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Analysis of Platsil Gel-10 Silicone-based Coating Applied to Polylactic Acid Hand Prosthesis

Grecia Casco[1], Alex Santos[2]
Faculty Mentor: Manuel Adalid Gamero-V[3]
[1,2,3]UNITEC, Honduras, Grecia1234@unitec.edu, manuelgamero@unitec.edu

***Abstract*—This study explores the application of a Platsil Gel-10 silicone coating to a polylactic acid (PLA) hand prosthesis fabricated through fused deposition modeling (FDM). The objective was to evaluate both thermal behavior and aesthetic performance of the coated structure under practical stress conditions. Thermal characterization was conducted on individual prosthetic fingers using K-type thermocouples during controlled and high-intensity heat exposure. Temperature progression followed a largely linear trend across trials, suggesting predictable heat transfer behavior and no immediate signs of material instability. Beyond thermal response, the surface and visual qualities of the silicone layer were examined. Color matching was assessed against a reference skin tone, and surface morphology was inspected using microphotography. The coating demonstrated detailed reproduction of dermal features, including fine ridges and pores, while adhesion testing showed no early delamination under cyclic loading. Tactile evaluation indicated a compliant surface texture comparable to soft tissue. Although initial performance was encouraging, limitations were observed in color retention and in the projected durability of the coating under prolonged mechanical wear. These findings highlight areas for material formulation refinement. Overall, the results indicate that silicone-coated PLA structures may provide a cost-accessible pathway for improving the cosmetic realism of upper-limb prostheses, particularly in settings where manufacturing resources are constrained.**

***Index Terms*—Silicone elastomers; PLA prosthetics; aesthetic coating; fused deposition modeling; synthetic skin.**

I. Introduction

Upper-limb amputation involves consequences that extend beyond the immediate loss of anatomical structure. In many cases, the effects are evident in professional activity, personal identity, and patterns of social interaction. For this reason, the development of hand prostheses has increasingly moved past purely mechanical objectives. Earlier designs were largely centered on restoring grasp and movement. Clinical follow-up and patient feedback, however, have demonstrated that functional performance alone does not determine long-term use. Several reports identify dissatisfaction with cosmetic appearance as a significant contributor to prosthesis abandonment, even when mechanical function is preserved [1]. These findings suggest that aesthetic integration should be considered alongside biomechanics in contemporary device design. Fig. 1 provides a visual overview of the broader landscape of upper-limb prosthetics and the role that surface aesthetics plays within it, situating the present work within current trends in rehabilitation engineering.

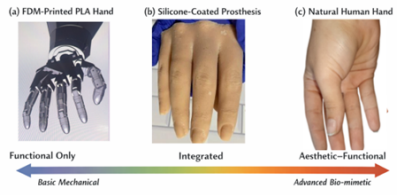

Fig. 1. *Overview of the prosthetic hand fabrication approach: from FDM-printed PLA substrate to silicone-coated aesthetic prototype.*

Within this framework, fused deposition modeling (FDM) with polylactic acid has become a practical fabrication option. PLA is widely used in biomedical prototyping due to its recognized biocompatibility, dimensional stability, and compatibility with affordable desktop printing systems. These characteristics have contributed to its widespread adoption in open-source prosthetic development initiatives. Nevertheless, when used as an external surface material, PLA presents a clear limitation. In its uncoated state, the material lacks the visual and tactile properties associated with human skin, which directly affects perceived realism and user acceptance [2,3].

Among the available coating materials, silicone elastomers are frequently considered because of their chemical and mechanical stability. The siloxane (Si-O-Si) backbone contributes to chemical inertness and allows the material to maintain dimensional consistency over a broad temperature range. In addition, many medical-grade silicones are suitable for prolonged skin contact, a requirement that limits the number of viable polymer alternatives.

From an aesthetic standpoint, silicones can be pigmented using cosmetic-grade oxide powders to approximate specific skin tones within the CIE L*a*b* color space. They can also be cast in molds capable of capturing fine surface detail, enabling reproduction of dermal features such as fingerprint ridges and pore patterns. While other coating systems exist, few offer this combination of stability, processability, and visual realism at a similar material cost [2,8].

Surface microtopography has implications beyond appearance alone. Recent work has shown that the roughness profile of a prosthetic surface modulates local biological interactions at the device–skin interface, including protein adsorption patterns

and the inflammatory response of peri-prosthetic tissue [5]. This finding reinforces the need to actively control the surface condition of FDM-printed substrates before coating, since the characteristic layer-by-layer striation produced by FDM printing can propagate through a silicone layer if not adequately reduced during post-processing. Efforts to develop synthetic skin substitutes can be traced back several decades. In the 1970s, polyurethane-based prototypes developed at Harvard demonstrated that engineered polymer matrices could function as tissue surrogates under controlled conditions [6]. During the following decade, materials such as polycaprolactone and other aliphatic polyesters (including PLA, PGA, and their copolymers) entered clinical research as biocompatible scaffold candidates with adjustable mechanical properties [7,12]. More recently, the most significant shift has occurred not only in material selection but in fabrication methodology. The integration of 3D scanning, computer-aided design, and additive manufacturing has made it possible to reproduce patient-specific geometries with substantially reduced production time and cost compared to traditional prosthetic workflows [4].

Silicone formulation research has, in parallel, addressed the material's known limitations. $Nano-TiO_2$ reinforcement has been shown to improve hardness, tensile strength, and colorimetric stability without compromising biocompatibility [8]. Microwave-assisted silicone/PMMA blending offers improved mechanical performance and shorter processing times [9]. At the other end of the spectrum, thiol-ene surface chemistry provides a route to grafting functional groups directly onto the silicone network, substantially improving resistance to microbial attachment and chemical degradation [11]. These developments collectively expand the design space for clinically viable silicone coatings.

Acceptance data add further urgency to the problem. More than 70 % of upper-limb prosthesis users report dissatisfaction with their devices, and more than half ultimately abandon them; in comparative assessments, silicone prosthetic systems consistently score highest when evaluators rank appearance, haptic quality, and perceived naturalness [11, 13]. ISO 10328 and ISO 22523 define the structural testing and terminology frameworks within which any new prosthetic material system must be validated [7], and both standards implicitly acknowledge aesthetics as a component of overall device acceptability. Within this context, the present work examines the use of Platsil Gel-10 as a pigmented silicone coating applied to an FDM-printed PLA hand prosthesis through plaster-mold casting. The study considers several aspects of performance. Thermal behavior of the coated structure was analyzed under controlled conditions, while aesthetic fidelity was assessed through colorimetric measurements and microphotographic surface inspection. Adhesion stability following mechanical cycling and qualitative tactile response were also evaluated.

The objective of combining these analyses was to determine whether this fabrication strategy satisfies the multi-scale design parameters [13], particularly in terms of chromatic accuracy, surface texture reproduction, and mechanical compliance. An additional consideration was whether these criteria could be achieved within cost limitations typical of resource-constrained clinical settings. The broader context for this work is established by two converging trends in the prosthetics literature. First, the acceptance data cited above make clear that aesthetics is not peripheral to prosthetic function but central to it: a device that users wear consistently is a device that works. Second, the bioinspired design framework formalizes the multi-scale criteria that a prosthetic skin analog must satisfy, specifying chromatic fidelity at the macroscopic scale, texture replication at the mesoscopic scale, and mechanical compliance at the microscale. [13] These criteria provide the evaluative structure for the results reported in the following sections.

II. Methods and Materials

The experimental process was organized in four main stages. First, the prosthetic hand geometry was finalized and fabricated using fused deposition modeling. This was followed by preparation of the plaster mold and subsequent casting of the silicone layer. After curing, the coated assembly underwent thermal characterization. The final phase involved evaluation of aesthetic properties and functional performance. Platsil Gel-10, a platinum-catalyzed, two-component addition-cure silicone, was selected as the coating material. The choice was based primarily on its Shore A hardness, which approximates the compliance of human skin, as well as its ability to accept pigmentation across a wide color range. The material has also been reported in maxillofacial prosthetic applications, supporting its suitability for extended skin contact [9]. Figure 2 provides an overview of the experimental sequence, and each phase is detailed in the sections that follow.

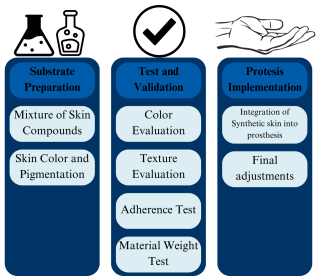

Fig. 2. *Overview of the prosthetic hand fabrication approach: from FDM-printed PLA substrate to silicone-coated aesthetic prototype.*

The evaluation included comprehensive testing to assess adhesion, durability, and color stability of the silicone coating. Additionally, considering the challenges posed by color reproduction in 3D manufacturing for soft tissue prostheses, special attention was given to combining color and mechanical properties for 3D printing, with the objective of a natural and aesthetically pleasing appearance. The results of these evaluations provide valuable insight into the potential of silicone-based polymer coatings as a promising approach to improving the aesthetic quality and realism of the prosthetic hand, contributing to its overall acceptance and functionality.

A. Prosthesis Design and FDM Fabrication

The development of the hand prosthesis prototype was carried out using advanced modeling software, specifically SolidWorks, recognized for its three-dimensional modeling capabilities. The hand prototype extends to the wrist and was scaled to ensure accurate and proportional representation of human dimensions. The prototype was printed using an Ender 3 V2 3D printer. The selected material for printing was polylactic acid (PLA), chosen for its biocompatibility and suitability for 3D printing technologies, thereby facilitating the production of a device that is both functional and tailored to the specific needs of the prosthesis. The choice of PLA+ over thermoplastic polyurethane was deliberate: while TPU offers superior flexibility, its lower dimensional rigidity introduces geometric variability that compromises the accuracy of mold transfer and reduces consistency in silicone-skin fit. After printing, all surfaces were sanded progressively to reduce the layer-by-layer striation characteristic of FDM deposition, which otherwise propagates through the silicone layer and degrades texture replication fidelity.

B. Silicone Skin Preparation

A negative plaster mold of the printed hand was cast using Plaster of Paris at a water-to-plaster ratio of 375 mL: 500 g. Once cured, Platsil Gel-10 components A and B were combined at a 1:1 volumetric ratio. Pigmentation was introduced before mixing by blending cosmetic-grade oxide powder (2 g) and silicone pigment (5 mL) into the liquid silicone, adjusting proportions iteratively against a reference skin-tone swatch until a satisfactory visual match was achieved. The pigmented mixture was poured into the mold, de-aired for 5 minutes, and allowed to cure at ambient temperature. The full bill of materials is presented in Table I.

TABLE I
UTILIZED MATERIALS

Silicon Mix	
Material	Quantity
Platsil Part A	60 milliliters
Platsil Part B	60 milliliters
Silicon pigment	5 milliliters
Color powder	2 milliliters
Plaster Mix	
Plaster	500 grams
Water	375 milliliters

C. Thermal Conductivity Evaluation

Each finger (index, middle, ring, little, and thumb) was subjected individually to a controlled and constant heat source under two distinct intensity regimes. In the controlled-conditioning protocol, a low-intensity heat source was applied at approximately 22 degrees C ambient temperature. In the high-intensity protocol, the digit was exposed to direct flame. Temperature at the surface of each digit was recorded continuously at 1-second intervals using a K-type thermocouple probe in direct contact with the silicone coating, producing a complete time-temperature curve for each test. An infrared thermographic camera provided spatial validation of thermocouple readings and confirmed the absence of anomalous hot spots. Each test was terminated at the onset of visible material change, which is why exposure durations differ between digits. Because of this protocol design, inter-digit comparisons in this study reflect relative thermal accumulation expressed as the delta T between initial and maximum temperature, not time-normalized thermal conductivity rates. The principal variable of interest was the linearity of the temperature-time curve, which serves as a proxy for material homogeneity and thermal conductivity stability. (Fig. 3)

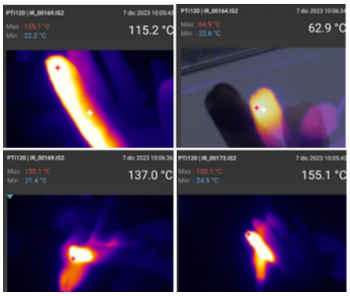

Fig. 3. *Experimental setup for thermal characterization of the prosthetic fingers using K-type thermocouple probes.*

D. Experimental Setup

Each finger of the prosthesis (index, middle, ring, little, and thumb) was individually subjected to a controlled and constant heat source. The temperatures reached by each finger were recorded at regular intervals using precise thermocouple sensors to map thermal evolution over time.
Temperature was recorded in degrees Celsius, and data were plotted as a function of time to analyze thermal trends. Special attention was given to the linearity of the thermal response, which indicates stable and predictable thermal conductivity of the material. (Fig. 4).

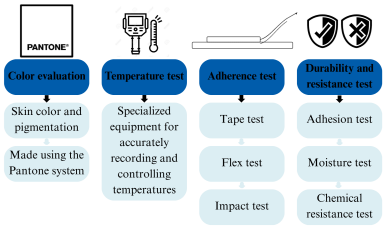

Fig. 4. *Visual representation of the validation and tests.*

E. Colorimetric Evaluation

Color fidelity was assessed by comparing each silicone sample against physical Pantone Matching System (PMS)

swatches under standardized neutral-white illumination. Five sample configurations were evaluated: two flat-surface samples (A and B) produced to verify consistency of the pigmentation protocol, and three anatomical samples (Finger 1A, Finger 2A, and Hand A) representing the coating as applied to the prosthesis geometry. Three independent observers recorded the primary PMS match, any secondary chromatic variation observed, and an overall homogeneity rating. Results are reported in Table IV.

F. Aesthetic and Functional Evaluation

Aesthetic assessment was structured around four criteria: color fidelity, surface texture replication, adhesion integrity, and tactile response. Color fidelity was evaluated by placing the coated prosthesis alongside a standardized reference skin-tone sample under controlled laboratory illumination and recording observer-rated similarity. Surface texture was assessed using microphotography at 10x magnification, with image parameters (contrast, brightness, resolution, and noise) adjusted in Adobe Photoshop to maximize feature visibility; images were compared against photographs of the corresponding region of a natural hand. Adhesion integrity was assessed through peel and manual flex cycling. Tactile response was evaluated by manual compression and informal user feedback, scored against the sensation reported for the reference skin. A summary of criteria, methods, and outcomes is provided in Table II.

TABLE II
AESTHETIC AND FUNCTIONAL EVALUATION RESULTS

Criterion	Assessment method
Color fidelity	Visual comparison vs. skin reference
Surface texture	Microphotographic analysis (10x)
Adhesion to PLA	Peel and flex cycling
Tactile response	Manual compression/user feedback
Long-term durability	Accelerated wear simulation

G. Selection and Preparation of Materials

A negative plaster mold of the printed hand was produced using Plaster of Paris at a fixed water-to-plaster ratio of 375 mL to 500 g. This ratio was selected to balance working time against final mold hardness. Platsil Gel-10 parts A and B were combined at a 1:1 volumetric ratio. Before mixing, cosmetic oxide powder (2 g) and silicone pigment (5 mL) were incorporated into part A and adjusted iteratively against Pantone reference swatches under neutral illumination until a satisfactory visual match to the target skin tone was achieved. The combined mixture was poured into the mold, de-aired manually for approximately 5 minutes to eliminate visible entrapped bubbles and allowed to cure at ambient temperature. Once cured, the silicone skin was carefully removed from the mold and fitted over the printed PLA hand.

H. Adhesion and Tactile Sensation Tests

Seven test modalities were applied to the coated prosthesis to evaluate mechanical and environmental durability. Tape-peel adhesion testing used high-tack adhesive tape applied firmly to the coated surface and removed with a steady, controlled motion; the criterion was absence of delamination, edge lifting, or adhesive residue transfer. Flex cycling subjected the prosthesis to repeated peel-and-flex movements calibrated to the anatomical range of motion of a human finger joint; the coating was inspected after each cycle for cracking or separation. Impact resistance was evaluated by applying free-fall weights to the coated surface from a fixed height. Load-bearing capacity was assessed using an incremental static load from 100 to 200 grams applied to the prosthetic hand. Abrasion resistance was tested using standardized sandpaper under uniform applied pressure for a fixed number of cycles. Moisture resistance involved prolonged submersion of the coated prosthesis in water, followed by drying and re-evaluation of elasticity and surface integrity. Chemical resistance was assessed by immersing the prosthesis in solutions representing disinfectants, skin oils, and cosmetic compounds commonly encountered in daily use. All tests are compiled in Table V. These tests constituted a critical component in evaluating how effectively the synthetic skin bonded to the prosthesis. Proper bonding between materials is essential when adhering synthetic skin to prosthetic structures.[10]

I. Surface Texture Evaluation

Microphotographic documentation was performed using the "Magnifying Glass + Flashlight" mobile application at 10x magnification. Images were post-processed in Adobe Photoshop with uniform adjustment of contrast, brightness, noise reduction, and resolution enhancement applied identically across all samples to ensure comparability. Two finger configurations (Finger 1A and Finger 2A) were selected for comparative analysis; their surfaces were examined against reference photographs of a natural human hand captured under the same lighting conditions.

J. Integration of Results into Prosthesis Design

Based on the obtained results, adjustments were made to the design and composition of both the prosthesis and the synthetic skin to optimize thermal and aesthetic performance. This iterative process allowed refinement of the prosthesis, improving both functionality and appearance.

III. RESULTS

A. Thermal Response of the Prosthetic Fingers

Table III presents the raw thermal data recorded for each finger under both exposure regimes. Across all conditions, the temperature–time relationship was linear throughout the exposure window, indicating uniform thermal diffusivity within the PLA–silicone bilayer and confirming the absence of localized defects or voids in the printed and coated structure. Under controlled conditions, the index digit accumulated the greatest temperature rise while showing no visible material damage,

establishing approximately 115 °C as the short-term thermal tolerance threshold for the Platsil Gel-10 coating on a PLA substrate. The ring digit exhibited localized micro-blistering at a maximum temperature of only 64.9 °C after 2 s of exposure, indicating that sustained moderate-temperature exposure can cause surface-level damage at lower thresholds than brief high-temperature pulses. The little finger reached 37.6 °C in only 1 s, consistent with the expectation that reduced silicone volume lowers thermal mass and accelerates surface temperature rise. Under high-intensity conditions, the index digit reached 155.1 °C with ignition initiating at t = 8 s and progressive layer separation thereafter, while the thumb reached 126.3 °C and showed delamination and surface discoloration. Together these observations identify approximately 126 °C as the onset of structural failure under direct flame. Infrared thermography confirmed the thermocouple readings and showed no localized temperature anomalies inconsistent with uniform heat diffusion through the material cross-section.

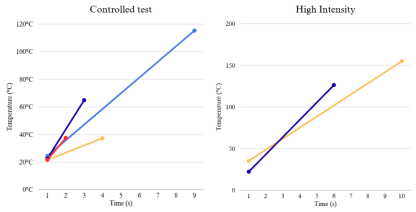

Fig. 5. *Time-temperature profiles for each prosthetic digit under controlled conditions (left) and high-intensity flame exposure (right). Dashed line marks T max; vertical line in the right panel marks ignition onset at t = 8 s.*

TABLE III
TEMPERATURE TEST

Fire Resistance Tests Under Controlled Conditions			
Test	Initial Temperature	Exposure time	Maximum temperature reached
Index	24.5 °C	8 segs	115.3 °C
Middle	21.6 °C	3 segs	37.4 °C
Ring	22.6 °C	2 segs	64.9 °C
Little finger	21.7 °C	1 segs	37.6 °C
Fire Resistance Tests Under High Intensity Conditions			
Test	Initial Temperature	Exposure time	Maximum Temperature reached
Index	35.2 °C	10 segs	155.1
Thumb	22.2 °C	6 segs	126.3

Fig. 6 translates these data into ΔT values ($T_{\max} - T_0$) for each finger under both regimes, making the exposure-dependent thermal accumulation directly visible. Under controlled conditions, the index finger accumulated the greatest ΔT (90.8 °C), reflecting its comparatively larger thermal mass. Under high-intensity conditions, the index finger again dominated (ΔT = 119.9 °C), followed by the thumb (104.1 °C). The middle and little fingers, with their shorter exposure times, showed considerably lower accumulation under both regimes, consistent with the lower thermal energy delivered during the test.

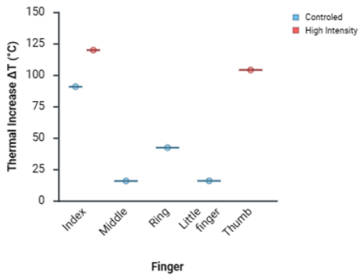

Fig. 6. *Thermal accumulation ($\Delta T = T_{\max} - T_0$) per prosthetic finger under controlled (blue) and high-intensity (red) heat exposure conditions.*

These results are particularly relevant from a safety standpoint: the linear response means that the thermal behavior of the composite is predictable and can be modeled, which is a prerequisite for any device that will be in prolonged contact with the human body. No non-linear transients were observed, and no evidence of delamination or structural change in the silicone layer was apparent after thermal testing.

B. Colorimetric Evaluation

Results of the Pantone PMS comparison across all five sample configurations confirmed that the pigmentation protocol can achieve consistent color output under controlled mixing conditions: Sample B, which showed no secondary chromatic deviation, demonstrated that the formulation can produce a homogeneous, stable skin tone when the mixing sequence is followed carefully. Sample A showed a secondary tone, identified as PMS #C6B8C5, alongside the primary match of PMS #D3AEA6, a divergence attributed to incomplete oxide powder dispersion prior to mixing rather than to a material limitation of the silicone system. Among the anatomical samples, Finger 2A and Hand A produced the strongest results, with near-exact PMS correspondence and no secondary color variation observed. These samples represented the final, iteratively refined mixing protocol, and their performance confirms that consistent colorimetric fidelity is achievable with this system across both light and dark reference skin tones. Finger 1A showed a slight reflectance discrepancy relative to the PMS swatch, an effect attributed to surface microtopography scattering incident light differently from the flat reference surface rather than to a genuine pigmentation error. (Table IV)

C. Surface Texture Evaluation

Microphotographic comparison between the two finger samples revealed a meaningful difference in texture replication quality that correlates with identifiable process parameters. Finger 1A, under initial visual inspection, appeared to show

TABLE IV
COLORIMETRIC EVALUATION BY PANTONE MATCHING SYSTEM (PMS)

Sample	Primary PMS match	Secondary tone
Sample A	PMS #D3AEA6	#C6B8C5
Sample B	PMS #E4CED1	Minor drift
Finger 1A	PMS #9B7B64	Slight deviation
Finger 2A	PMS #4E3B35	None noted
Hand A	PMS #D0AF7C	None noted

inadequate texture replication. Subsequent microphotographic analysis, however, confirmed the presence of subtle dermal features including shallow ridge patterns and pore openings that were not visible to the naked eye, indicating that texture transfer did occur but at a depth below the threshold of unaided vision. This result is consistent with reduced mold-contact pressure or a thinner silicone layer in the 1A configuration. Finger 2A showed pronounced, well-defined wrinkle topography visible even without magnification, with microphotographic analysis confirming fidelity superior to 1A across all assessed features including ridge depth, pore definition, and surface continuity. The progression from 1A to 2A demonstrates that texture transfer in mold-cast silicone is sensitive to silicone volume and mold-contact conditions, and that this quality parameter can be improved systematically through process adjustment without changing the material formulation. Fig. 7 presents the three-panel surface comparison.

Fig. 7. *Microphotographic surface comparison: (a) uncoated PLA substrate, (b) Platsil Gel-10 silicone coating, and (c) reference human skin. Scale bar: 1 mm.*

D. Adhesion and Durability

All seven test modalities produced passing outcomes. In the tape-peel test, no delamination was detected after removal of high-tack tape, and the tape surface showed no transferred adhesive or silicone material, indicating strong interfacial bonding between the cured silicone layer and the PLA substrate. Flex cycling demonstrated full elastic recovery after repeated deformation, with no crack initiation or edge separation observed at any point during the cycle sequence. Impact testing produced no fracture, deformation, or surface disruption.

Load-bearing evaluation confirmed structural stability up to 200 g without detectable strain or deformation in the silicone skin. Abrasion testing with standardized sandpaper produced no measurable thinning, color loss, or texture change, suggesting that the outer silicone surface maintains mechanical integrity under friction conditions representative of normal daily contact. Moisture immersion produced no swelling, deformation, or elastic property change after prolonged exposure and subsequent drying. Chemical immersion in disinfectants, skin oils, and cosmetic compounds produced no surface deterioration or discoloration, which has practical significance given that prosthesis cleaning with alcohol-based agents is a routine activity for many users. The complete test matrix is presented in Table V.

TABLE V
ADHESION AND DURABILITY TEST RESULTS

Test	Protocol	Key findings	Outcome
Tape peel	High-tack tape applied to coated surface; removed with steady controlled motion	No delamination; no adhesive residue on tape; no edge lifting detected.	Pass
Flex cycling	Repeated peel-and-flex cycles at anatomical joint range of motion	Full elastic recovery; no cracking, separation, or morphological change after cycling.	Pass
Impact resistance	Free-fall weights applied to coated surface at controlled drop height	No fracture, tearing, or permanent deformation; surface texture unchange.	Pass
Load bearing	Incremental static load 100 to 200 g applied to prosthetic hand	Structural stability maintained at 200 g; no deformation or stress signs.	Pass
Abrasion	Standardized sandpaper cycles with uniform pressure	No measurable thinning, layer separation, color loss, or texture degradation.	Pass
Moisture immersion	Prolonged water submersion; dried and re-evaluated	Elasticity and structure fully retained; no swelling, deformation, or discoloration.	Pass
Chemical resistance	Immersion in disinfectants, oils, and cosmetic compounds	No surface deterioration, color change, or structural degradation observed.	Pass

Adhesion testing showed no delamination or edge lifting after initial peel and flex cycles, and the silicone layer returned to its original position without a visible crease after flexion. Tactile assessment indicated a compliance response broadly consistent with natural skin under the compressive loads applied, with no sensation of hard substrate breakthrough reported by evaluators. (Fig. 8)

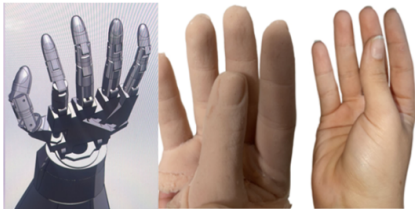

Fig. 8. . *Side-by-side comparison of the SolidWorks model (left), silicone-coated PLA prosthetic hand (middle), and a natural human hand (right) under standardized lighting.*

Areas for improvement were identified in relation to long-term performance: after extended simulated wear, minor surface tackiness and slight pigment migration were observed at high-contact zones such as the finger pads and palm. These findings are consistent with established failure modes of unmodified silicone formulations under cyclic loading and perspiration exposure [8].

IV. Discussion

The linear thermal behavior observed across all prosthetic fingers (Fig. 6, Table III) suggests that the PLA-silicone assembly functions as a relatively uniform composite under the tested conditions. From a materials standpoint, this consistency is encouraging. It also indicates that heat accumulation can be modeled with reasonable confidence. In practical terms, this allows design parameters to be adjusted, for example by defining a maximum permissible surface temperature and estimating the exposure duration required to reach that value for different finger geometries. Such predictability is important when considering safety validation for body-worn devices and represents a necessary step toward clinical applicability. With respect to surface realism, the mold-casting procedure played a central role in achieving the texture detail shown in Fig. 6. Because the liquid silicone cures in direct contact with a plaster impression of the printed substrate, fine surface features are transferred mechanically to the elastomer layer. Application methods such as spraying or brushing do not offer comparable spatial resolution. The additional processing steps, including mold preparation, air removal, and curing control, introduce complexity and require calibration to obtain consistent wall thickness. However, the resulting contrast between the striated FDM surface and the silicone layer reproduced in panels (a) and (b) indicates that the added effort is justified. The durability concerns noted during extended wear simulation, particularly localized tackiness and pigment migration in high-contact regions, are consistent with known limitations of addition-cure silicones [8,9]. Addressing these issues will likely require incremental material modification. For example, low-percentage $nano - TiO_2$ reinforcement at concentrations between 0.5 and 2.0 wt% has been associated with improved tensile behavior and enhanced UV-related color stability in maxillofacial silicone systems [8]. Increasing interfacial adhesion may also be beneficial. Surface activation of the PLA substrate through oxygen plasma or corona treatment would be expected to raise surface energy and reduce the probability of progressive delamination at the PLA–silicone interface. In addition, surface grafting strategies such as thiol-ene functionalization could improve resistance to perspiration uptake and microbial accumulation [11] in medical-grade silicone applications. Overall, the present findings indicate that mold-cast Platsil Gel-10 provides a feasible baseline approach for improving the aesthetic quality of FDM-printed PLA prostheses. While durability enhancements remain necessary, the material and processing costs are relatively low compared to the visual and tactile gains achieved. This balance is consistent with the accessibility objectives that underpin the adoption of FDM-based fabrication strategies.

V. Conclusions

Thermal testing showed a mainly linear relationship between temperature and time in all five prosthetic fingers, both under controlled conditions and during high-intensity exposure. This pattern indicates consistent behavior across the PLA-silicone assembly. The observed response suggests that heat transfer within the composite is predictable, which is relevant from a safety and design standpoint. Microphotographic inspection of the coated surface showed that the mold-casting approach preserved fine dermal details. Features such as fingerprint ridge patterns, pore openings, and wrinkle contours were clearly visible in the replicated layer. In contrast, direct coating techniques did not reproduce these structures at comparable resolution, as shown in Fig. 7. Colorimetric evaluation using the Pantone Matching System confirmed near-exact skin-tone correspondence across five sample configurations spanning light to dark reference tones. Pigment mixing homogeneity is the primary determinant of colorimetric consistency, and the formulation can produce stable, reproducible color when the mixing protocol is done with the appropriate ratios. Long-term durability remains the principal limitation: surface tackiness and pigment migration at high-contact zones were observed during tests after extended wear simulation. Nano-filler reinforcement, PLA surface activation before coating, and thiol-ene surface grafting are identified as the most promising strategies for improvement. The fabrication process combines FDM printing with plaster mold casting and subsequent application of pigmented silicone. Each of these steps can be implemented using affordable materials and equipment. For this reason, the approach may be suitable for rehabilitation settings in which commercially manufactured silicone prostheses are financially inaccessible. UV-induced color drift and long-term mechanical wear durability are iden-

tified as the priority targets for second-generation formulation development.

VI. Limitations and recomendations

Beyond the durability issues already noted, the present study is limited in scope in several respects. The thermal evaluation was conducted under bench-top conditions and did not replicate the complex heat flux patterns that arise from body-worn use or environmental temperature cycling. Future work should include in-situ thermal monitoring during simulated daily-use protocols. The aesthetic evaluation, while multi-criteria, relied on observer judgment and informal tactile feedback rather than standardized psychophysical instruments; quantitative CIE L*a*b* measurements and validated haptic assessment tools should be incorporated in subsequent studies. adhesion testing was conducted over a limited cycle count; long-term fatigue performance over thousands of flex cycles under realistic perspiration and mechanical load conditions remains uncharacterized. This study did not include UV exposure trials, which are needed to quantify the color drift reported for unmodified silicone systems in the literature [8]. The most practically important limitation is the absence of evaluation by actual prosthesis users. The entire evaluation was conducted in a laboratory setting with observer-rated outcomes; no amputee users or certified prosthetists participated. A follow-up study should incorporate a structured user perception protocol, using validated instruments such as the Trinity Amputation and Prosthesis Experience Scales aesthetic satisfaction subscale, with a minimum participant sample sufficient for statistical analysis of acceptance outcomes. On the formulation side, three improvement strategies are supported by existing evidence and should be prioritized. Surface activation of the PLA substrate by oxygen plasma or corona discharge prior to coating would convert part of the silicone-PLA interface from mechanical to chemical bonding, increasing delamination resistance under dynamic loading. Nano-TiO2 reinforcement at concentrations in the range of 0.5 to 2.0 weight percent has been reported to improve tensile strength and UV color stability in maxillofacial silicone without compromising biocompatibility [5]. Thiol-ene surface grafting onto the cured silicone exterior can introduce cross-linked functional groups that resist perspiration absorption and reduce microbial colonization, a mechanism documented in the literature for medical-grade silicone substrates [11]. Systematic evaluation of these strategies against the baseline characterized here would constitute a complete second-generation coating development program. Advancing this approach would likely benefit from collaboration with materials scientists experienced in silicone surface engineering, particularly if the objective is to move toward a clinically viable second-generation coating system. Despite aesthetic improvements, durability and flexibility challenges remain. A more integrated approach between synthetic skin and prosthetic technology is recommended to balance aesthetics and functionality. The methodology that covalently bonds non-toxic polymeric materials to medical-grade silicone using thiol-ene chemistry presents an interesting opportunity for further exploration. By leveraging this method, it may be possible to improve long-term durability and mechanical resistance of silicone polymer coatings while offering a versatile method for grafting monomers with diverse functionalities. This innovative technique has the potential to enhance prosthetic hand coating performance, extending its lifespan and improving overall quality. [11]

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