Skin Applicator

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Abstract

During this semester we were charged with the task of designing an applicator device for a topical drug solution. The motivation for this design comes from our client, Dr. Bill Fahl, who—along with his associates—has developed a drug for the prevention of radiation-induced burns. Our client had a few main requirements for this design, and over the course of this semester we sought to create a prototype which conformed to these standards. In the end, we came up with two separate devices which we believe each have unique and redeeming qualities over current devices on the market. In the future we will attempt to contribute additional design alternatives, test all design prototypes, and pursue large-scale manufacturing of one of these devices via injection molding.

Background

- Radiation burns (dermatitis) is a major side effect experienced by cancer patients undergoing radiation therapy [1]
- Currently no sufficient method exists for preventing radiation burns from occurring as a result of radiation therapy [2]
- The high-energy electron beam used in radiation therapy creates oxygen free radicals which damage the surrounding tissue
- Our client has developed a drug solution incorporating norepinephrine to prevent radiation burns from occurring as a result of radiation therapy

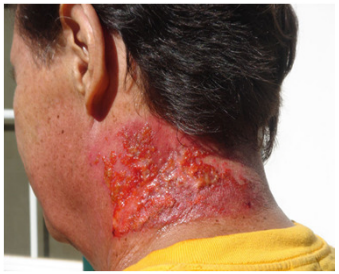


Figure 1: A patient exhibiting radiation-therapy-induced dermatitis.
(Source: http://www.cancer-throat.com/index.php?s=labricate)

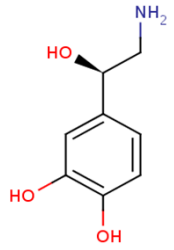


Figure 2: Norepinephrine, the drug used in the client's trials.
(Source: http://www.hmrb.wisc.edu/metabolomics/mol_summary/?molName=Norepinephrine)

Motivation

•The client's drug solution, a 70:30 ethanol:water mixture containing norepinephrine, requires an effective method to deliver this drug topically to radiation-therapy patients
•The client is preparing to commence a relatively large-scale clinical trial which would benefit from an effective application method

Client Requirements

- The device should apply 8.0 mL of the drug solution to approximately 225 cm^2 of skin
- The device should be disposable (i.e. single-use)
- The device should be relatively light-weight and handheld
- The drug solution must be contained in a glass ampoule

Final Design

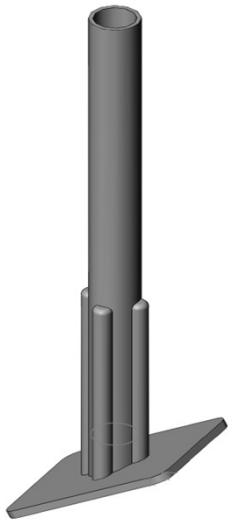


Figure 3: The first design

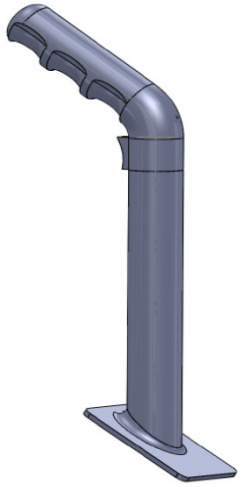


Figure 4: The second design

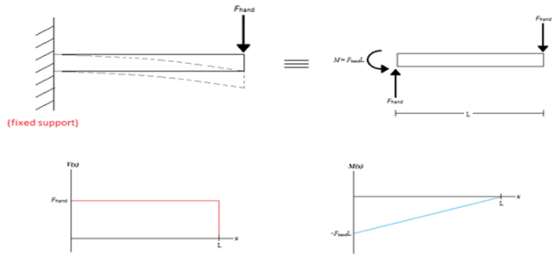
Key Features of the Final Designs:

- The first design:
  - simple, straightforward design
  - glass ampoule is crushed to release the drug via bending-moment breaking mechanism
  - employs four symmetrically placed cylindrical ridges to promote gripping and decrease the required ampoule-breaking force

- The second design:
  - slightly more complex design
  - employs spring-loaded triggering mechanism to crush the glass ampoule
  - handle is ergonomically designed to facilitate prolonged use of the device

Testing/Calculations

•When designing the first device, we wanted to ensure that the average user can easily fracture the glass ampoule via the bending-moment breaking mechanism
•Our initial idea for the first design was to use a hollow cylinder fractured by a three-point bending mechanism
•After performing calculations, we determined that this model required an excessively large force to yield the HDPE handle
•By including the cylindrical ridges, a cantilevered-beam mechanism was devised, which significantly reduced the required force, as confirmed by our calculations (see below)



$$F_{yield} = \frac{\pi \cdot \sigma_{yield} \cdot \left(d_o^4 - d_i^4\right)}{32 \cdot L \cdot d_o} = \frac{\pi \cdot \left(28\times10^6 \ \mathrm{N/m^2}\right) \cdot \left[(0.018\ \mathrm{m})^4 - (0.015\ \mathrm{m})^4\right]}{32 \cdot (0.120\ \mathrm{m}) \cdot (0.018\ \mathrm{m})} \approx 69.2\ \mathrm{N}\ (15.5\ \mathrm{lb}_f)$$

Future Work

- Create a few more design alternatives for user testing
- Conduct user testing of the various design alternatives to determine the most user-friendly design
  - pressure mapping via capacitive technology
  - EMG monitoring during use
  - qualitative surveys to assess user feedback
- Design a mold for large-scale manufacturing using injection molding

References

1. Prat, M., Bey, E., Brachet, M., Trompier, F., Ernou, I., et al. (2008). New therapeutic approach in the treatment of severe radiation burn: Surgery and local stem cell therapy. *Wound Repair and Regeneration*, *16*(6), A78.

2. Lataillade, J., Doucet, C., Bey, E., Carsin, H., Huet, C., et al. (2007). New approach to radiation burn treatment by dosimetry-guided surgery combined with autologous mesenchymal stem cell therapy. *Regenerative Medicine, 2*(5), 785-794.