Advancing Digital Dentistry with High Strength, High Toughness 3D Printable Urethane Denture Base Formulations

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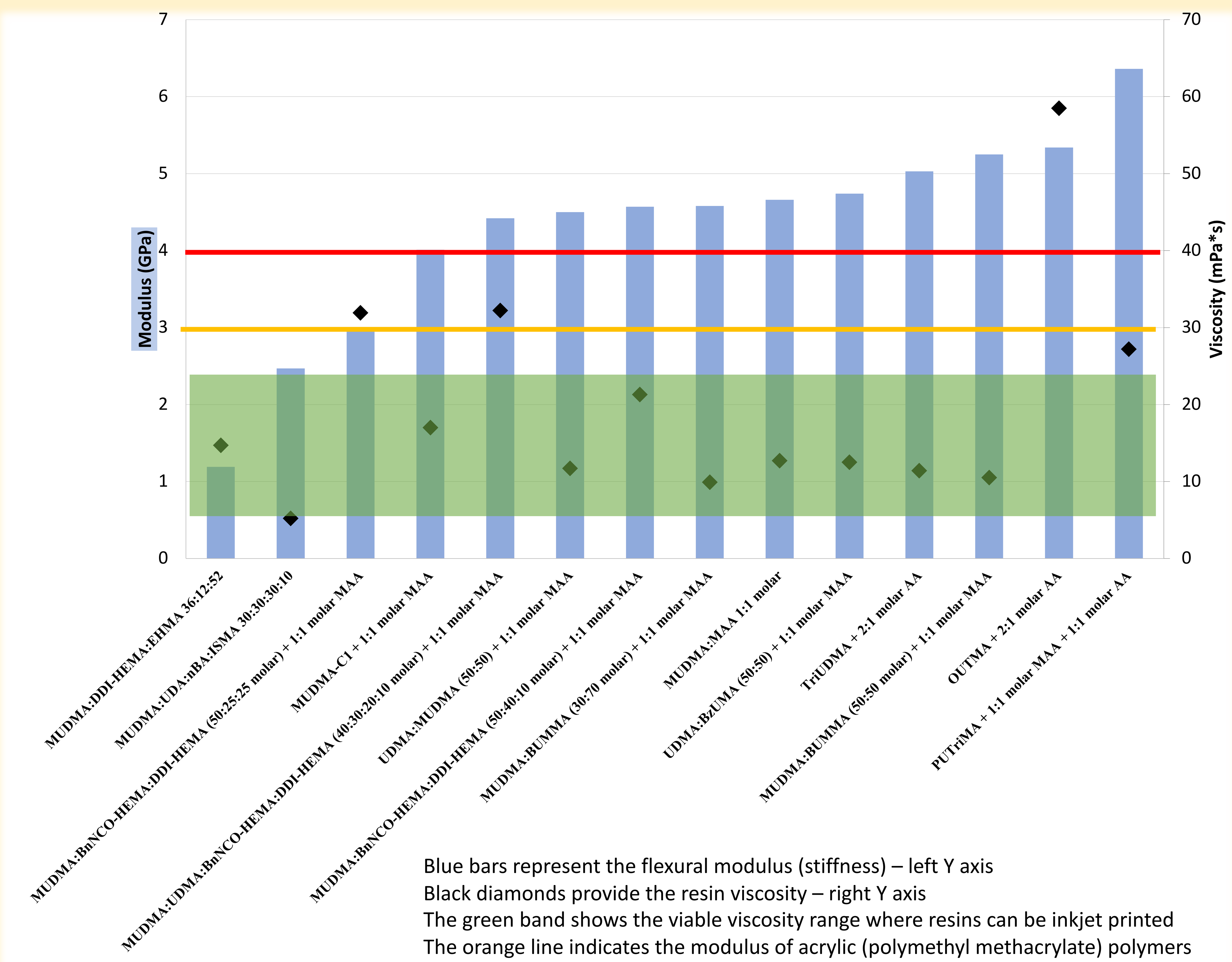
INTRODUCTION

Interest in 3D printed denture technology has risen rapidly as digital dentistry is becoming common place, yet 3D printed denture base resins used today share the same limitations in flexibility, fracture toughness, and minimum thickness as conventional poly(methyl methacrylate) (PMMA). We formulated low to moderate viscosity urethane resins to maximize non-covalent interactions known to enhance polymer strength and toughness. Low viscosity formulations can be used in vat-based 3D printing to produce separate denture base and denture tooth components that are then bonded together in final form. However, very low viscosity resins (<25 mPa*s) permit multimaterial inkjet printing to be used to build monolithic multi-material structures without the added step of integrating the teeth and base. A range of viscosity enables the use of both these 3D printing technologies, and the range of modulus as well as strength and toughness properties of the novel materials enables the cost-efficient construction of full and partial dentures that out-perform current 3D printed or analog format prosthetics.

RESULTS



Blue bars represent the flexural modulus (stiffness) – left Y axis
Black diamonds provide the resin viscosity – right Y axis
The green band shows the viable viscosity range where resins can be inkjet printed
The orange line indicates the modulus of acrylic (polymethyl methacrylate) polymers
The red line indicates the minimum modulus for denture tooth materials

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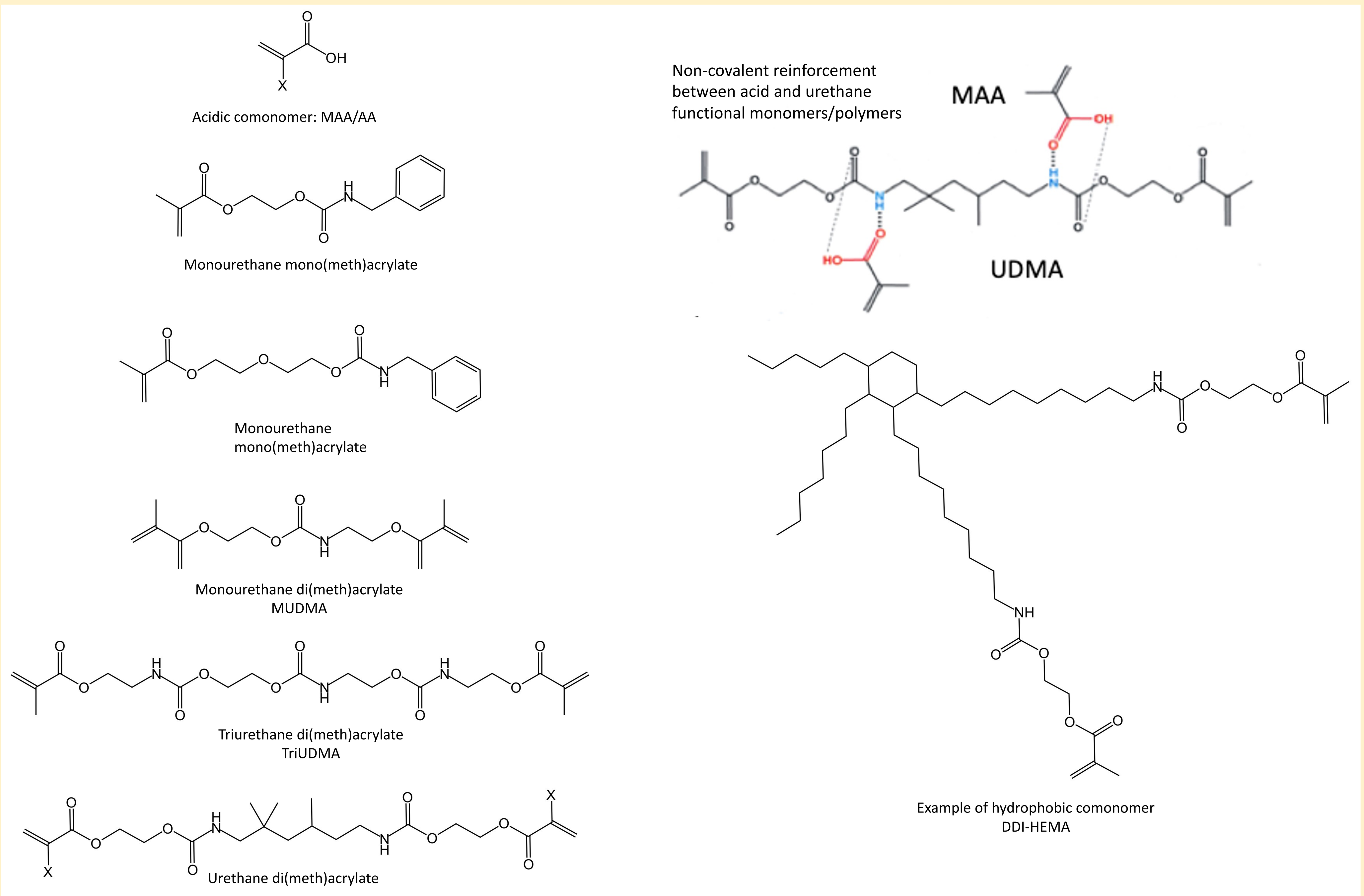
METHODOLOGY

Formulations were mixed on a molar basis typically with 1:1 or 1:2 urethane-acid functional group ratio along with 1:1 urethane monomer:reactive diluent. Once homogeneous, formulations were tested via viscometer to measure resin viscosity. Samples for mechanical testing were loaded into a mold of desired dimensions and exposed to a 365nm light for 4 minutes total. Conversion was monitored via C=C peak using FT-IR. After 4 minutes of exposure samples were put into an oven at 80°C for 1 hour under 365/405nm light. Once post-cured samples were put under 3-point bending using the MTS to measure flexural strength, modulus, and toughness. Some samples were 3D printed using a Mars Elegoo printer with 1wt% diphenyl(2,4,6-trimethylbenzoyl)phosphine oxide (TPO) and 0.1wt% 2,5-bis(5-tert-butyl-2-benzoxazoyl)thiophene (BBOT). They were then subject to the same post-cure and tested on the MTS. Wet samples were tested after 48 hours in 37°C water. The Stansbury lab does not have an inkjet printer but certain formulations were made available for external validation that several of these very low viscosity formulations were indeed amenable for inkjet deposition. Pigments were added as needed to obtain provide esthetic pink (denture base) and white (denture tooth) appearance whether for vat-based or inkjet delivery.

Besides the demonstrated ability to independently control both resin viscosity and polymer modulus values, the novel urethane-based 3D printable formulations provide strength and toughness results that dramatically exceed that of conventional acrylic denture base and tooth materials.

MATERIALS



PURPOSE & CLINICAL IMPLICATIONS

The American Dental Association underlines the impact of oral health on general health. More than 60 adverse health conditions, including diabetes and heart disease are linked to poor oral health. Full or partial dentures can restore the function and aesthetics of missing teeth, and over 44 million people in the U.S. rely on these dental prosthetics with many more left in need.

CONCLUSION

This work highlights the potential for use of high-performing urethane-based monomers for both denture tooth and denture base applications using either a two-step vat-based DLP 3D print platform or a single-step inkjet print process. These approaches reduce the expense to produce dental prosthetics, which is expected to expand accessibility and clinical function of dentures.