



Fracture Toughness of Water-immersed, Milled Monolithic Denture Bases

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INTRODUCTION

Screw-retained implant-supported prostheses can now be made available in a single day by judiciously preparing for implant placement and converting the prosthesis from a pre-made denture base already containing teeth that are in occlusion. This initial prosthesis will allow the newly placed implants to osseointegrate and become stable while, at the same time, provide the patient the ability to chew and speak during the healing process. This prosthesis is then replaced after healing and is not meant for long-term clinical use.

Typically, these “initial dentures” (interim) are digitally designed and milled from pre-polymerized, pre-shaded discs of polymethyl methacrylate (PMMA). Both the denture base and teeth will therefore be monolithic and will be fabricated from the desired tooth shade material.



MONOBLOCK ALL PMMA DENTURE



SAME DENTURE WITH PINK-COLORED COMPOSITE ADDED TO SIMULATE GINGIVA

<https://sprintray.com/fully-printed-dentures-accessibility/>

Image from Lee Culp

The denture flanges are then veneered with a pink-colored composite to simulate the color and texture of gingival tissues. This technique is inexpensive, provides a relatively esthetic appearance, and the bond of the denture tooth to the denture base material is not compromised, because individual teeth are not placed and bonded – the entire structure is one piece of PMMA.

Because these interim prostheses are worn for up to 3 months, the question arises as to their strength and other physical properties as compared to materials designed for more long-term use (definitive prostheses). Thus, the cost of materials and expense of labor involved with fabrication of a more definitive prosthesis might be wasted during this initial, short-term use period.

The only literature describing interim materials comes from manufacturer’s brochures, which provides values that vary widely, without explanation. The effect of water absorption on the mechanical properties of these materials is also unknown, and have a crucial impact on the short-term durability of these products.

Two characteristic properties are important when comparing these types of materials: (1) fracture toughness (the ability of the resin to resist fracture) and (2) flexural strength (the ability of the material to withstand flexural forces).

PURPOSE

This study measured differences in fracture toughness among a wide variety of commercial PMMA discs commonly used to create interim prostheses and compared those values to a control material known to be appropriate for long-term, definitive clinical use.

In addition, fracture toughness values were obtained in the dry state, as well as after 1 and 3 months water immersion.

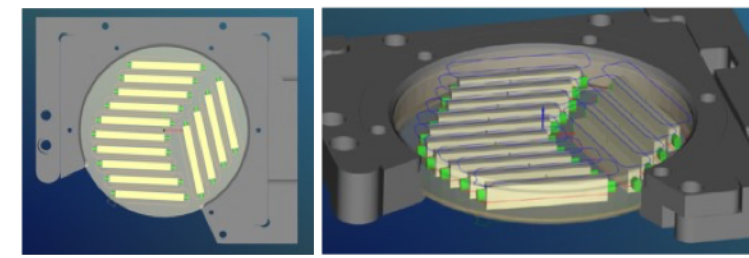
HYPOTHESES

1. Fracture toughness of the control product will be significantly greater than all of the interim PMMA products, regardless of water storage condition
2. Water storage will result in a significant decrease in fracture toughness for all products, but the CONTROL product will be affected the least.
3. Significant differences in fracture toughness among the interim PMMA products is expected, but no specific ordering can be expected.

METHODS

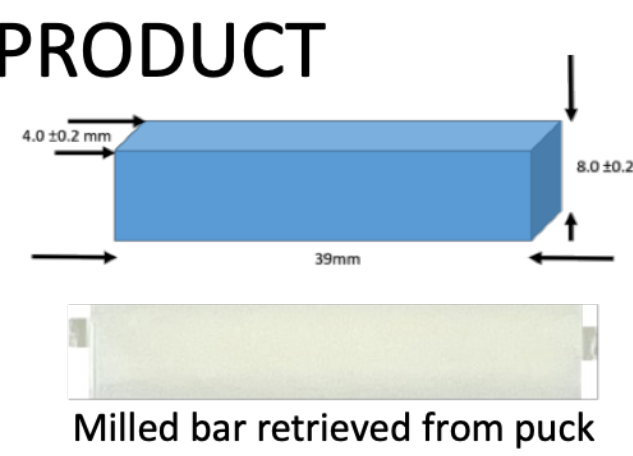
SPECIMEN FABRICATION

DIGITAL DESIGN



All specimens milled from pre-polymerized pucks within the tolerances of the ISO. Specimens retrieved by separating the small supports

FINISHED PRODUCT



MATERIALS USED



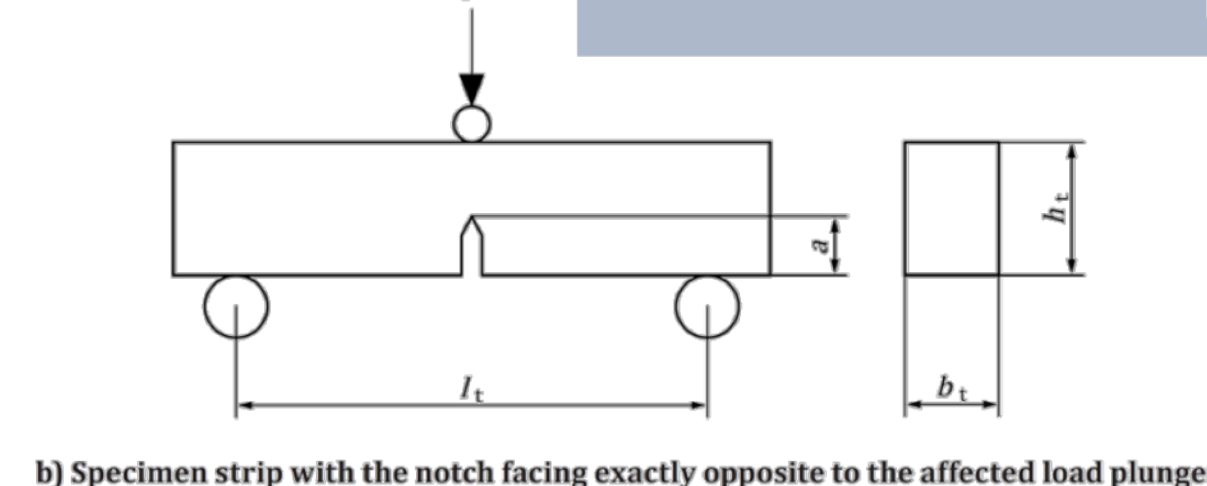
“Long-Term” CONTROL Product



HUGE and HUGE 2 from different lots

“Short-Term” Test Products

TEST METHODS



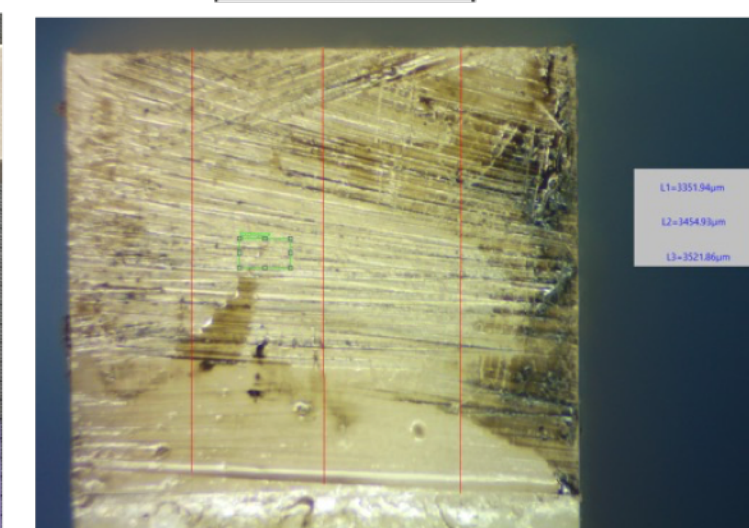
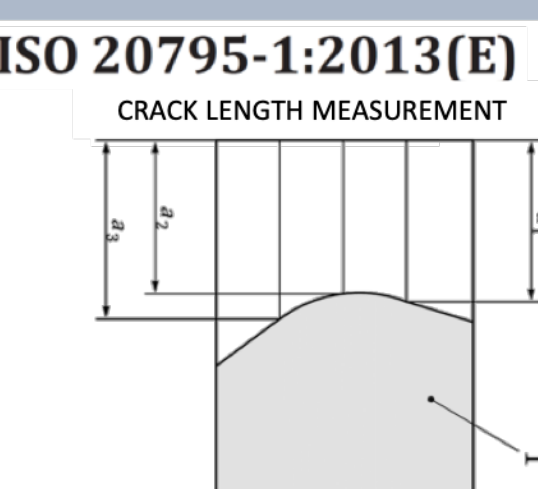
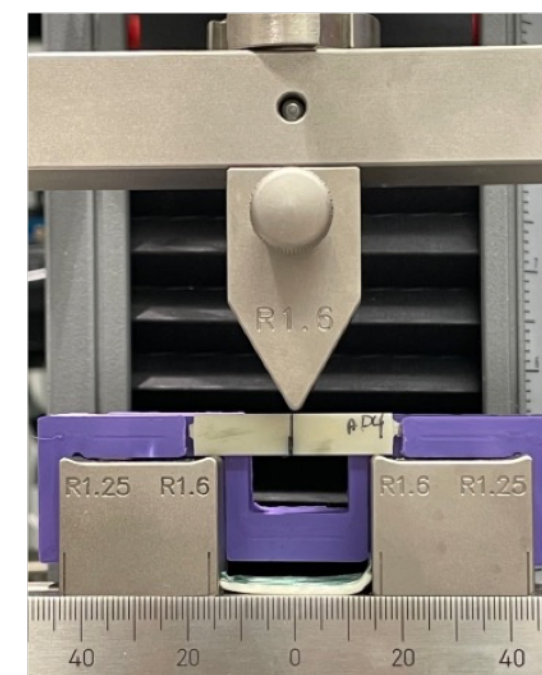
b) Specimen strip with the notch facing exactly opposite to the affected load plunger

Notch made using custom jig, finalized using fresh razor blade in glycerin.

Notch coated with India Ink for length identification

Instron 5544, loaded in 3-point jig at 1mm/min

Load at separation recorded



Screen print – microscopic image of crack length measurement

$$K_{\max} = \frac{f P_{\max} l_t}{(b_t h_t^{3/2})} \times \sqrt{10^{-3}} \text{ MPa m}^{1/2}$$

Maximum Stress Intensity Factor Calculation

1.9 MPa*m^{1/2} NEEDED TO PASS
(for an impact-resistant formulation product)

Specimens tested dry, and after 1 or 3 months storage in tap water, dark-stored at 37°C

Specimens tested in random order within each storage condition

Ten specimens per test condition

RESULTS

STATISTICAL ANALYSIS: 2-FACTOR ANOVA

Source of Variation	DF	SS	MS	F	P
MATERIAL	6	12.398	2.066	108.05	<0.001
STORAGE	2	1.482	0.741	38.747	<0.001
MATERIAL x STORAGE	12	0.259	0.0216	1.13	0.338
Residual	189	3.615	0.0191		
Total	209	17.754	0.0849		

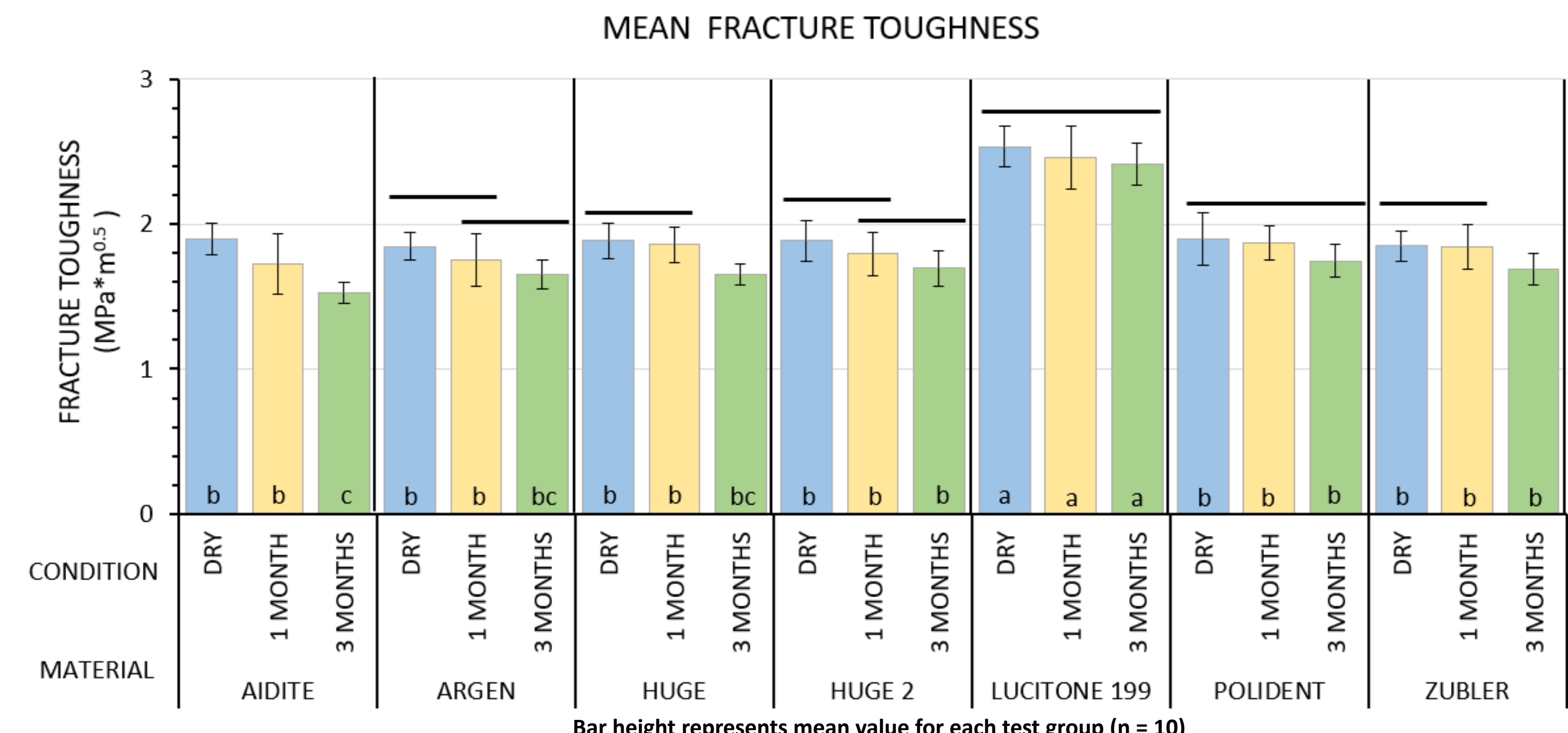
Difference in mean values among different levels of **MATERIAL** is greater than would be expected by chance after allowing for effects of differences in STORAGE. **There is a statistically significant difference (P = <0.001)**

Difference in mean values among different levels of **STORAGE** is greater than would be expected by chance after allowing for effects of differences in MATERIAL. **There is a statistically significant difference (P = <0.001)**

Effect of different levels of MATERIAL does not depend on what level of STORAGE is present. **There is not a statistically significant interaction between MATERIAL and STORAGE. (P = 0.338)**

Tukey post-hoc test to compare pair-wise mean values, all testing at pre-set alpha of 0.05

GRAPHICAL DEPICTION OF DATA



Bar height represents mean value for each test group (n = 10)

Vertical capped lines at end of each bar value represent +/- 1 standard deviation

WITHIN A MATERIAL: Values among columns designating “CONDITION” connected by a horizontal black bar are not significantly different

WITHIN A CONDITION: Values denoted using a similar lower-case letter are not significantly different

CONCLUSIONS

HYPOTHESIS 1 UPHELD

Fracture toughness of CONTROL denture base was significantly greater at each storage duration than all interim PMMA products – (however much more expensive)

HYPOTHESIS 2 PARTIALLY UPHELD

Control and Polident product fracture toughness not affected by water, all others were affected, thus no general statement can be made about monolithic PMMA materials

HYPOTHESIS 3 PARTIALLY UPHELD

Only within 3-month storage conditions were significant differences in fracture toughness noted among the interim PMMA products – (supports their short-term use)