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Effect of Printing Parameters and Storage Conditions on the Tensile Properties of Two Different Types of 3D-Printed Splint Materials

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Highlights : The printing layer thickness does not significantly influence tensile strength, whereas the type of material and storage conditions have a significant impact on tensile strength values

Objective

To evaluate the effect of printing layer thickness, and storage conditions on the tensile properties of two different types of 3D-printed splint materials.

Introduction

An occlusal splint is clinically approved for patients with a history of pain, diagnosed with temporomandibular disorder (TMDs), or exhibiting bruxism or clenching behavior.

Therefore, the stress tolerance ability of an occlusal splint material, which can withstand loads or stress before breaking from parafunctional forces, is one of its important properties.

Currently, the Additive Manufacturing (AM) or 3D printing technique has been used to fabricate occlusal splint devices due to its time efficiency and accuracy.

However, data on suitable printing parameter settings and storage conditions for 3D printing occlusal splint material to achieve tensile strength values are generally scarce.

Materials and Methods

Four 3D-printed materials were used in this study. The **Experimental group** is Splint Soft type and Hard type, and the **commercial group** is KeySplint Soft and Hard type (Keystone Industries).

Twenty-four dog-bone shape specimens for each material were designed following ASTM-638: Type-IV and printed by a DLP technology 3D printing machine (MAX, ASIGA). As shown in **Figures 1A and 1B**.

For each material, two printing layer thicknesses, 50 and 100 μm , were horizontally printed, followed by post-processing according to the manufacturer's instructions.

Six specimens of each group layer thickness were stored at room temperature (Dry condition), and another six specimens were submerged in 37°C water for one week and cooled down before being tested (Aging condition) as shown in **Figure 1C**.

Tensile strength test and elongation at break were performed and measured at room temperature using a Universal Testing Machine (5566A, Instron) with a 10 kN load cell at crosshead speed 5 mm/min until specimen rupture as shown in **Figure 1D**. The data were calculated and analyzed using the Linear Regression model. The levels were compared by post hoc Tukey test using JMP Pro 16.2.

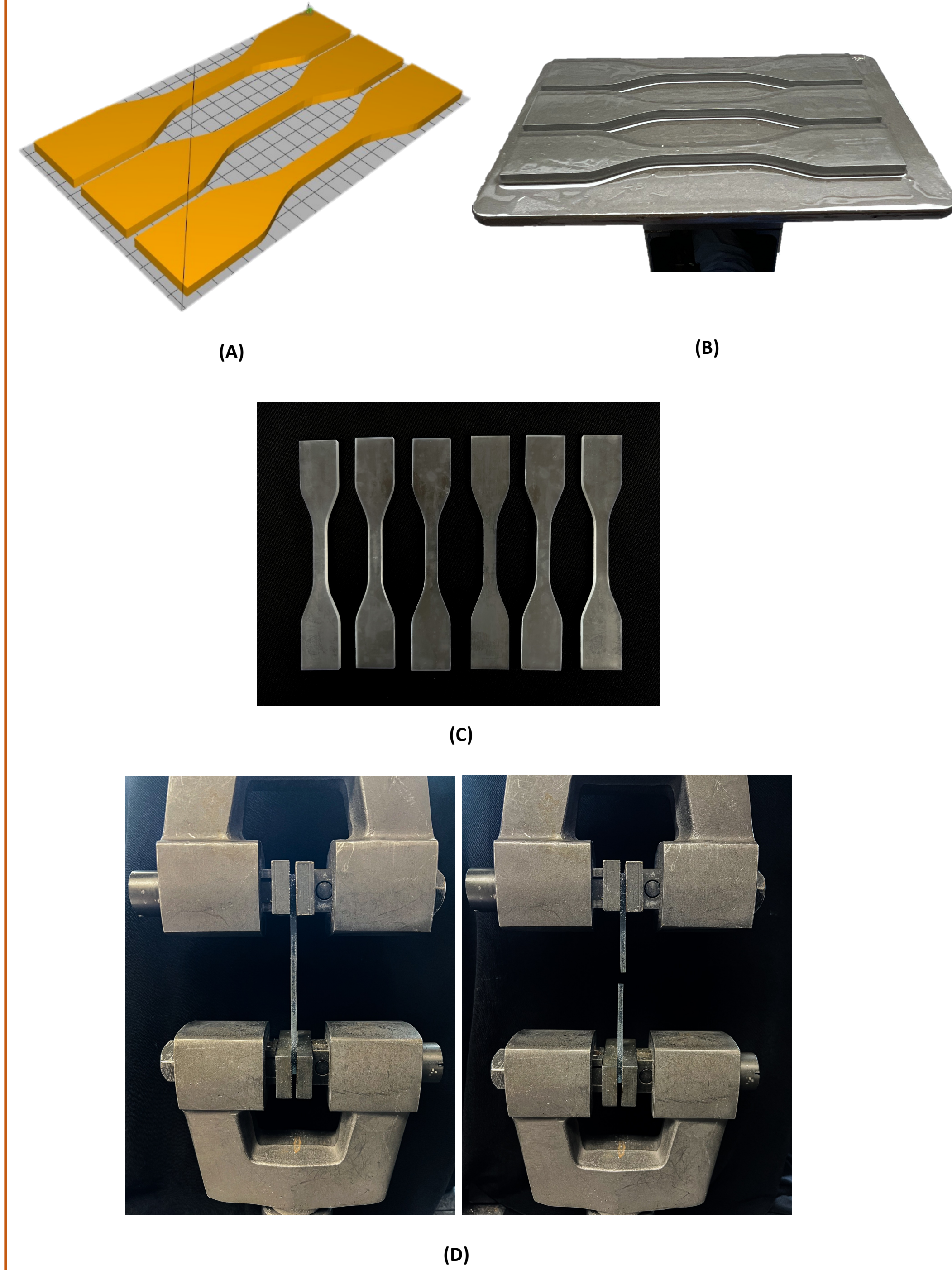


Figure 1. (A): Dog-bone shape specimens were designed followed ASTM-638: Type-IV, **(B):** Specimens were horizontally printed by a DLP technology 3D printing machine, **(C):** Specimens were prepared before being tested, **(D):** Dog-bone shape specimens were tested tensile strength and elongation at the break by Universal Testing Machine (5566A, Instron).

Results

KeySplint Hard showed the highest tensile strength value (56.58 ± 4.75 MPa), followed by the Experimental Splint Hard (30.28 ± 8.65 MPa), the KeySplint Soft (24.22 ± 4.74 MPa), and the Experimental Splint Soft (9.03 ± 6.65 MPa), respectively. ($P < 0.0001$), as shown in **Table 1**.

For printing layer thickness settings, printing at 50 μm and 100 μm layer thicknesses showed insignificantly different tensile strength values and elongation at break ($P \geq 0.0001$). However, the effect of aging conditions before being tested, the specimens stored in the dry condition showed a tensile strength value significantly higher than those stored in the aging condition ($P < 0.0001$), as shown in **Figure 3**.

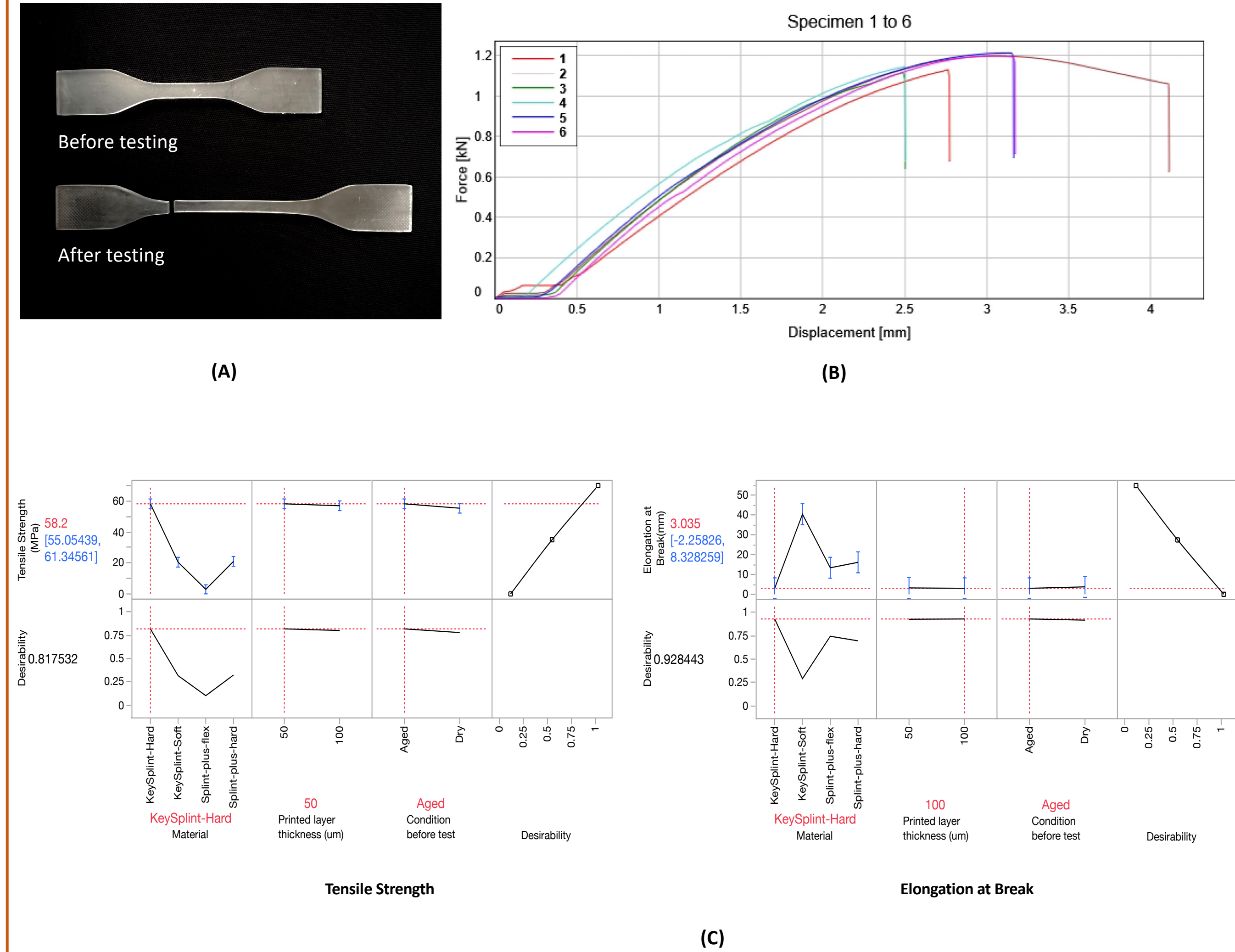


Figure 2: (A) : Specimens before and after being tested by Universal Testing Machine. **(B) :** Line graph between Force(kN) and Displacement(mm) of KeySplint Hard type, printed 100 μm layer thickness and stored in the aging condition before testing. **(C) :** Prediction Profiler of tensile strength and elongation at break.

Material	Storage condition	Layer thickness (μm)	N	Tensile Strength (MPa)		Significant level*	Elongation at Break (mm)		Significant level*
				Mean	Std Dev		Mean	Std Dev	
KeySplint Hard	Dry	50	6	55.38	5.49	A	4.05	1.76	A
		100	6	55.78	6.69	A	3.76	1.03	A
	Aging	50	6	58.20	3.96	A	3.24	0.66	A
		100	6	56.96	2.69	A	3.04	0.61	A
Experimental Splint Hard	Dry	50	6	37.11	4.55	B	11.4	4.48	A B
		100	6	38.66	3.18	B	8.44	4.33	A B
	Aging	50	6	21.02	3.81	C D E	15.5	5.25	A B
		100	6	24.32	3.58	C	16.2	2.89	A B C
KeySplint Soft	Dry	50	6	24.61	5.02	C	29.4	12.0	D
		100	6	27.84	4.03	C	35.4	7.84	D
	Aging	50	6	20.51	4.28	C D E	39.1	9.04	D
		100	6	23.73	3.02	C D	40.5	8.27	D
Experimental Splint Soft	Dry	50	6	14.80	2.56	E	29.9	6.32	D
		100	6	15.89	2.61	D E	29.0	11.2	D
	Aging	50	6	2.98	0.55	F	17.4	3.30	B C
		100	6	2.50	0.58	F	13.4	3.56	A B

*Levels not connected by the same letter are significantly different.

Table 1: The mean and standard deviation of tensile strength value (MPa) and elongation at break (mm) of 3D printed splint hard and soft type materials classified by storage conditions and layer thicknesses.

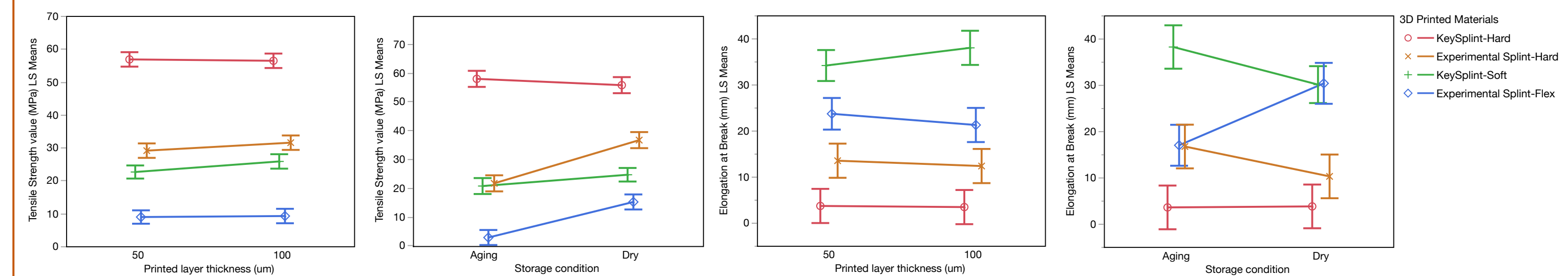


Figure 3: Schemes of Least Squares Mean Plot of tensile strength value and elongation at break of four different 3D printed splint materials with printed layer thicknesses and storage conditions.

Conclusions

1. The printing layer thicknesses of 50 and 100 μm insignificantly affected the tensile strength values and elongation at break.
2. The storage conditions, aging, and dry conditions significantly affected the tensile strength values.
3. KeySplint Hard type showed the highest tensile strength value, followed by Experimental Splint hard type, KeySplint Soft type, and Experimental Splint soft type, respectively.

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