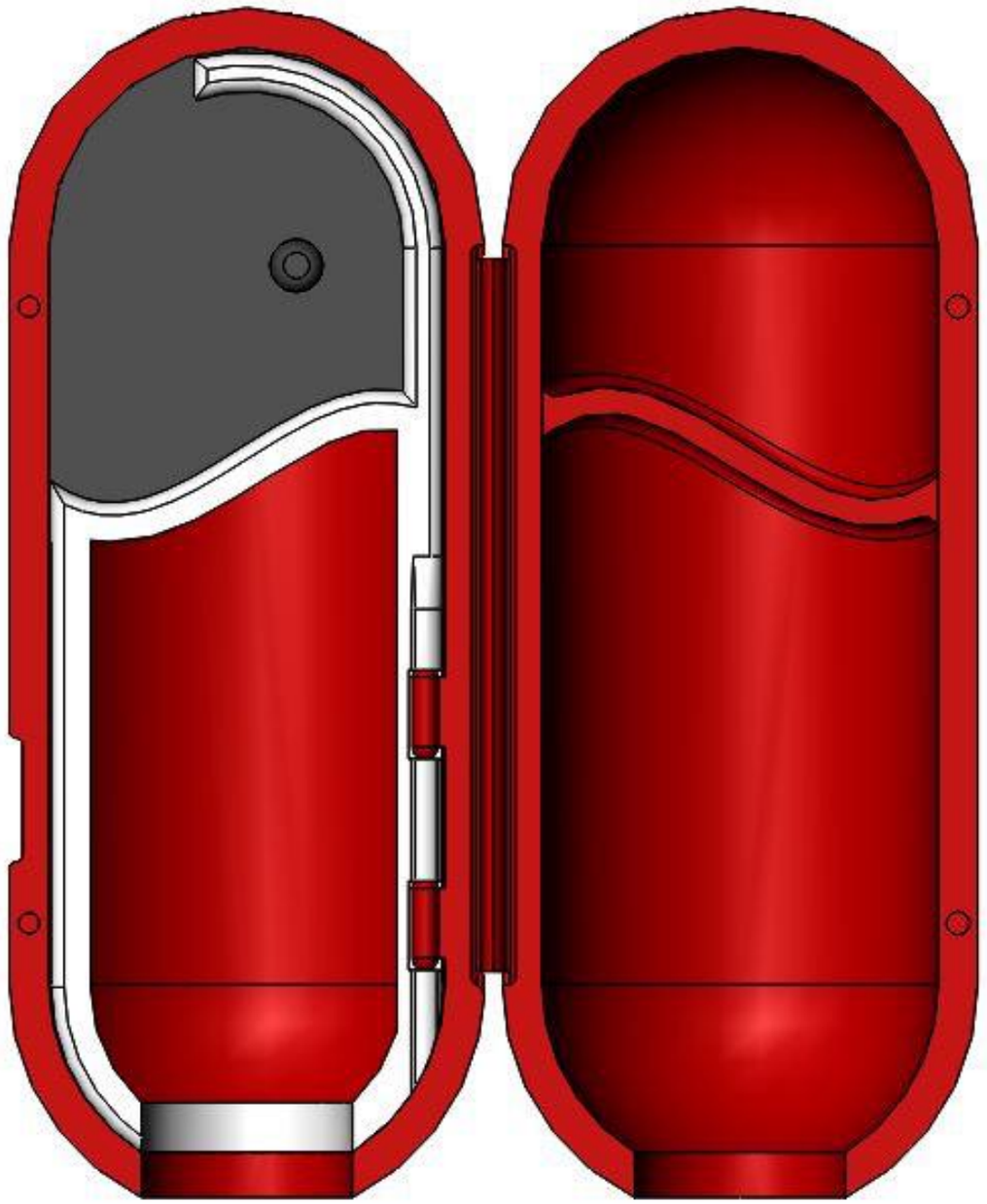
For times like these you desire a toothbrush system for one use or several... and you need it now. Often when receiving a disposable toothbrush it is delivered without the toothpaste already applied or it is supplied separately with a tiny foil seal that is nearly impregnable... particularly at 30,000 ft. or without glasses. And never any floss. This traditional product is often challenging and fails to provide a functional, elegant solution. And one that is environmentally friendly.

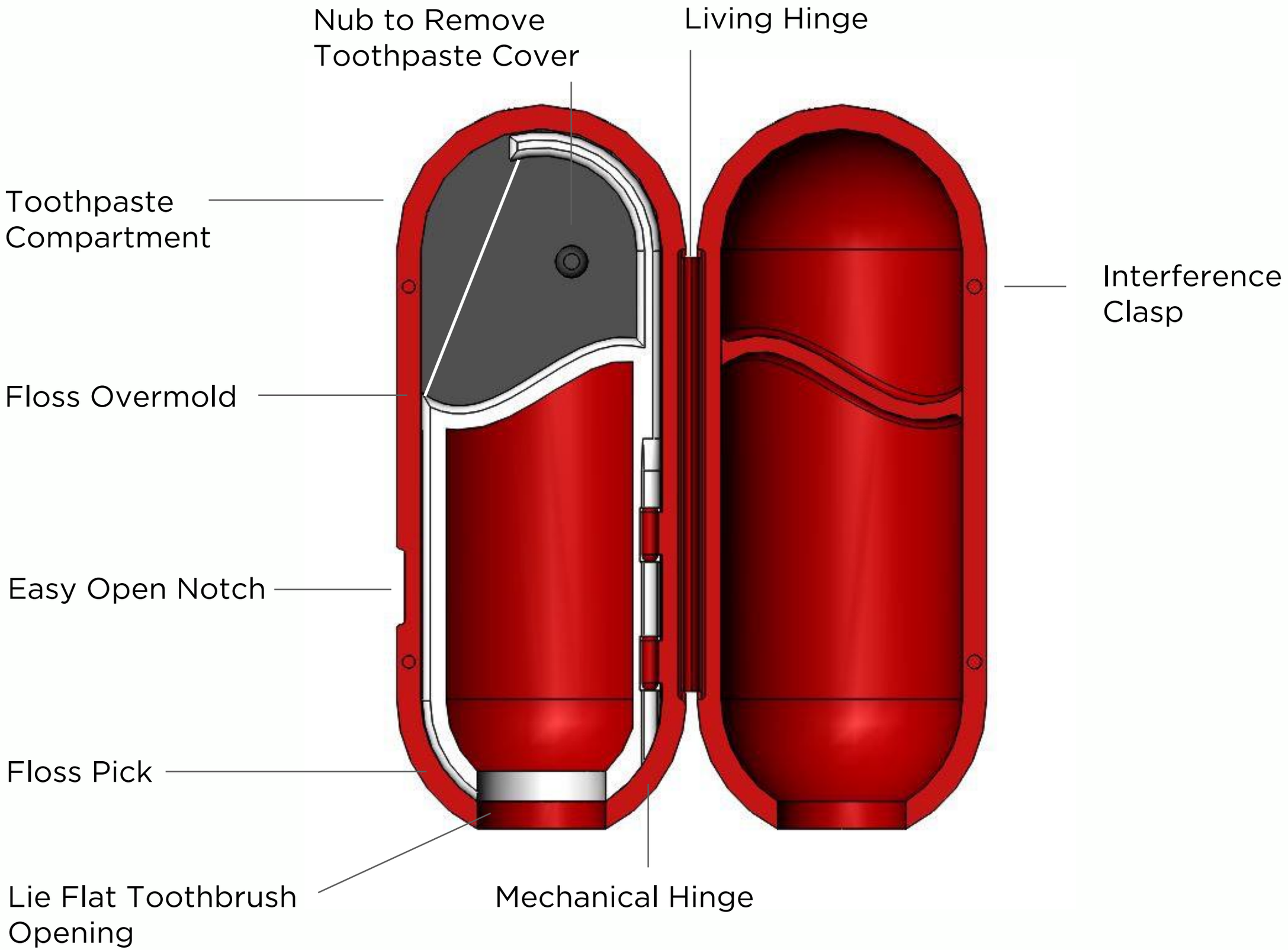


Objectives

Goal: create a seamless disposable toothbrush system integrating a toothbrush, floss pick and a single serving of toothpaste.

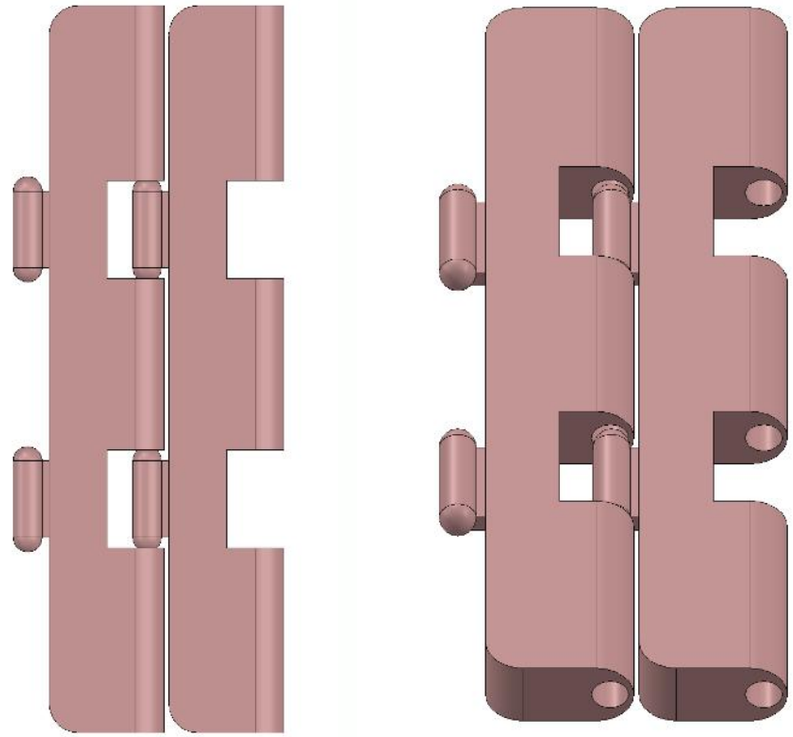
Technical goals: further explore living hinges, ribs, interference fits, mechanical hinges, over molding, undercuts in mold design, and family molds.

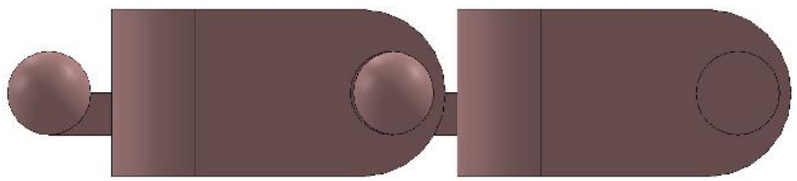



Nub to Remove Toothpaste Cover
Living Hinge
Toothpaste Compartment
Interference Clasp
Floss Overmold
Easy Open Notch
Floss Pick
Lie Flat Toothbrush Opening
Mechanical Hinge

Mechanical Hinge Design

In creating the floss pick it was desired to keep the pick with the pod as a single unit however the pick would need to be easily removed during flossing. The pick covers the toothpaste, so it is logical to have it pivot out of the way while brushing but still remaining attached to the toothbrush case. To form this pivot and allow easy removal, a mechanical hinge was designed. The interference needed to allow a smooth pivot would be determined through cutting a test mold with varying amounts of interference for a similar watch link design. Links with interference of .004” and .008” per pivot point were tested. The female side of the hinge was formed with a 1/16” steel pin which lay in the mold.





Mechanical Hinge Mini Mold

In shooting test parts, it was determined the proper amount of interference to create a pivot and allow easy removal of the part was .009” per pivot point. While shooting test parts, a defect immediately visible was sink directly behind the hollow areas where the rod is inserted to form the pivot point (a result of the change in part thickness). Increasing holding pressure and reducing part volume minimized this sink. Ultimately, this drove a subsequent decision to move away from a family mold for the floss pick and toothpaste cover due to difference in holding pressures needed. Additionally in the final mold to reduce thickness of the part and maintain uniform thickness throughout, the pivot area was made thicker than the remainder of the part. As a result thickness is preserved around the steel pin.

Interference Fit Mini Mold

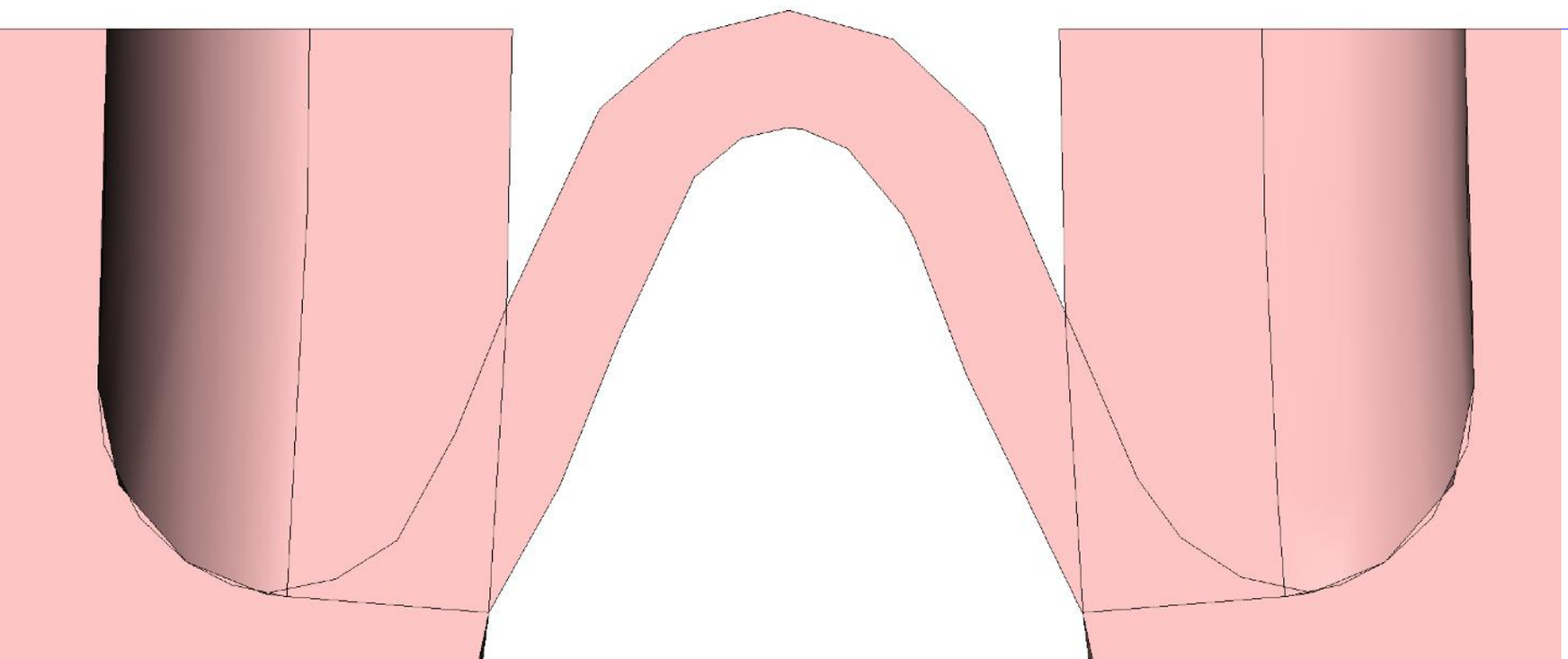
To close the capsule, interference fits were created; it is comprised of two 3/64” nominal boss/base features. They hold the capsule closed through fiction and a rotational moment applied at the living hinge. Due to shrinkage of plastic, various amounts of interference were tested: nominal -.001”, +.001”, +.002”, +.003”, +.004”. The base was created using a 3/64” tight tolerance steel pin that was epoxied into the mold. Through trial and error it was determined an oversized boss of .002” was appropriate to hold the capsule closed.

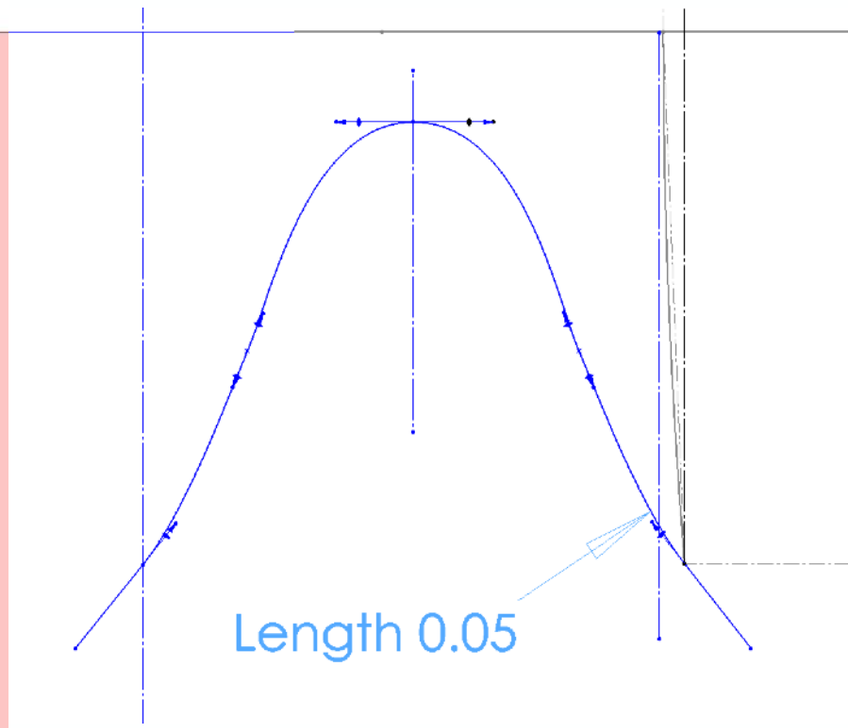
Undercuts

Creating the mechanical hinge in the pod itself required making large undercuts with tight tolerances at a small scale. To form the protrusions large bosses come from the B side of the mold through the base of the part (so it was still able to pull cleanly from the mold). The holes on the underside of the pod are needed for the hinge but double as air vents allowing the toothbrush to dry.

Living Hinge

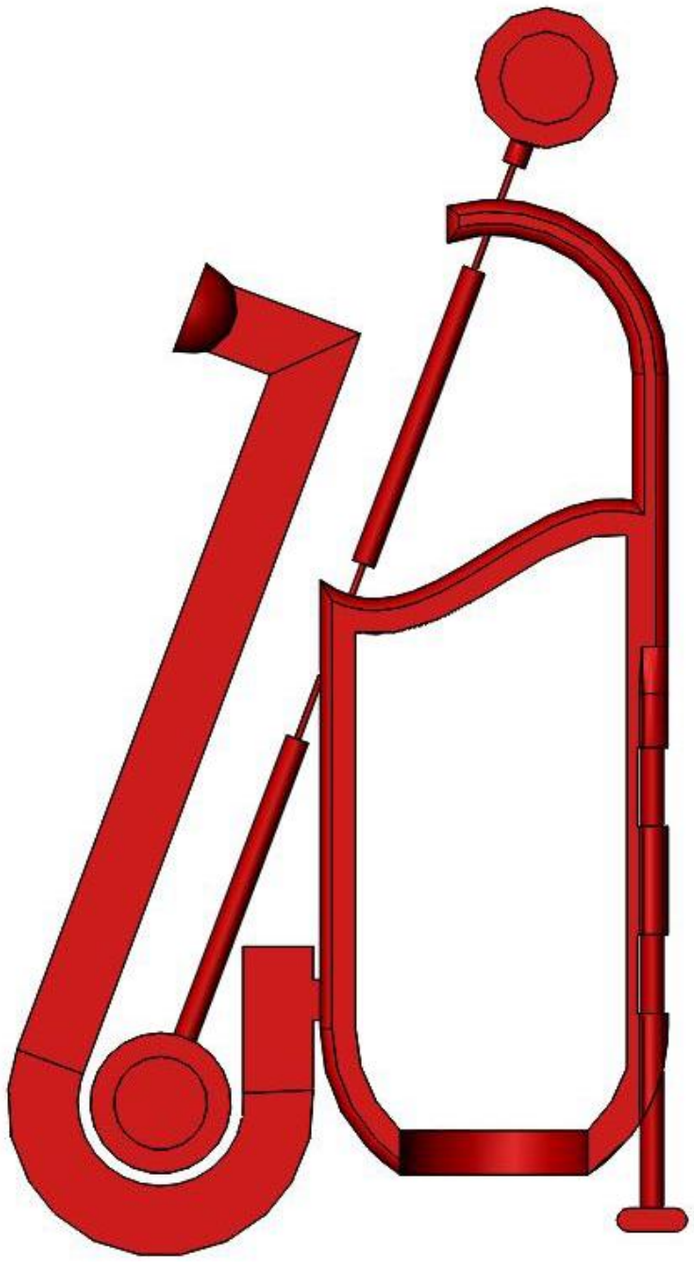
To create the pods main hinge, an injection molded living hinge was the natural solution. In designing the movement a butterfly hinge was desired but this does not work well on a pod shape, so a fixed length hinge was created. The fixed length matched the length of curvature of the pod so when closed the hinge is recessed and flat with the exterior of the pod creating a seamless design. The overall thickness of the hinge is .009”. Polypropylene was selected for this part due to its ability to sustain repeated bends without stress cracking. Additionally, this material is food safe in the Product Realization Lab.





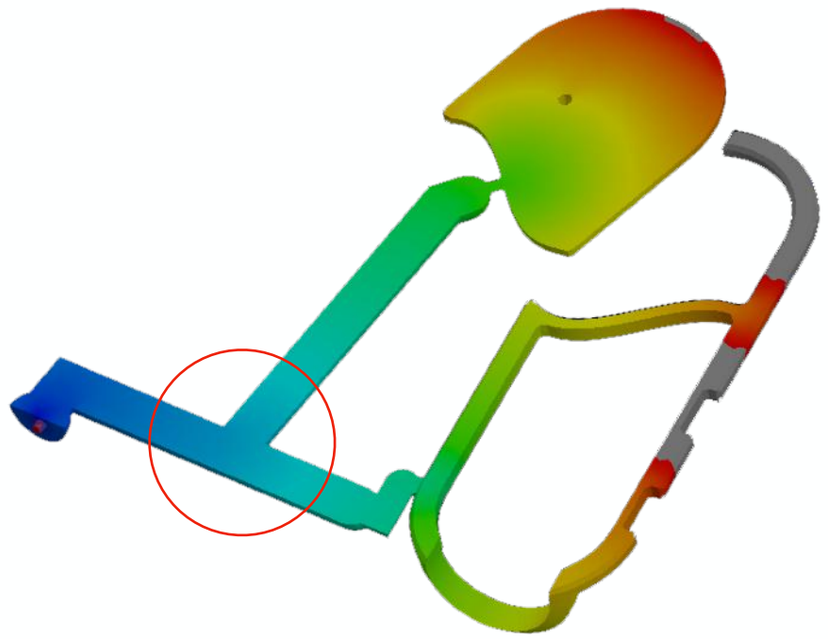
Overmold Design

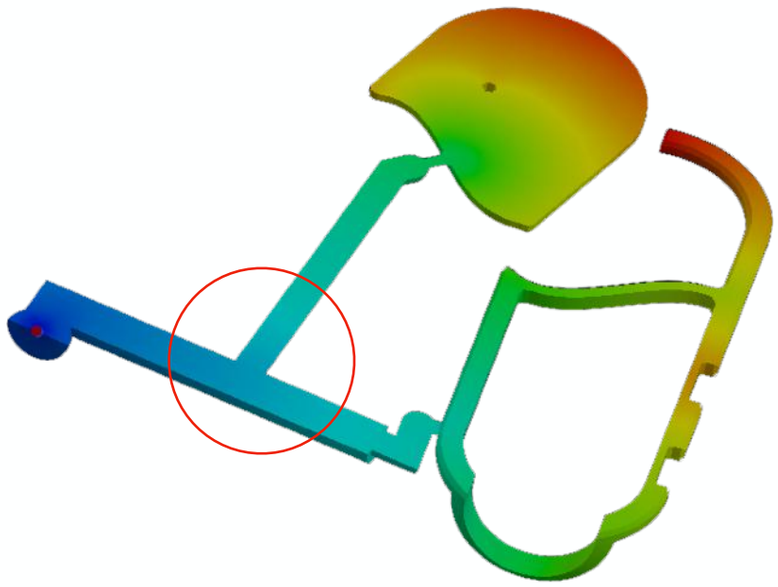
The floss pick's overmold required cylindrical .013" OD floss to be pulled taut across the part while PP was shot. Shut off surfaces were critical, so a narrow channel was created with a 1/64" end mill. To reduce machining time a 1/16" void was created in areas before and after the shutoffs. The floss was self-terminated on two 1/4" press fit pins with a slit down the centerline for alignment purposes.



Flow Simulation/ Family Molds

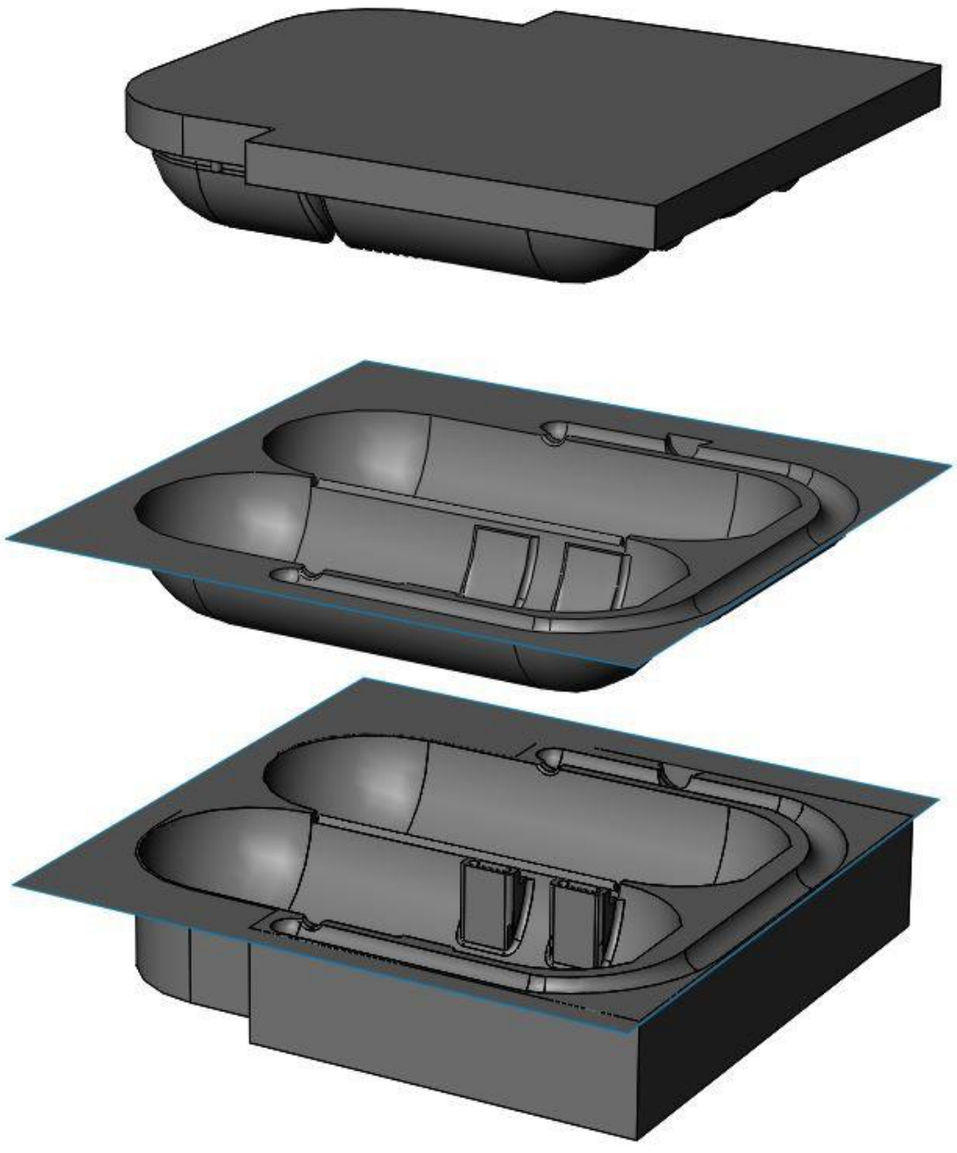
Initially a cover for the capsule of toothpaste in addition to the floss pick were to be molded in a family mold. This would reduce machining to one piece of stock. In flow simulation with 3/16” runners the cover filled at a much faster rate. As a result, a second simulation was performed with a modified smaller 1/8” runner for the cover limiting the flow. With the addition of varying the length just slightly, fill times for both were able to converge. Ultimately in version two this would change as the pick needed a different holding time.





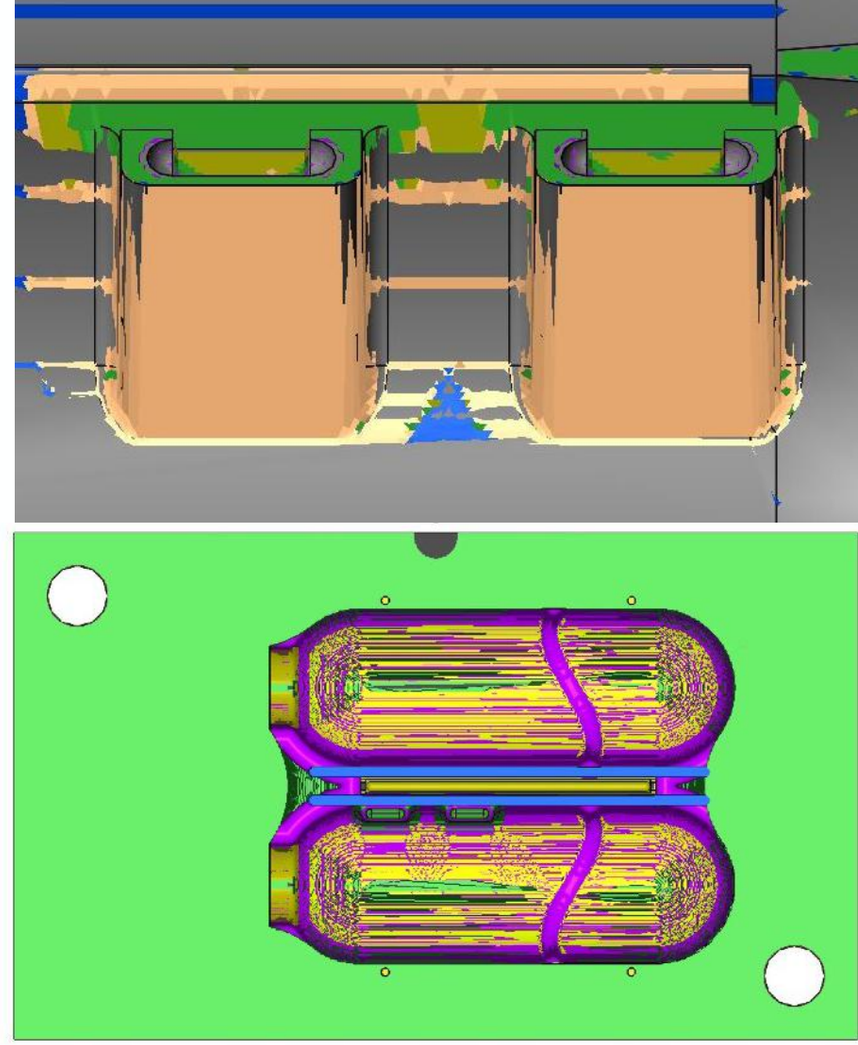
CAD

To create the mold for the pod each half was first modeled individually before being brought together into a single part. The exterior surfaces were then knit and shut off surfaces created to form single parting surface. A piece of stock was then split and boss features were extruded. The overall process of creating the mold insert was complex as splitting the mold using surfaces and the positive of the part often created zero thickness geometry if not careful. Additionally, if anything had to subsequently change most aspect of the mold's knit surface failed and had to be manually regenerated.



CAM

Although the pod, pick and cover in CAD came together into one unit, machining the mold geometries would prove challenging. In CAM it was apparent the tools could not create the sharp bosses required. In complex geometry, based on shutoff surfaces, the molds turned out to be much more challenging to machine. Not taking into account the corners tools could access proved detrimental when machined. Unintentional radii caused the mold halves to not close. Further machine operations would be required to remove these features. In one case the mold could not be machined further so the Arburg was use to deform the aluminum destroying the bosses. In version two of the mold, the part was designed for CAM based on the toolset.

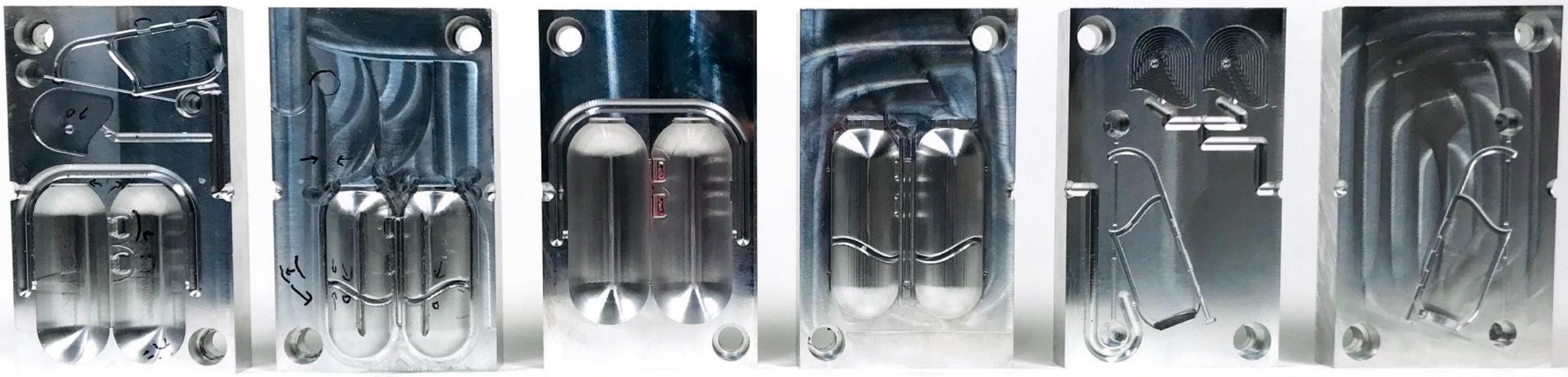


Top: Version two bosses redesigned for CAM. 1/32” fillets used to ensure shutoff surfaces did seal.

Bottom: Marked in blue by CAM, 1/32” trace operation to create the living hinge did not interfere with partial dome shape of pod (V2). Full tool with angled shaft modeled in CAM to test for collisions.

3D CNC Milling

Shell mill 3” 6 flute
Drill .358”
Drill .0625”
Center Drill #1
Flat end mill 1.0” 4 flute
Flat end mill .25” 4 flute
Ball end mill .25” 4 flute
Flat end mill .125” 3 flute
Ball end mill .125” 3 flute
Flat end mill .0625” 3 flute
Ball end mill .0625” 3 flute
Flat end mill .03125” 2 flute
Ball end mill .03125” 2 flute
Flat end mill .01563” 4 flute

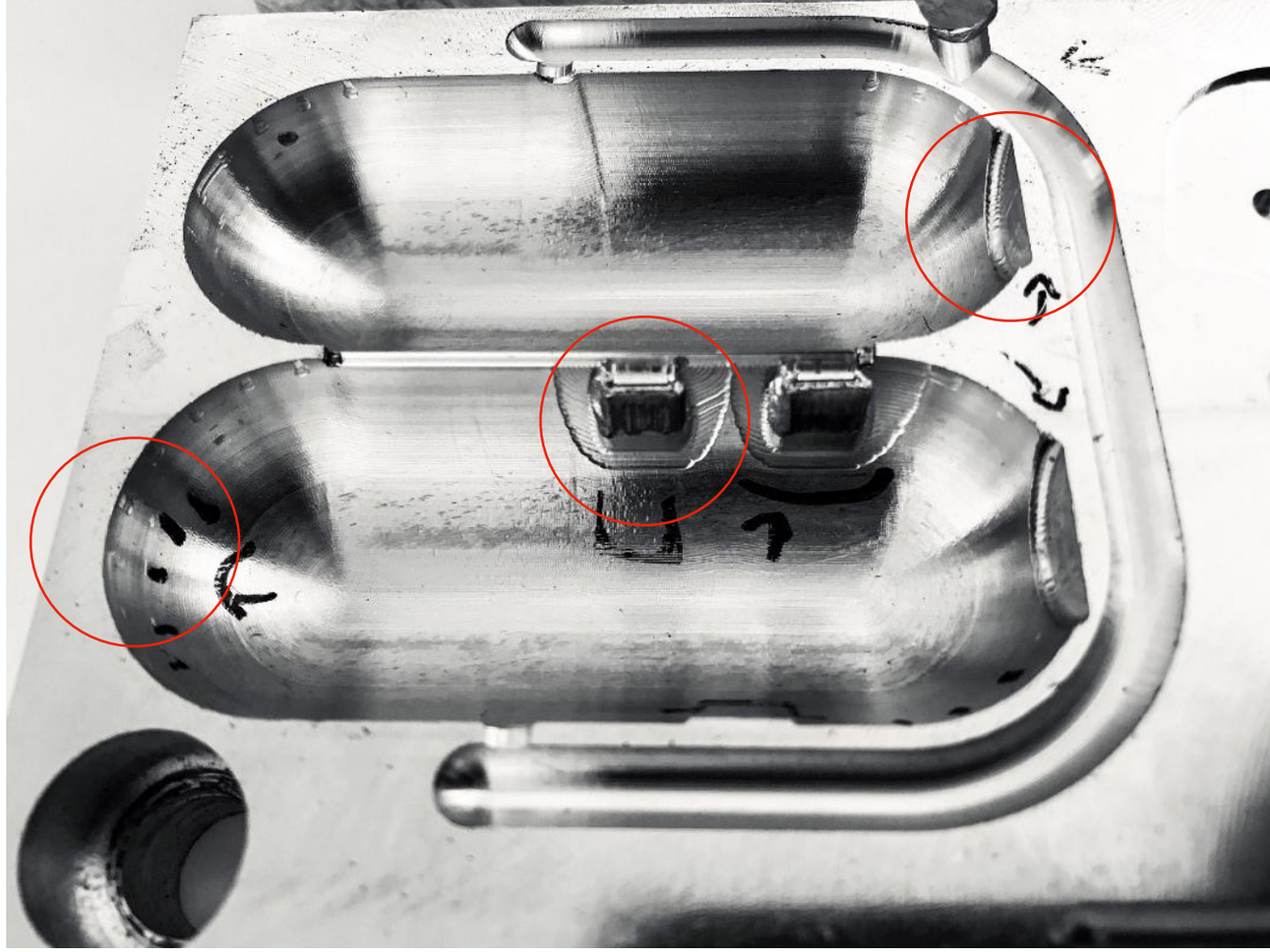


3D CNC Milling

Molding V1

Mold V1 Revisions

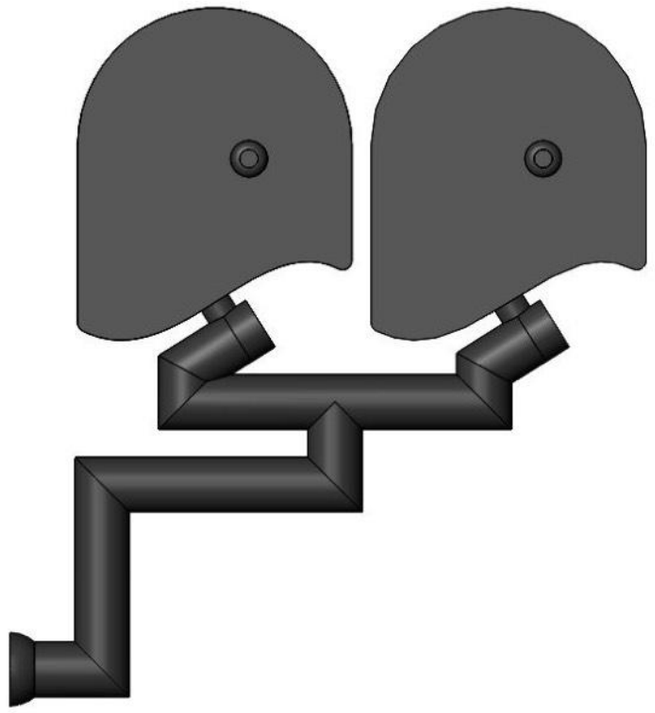
Pod Mold - Cavity - A Side:
1. 0.010” shut off on toothbrush opening at bottom of pod was an insufficient shutoff surface. 2. Poor selection of machining boundaries caused small marks around side of the pod as smaller tools hold higher resolutions by default in CAM and therefor sometimes cuts deeper (based on minimum depth of cut). 3. Similarly around the bosses machine marks are visible due to a different tool being used to scallop the entire cavity.

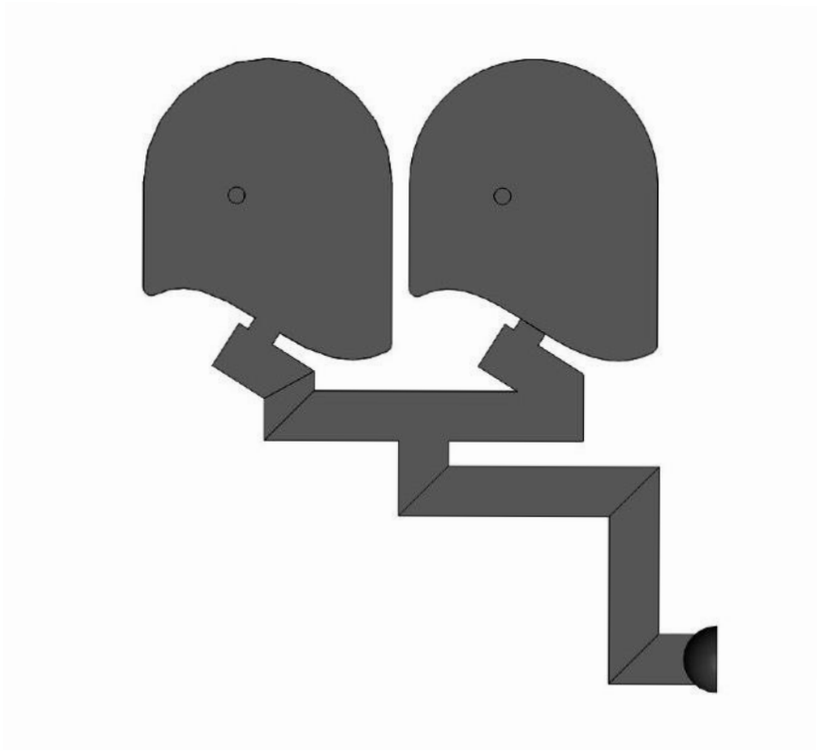


Pod Mold - Core - B Side:
1. Parallel lines on the top surface were caused by the tool not being extended far enough from the collet when cutting the living hinge with a 1/32” end mill in the center of the two pod halves. 2. The ribs were cut with a parallel operation (est. 7min) which moved vertically causing a very rough finish whereas contour which would take passes horizontally was providing an estimate of 46min. 3. Sink experienced on the rear side of the ribs could be minimized by making the thickness less than the pods wall or by thickening the overall part thickness.

Flow Simulation/ Family Molds

Having additional space in the 3x5” stock, a second cover could be molded on each shot. To ensure similar results a symmetric runner system was used so each would fill in parallel at similar rates.

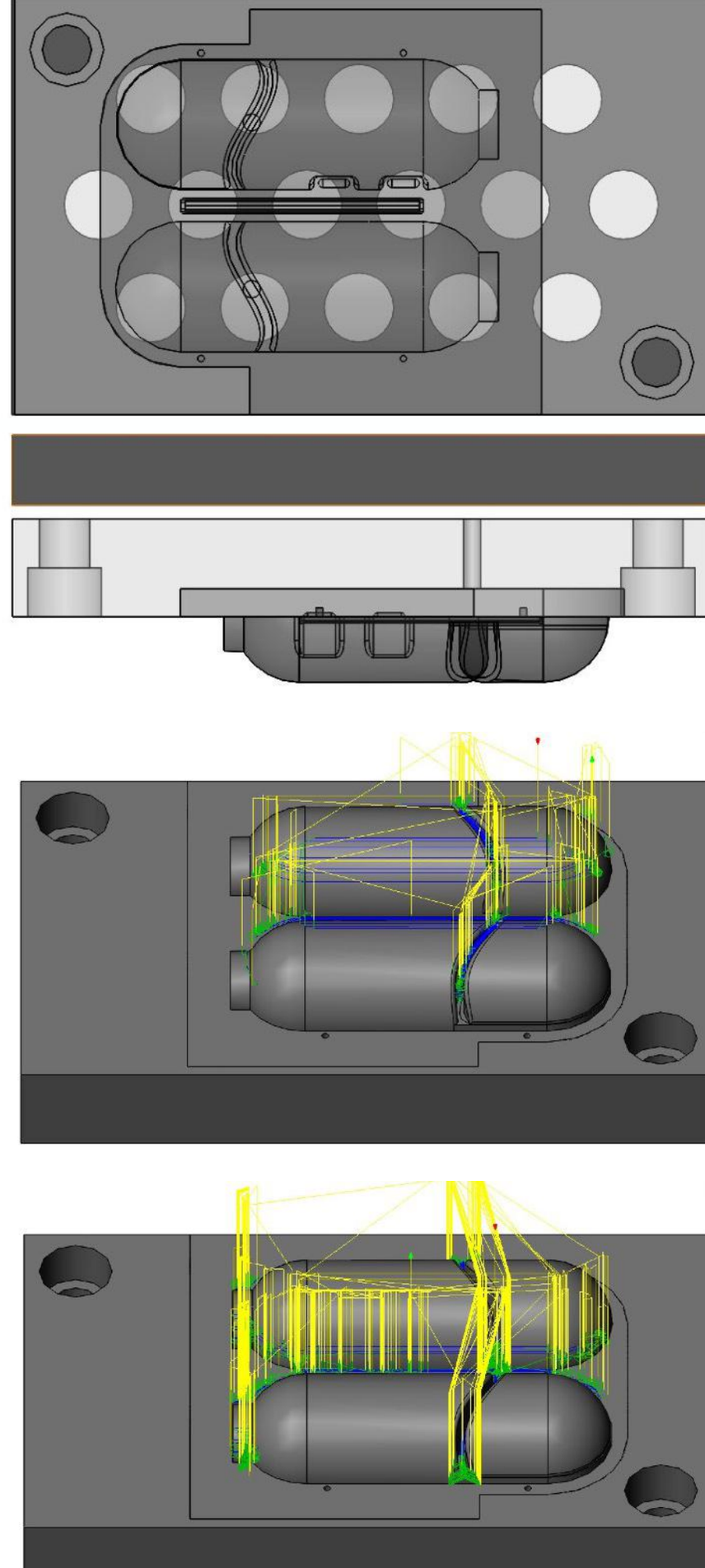




Ejector Pins

Although the CAM for the rib in the first version produced a rough surface finish precluding the pod from being easily removed from the core, ejector pins were additional added in version two. One 1/16” pin was placed on each of the ribs. Because the rib is 1/16” wide as well as 1/2” deep a creative way to drill the hole was needed. Simply using a center drill would not have been possible due to the core. Drilling straight through from stock top would have produced wandering, likely not locating the hole on the center of the rib.

First the 1/16” square end mill (1/2” length of cut) was used to remove 3/8” of material from the rib section. Then holes were drilled with the end mill 1/8” into the remaining stock. A tool change to the 1/16” drill was then required, drilling down 1/4” past the rib before the rib was cut the remaining bit with the 1/16” end mill. Lastly the stock was flipped and 1/8” holes were drilled to meet with the 1/16” holes at the surface. Smaller 1/16” holes were not created through the entire stock out of fear of the ejector pins bucking due to drill wandering.

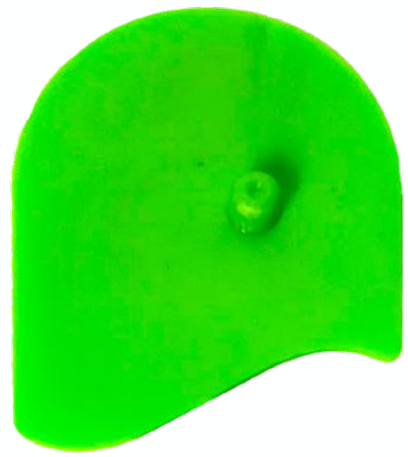


Molding V2

Mold: 3x5
Clamping force: 18.0 t
Dosage volume: 1.42 in3
Injection rate: 1.0 in3/s
Injection pressure: 13500 psi
Holding pressure: 5000 | 5000 psi
Holding time: 0.10 | 0.10 s

Molding V2

Mold: 3x5
Clamping force: 20.0 t
Dosage volume: 0.48 in3
Injection rate: 1.0 in3/s
Injection pressure: 13500 psi
Holding pressure: 2000 | 2000 psi
Holding time: 0.20 | 0.20 s



Molding V2

Mold: 3x5
Clamping force: 25.0 t
Dosage volume: 0.5 in3
Injection rate: 1.0 in3/s
Injection pressure: 13500 psi
Holding pressure: 2000 | 2000 psi
Holding time: 0.20 | 0.20 s
Mold opening: 0.44 | 2.00 | 1.50 in/s

Pick:
Overmold of floss failed in multiple shots as a result of pour shutoffs around the material. PP seeped into the 1/16” space beyond the shutoff, reducing pressure helped marginally. Additionally mold opening was slowed to mitigate tearing in the floss when it was pulled off the pins. The 1/16” dowel pin for the mechanical hinge removed without issue.

Pod + Pick Assembly:
Overall hinge both mechanical and living molded fine. One boss/base pair failed as a result of the pin being torn out of the mold. During molding the pins also came out of the cover mold B side. Different glue is needed to ensure these remain in the mold.