

Mechanical Screening of VPP Photopolymers Beyond Shore Hardness

A hierarchical comparison of hardness, modulus and structural behaviour with application-specific validation

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Highlights

- Shore hardness, Young's modulus and observed structural response answer different mechanical questions and are not interchangeable.
- The Structured Mechanical Screening Protocol narrows candidates before full characterization; it is not a clinical or regulatory validation method.
- Test results depend on specimen geometry, orientation, cleaning, post-cure, conditioning, loading mode and environment.
- The Wedge Method can provide a qualitative comparative observation under a fixed protocol but does not measure modulus, toughness or strength.
- Application-specific standards and acceptance criteria must be selected within their exact product scope.

Abstract

Shore hardness alone does not describe bulk stiffness, fracture response, impact resistance or recovery behaviour. The Structured Mechanical Screening Protocol combines hardness, modulus and observed structural behaviour to narrow candidate VPP materials before full characterization.

The protocol is an engineering screening method, not a clinical or regulatory validation method. Application-specific standards and acceptance criteria must be selected for the intended product. ISO 20795-1, for example, should be cited only for denture base polymers within its scope, not as a universal dental, orthopaedic or medical-device threshold.

Candidate materials identified by the protocol require verification using appropriate specimen preparation, post-cure, conditioning, loading mode and service-environment tests. Finished medical or dental devices additionally require device-specific risk management and biological and regulatory evaluation.

Keywords VPP · material selection · Shore hardness · Young's modulus · structural behaviour · mechanical screening · Wedge Method · ISO 527 · ISO 868

Source use. Product and screening documentation is mapped in [1–4]; mechanical and photopolymer evidence in [5–12]; biological, quality-system and legal boundaries in [13–17].

1. Purpose and industrial use

Mechanical selection begins with the failure mode and service conditions of the intended article. A surface indentation measurement can help distinguish broad hardness zones, but it cannot define tensile stiffness, yield, fracture, impact resistance, fatigue, creep or recovery. Conversely, a modulus value does not describe fracture behaviour or long-term performance [1,2,5,6].

The 3Dresyns Structured Mechanical Screening Protocol (SMSP) is intended to reduce a broad portfolio to a manageable set of candidates. It combines hardness, modulus and qualitative structural observations before instrumented verification. Its output is a candidate list and validation plan, not a declaration of safety or conformity.

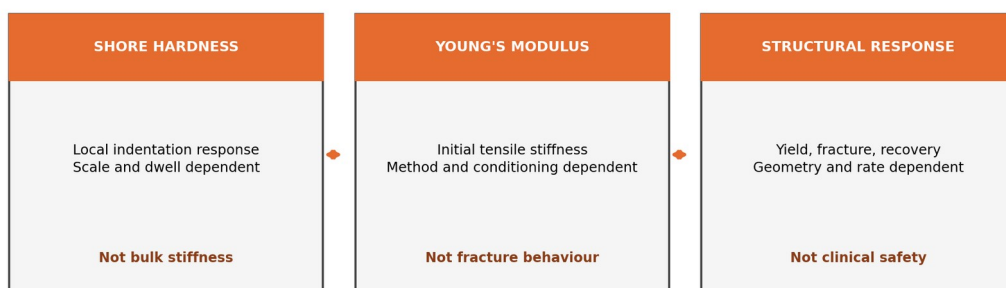


Figure 1. Hardness, modulus and structural response are complementary screening dimensions. None is a substitute for the others, and none establishes clinical safety.

2. Distinct mechanical responses

2.1 Shore hardness

ISO 868 specifies durometer methods for indentation hardness of plastics and ebonite. Results depend on the selected Shore scale, specimen thickness, support, temperature, dwell time and surface condition [10]. Shore values should therefore be reported with the method and conditions and should not be converted into a unique modulus.

2.2 Young's modulus

Young's modulus is derived from the initial tensile stress-strain response under a defined method. ISO 527 requires control of specimen geometry, preparation, conditioning and test speed [11]. Printed orientation, cure state, strain measurement and temperature can materially affect the result. A modulus value is comparable only when these conditions are known.

2.3 Structural behaviour

Yield, brittle fracture, stable deformation and elastic recovery reflect the complete stress-strain response and the test configuration. They cannot be inferred reliably from Shore hardness or modulus alone. When quantitative design decisions are required, appropriate tensile, flexural, impact, fracture, fatigue, creep or dynamic-mechanical methods must be selected from the intended failure modes.

KEY INSIGHT

A useful screening hierarchy asks three separate questions: how the surface resists indentation, how the bulk material deforms initially, and how the specimen yields, fractures or recovers under the relevant load.

3. SMSP screening hierarchy

Stage	Screening question	Evidence	Output
1. Hardness zone	What broad indentation response is required?	ISO 868 or controlled durometer data	Initial candidate families
2. Modulus range	What stiffness range follows from load and deflection?	ISO 527 or justified comparable method	Reduced candidate set
3. Behaviour screen	Is yield, fracture or recovery acceptable?	Observed response plus relevant instrumented test	Provisional behaviour category
4. Comparative check	Does a candidate reproduce a retained response?	Fixed qualitative protocol such as the Wedge Method	Supplementary process observation
5. Final validation	Does the article meet its specification in service?	Application-specific test plan and acceptance criteria	Qualified material-process route

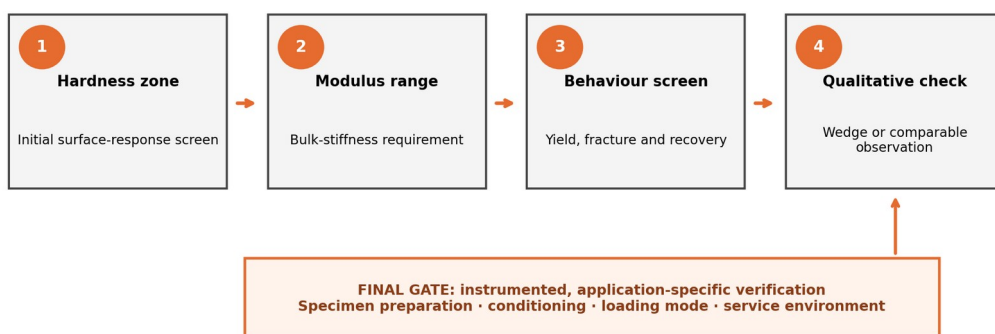


Figure 2. SMSP candidate-reduction sequence with an explicit instrumented and application-specific validation gate.

4. Wedge Method boundary

Within a fixed material, print, post-cure, conditioning and operator protocol, the Wedge Method can record a qualitative comparative response. It must not be converted into modulus, toughness or strength without an independently validated calibration against instrumented measurements.

The wedge geometry produces a non-uniform bending response. Manual force and support conditions are not instrumented, so fracture or deformation location is interpreted empirically. A Wedge observation may compare candidate conditions or serve as supplementary process control against a retained reference. It is not, by itself, a batch-release test and does not define a validated minimum post-cure.

5. Post-processing and comparability

Mechanical behaviour can change with conversion, network relaxation, temperature and removal of residual cleaning media. The magnitude and direction of change are formulation- and method-specific. Universal conversion or modulus-shift ranges should not be used as release criteria without a controlled dataset for the named material and process [5,6].

A comparative record should identify resin and batch, printer and orientation, exposure, cleaning, drying, post-cure equipment and conditions, specimen geometry, conditioning, test temperature, loading rate and measurement method. Data lacking these details may remain useful internally but should not be treated as directly comparable engineering values.



Mechanical screening reduces the candidate set. It does not establish clinical or regulatory suitability.

Figure 3. Mechanical evidence is conditional on specimen, process, test and application context. Screening reduces candidates but does not establish clinical or regulatory suitability.

6. Application-specific validation

6.1 General engineering parts

Select test methods from foreseeable failure modes. Tensile or flexural stiffness may be sufficient for an initial screen, while impact, fatigue, creep, stress relaxation, heat, chemical resistance or dimensional ageing can govern the actual application. Acceptance criteria must be defined before final material selection.

6.2 Dental materials

ISO 20795-1 concerns denture base polymers and should be applied only to products and intended purposes within its scope [13]. It is not a universal requirement for every dental article, occlusal device or orthodontic product. Other dental indications require their applicable product standards and justified specifications.

6.3 Medical devices

Mechanical screening can reduce material-selection risk but does not establish clinical safety. The legal manufacturer must define intended purpose, device classification, risk management, manufacturing validation, biological evaluation and the applicable conformity route. ISO 10993 provides a risk-based biological-evaluation framework; it is not a mechanical certification [14–17].

7. Reporting template

- Define the article, load case, environment, target property and foreseeable failure mode.
- Record all specimen, print, cleaning, post-cure and conditioning variables.
- Report Shore scale and method separately from modulus and structural-response observations.
- Label qualitative Wedge results as comparative observations, not calculated material properties.
- Identify the applicable product standard and its scope for every threshold or acceptance criterion.
- Complete instrumented and article-level verification before approving the material-process route.

8. Limitations

- The protocol is a candidate-screening framework and has not been presented as a validated predictive model.

- Hardness-to-modulus conversions are material-class dependent and can be misleading for crosslinked, viscoelastic, filled or anisotropic photopolymers.
- Manual structural observations are operator- and geometry-dependent.
- Ageing, fatigue, creep, stress relaxation, humidity, sterilization and chemical exposure require dedicated methods where relevant.
- Medical and dental suitability depends on the finished article and applicable legal and biological-evaluation route.

9. Conclusions

- Shore hardness, Young's modulus and structural response are distinct mechanical descriptors.
- SMSP can narrow a candidate set when each screening stage is reported with its method and limitations.
- The Wedge Method is a qualitative comparative observation and does not replace instrumented characterization.
- Post-processing and conditioning must be reported because mechanical results are process dependent.
- Final acceptance requires application-specific standards, specimens, service conditions and acceptance criteria.

Revision note

Version 5.3 narrows ISO 20795-1 to denture base polymers within scope, removes generic dental and orthopaedic thresholds, separates mechanical screening from clinical safety, adds an explicit final-validation gate and updates the ISO 10993 sensitisation and irritation references.

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Disclosure. Dr. Juan Seguro is founder and Scientific Director of 3Dresyns by Resyner Technologies S.L., the producer of the materials and selection tools discussed. Material properties depend on the complete formulation, process, printer, specimen and test method and must be verified for the intended application.

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