

Supplementary workflow documentation

Digital Sky Hook technical note

Supplementary Table S1. Expanded digital workflow controls and validation-oriented documentation.

Workflow stage	Documented control	Relevance
Facial acquisition	Non-contact multi-camera photogrammetry; patient at rest; no external compression of chin-support region	Reduces distortion of the soft-tissue surface used for support design
Scanner setup	Cloner/dOne 3D booth; approximate working distance 55 cm; acquisition time approximately 0.4 s	Provides standardized acquisition geometry and rapid capture
Calibration	Manufacturer-guided calibration target and software-guided camera alignment	Supports consistency of facial acquisition
Original file package	OBJ, MTL and JPEG components; working mesh handled in STL format	Preserves geometry and texture-related records while enabling CAD/manufacturing workflow
Digital traceability	Original records, converted files, prototypes and final design files preserved as distinct workflow stages	Supports auditability and potential remanufacturing
Design environment	Mesh-based support delineation; extrusion, duplication and Boolean operations	Converts resting facial topography into support geometry
Wire-retention architecture	L-shaped negative channels incorporated into printed components	Guides metallic framework adaptation and reduces freehand variability
Slicing and printing	FlashPrint; DLP printing; vertical orientation at approximately 90°; automatic supports	Documents additive manufacturing controls
Iterations	Three design/printing iterations before final standardization	Shows refinement rather than single-print assumption
Post-processing	Alcohol-based washing, complete drying, UV post-curing, support removal, finishing and polishing	Supports clinical handling of printed biocompatible resin
Assembly	Printed components joined after wire adaptation using chemically activated acrylic resin	Clarifies the hybrid digital-laboratory nature of the workflow
Quality control	Visual inspection, absence of visible warpage, laboratory fit and clinical passive seating	Provides practical verification while acknowledging absence of formal metrological validation
Regulatory traceability and material handling	Transparent biocompatible resin selected from supplier operating under Anvisa AFE; washing, drying, UV post-curing, finishing, polishing, cleaning instructions and clinical soft-tissue monitoring documented	Supports sanitary traceability and safe clinical handling while reserving device-specific prolonged skin-contact testing for future validation
Digital data governance	Original facial files, converted meshes, prototypes, final manufacturing files and documentation screenshots stored as versioned workflow stages; identifiable biometric files restricted	Improves auditability, remanufacturing potential and privacy-aware management of patient-specific digital records

Supplementary note. This expanded table is intended to support methodological transparency without overloading the main manuscript. It describes the technical decisions used in the present proof-of-concept and identifies the steps that remain operator-dependent or require future validation. It is not intended to imply full inter-operator, inter-scanner, inter-software or inter-printer reproducibility.

Supplementary Table S2. Recommended next validation endpoints.

Validation layer	Recommended metric	Purpose
Pressure mapping	Thin-film sensor pressure peaks and pressure-distribution area	Quantify soft-tissue contact behavior under clinical load.
CAD-to-print metrology	Best-fit alignment, color-coded deviation maps, mean absolute deviation, RMS error, and percentage of surface points within tolerance	Quantify whether the printed component reproduces the final design geometry.
Force behavior	Inline dynamometer or calibrated tension gauge at placement and after time in use	Quantify force decay and working elastic behavior.
Structural durability	Fatigue loading, thermal cycling, moisture exposure and repeated insertion/removal	Test the resin-wire-acrylic assembly under simulated clinical conditions.
Computational biomechanics	Finite element analysis with support geometry, hook position and force-vector scenarios	Estimate stress concentration and rotational tendency.
Clinical follow-up	Comfort scores, adverse events, objective wear time, adjustment burden and orthodontic outcomes when clinically justified	Move from feasibility toward prospective clinical evidence.

Supplementary Table S3. Exploratory CAD-to-as-built surface-congruence metrics.

The primary comparison was calculated from the scanned as-built clinical component to the nominal P1/P2 design surface after exploratory best-fit alignment. Values are intended as research-level congruence descriptors and should not be interpreted as certification-level dimensional metrology.

Metric	Value
Primary comparison	Scanned as-built component -> nominal P1/P2 design surface
Mean absolute distance	0.48 mm
RMS distance	0.62 mm
Median distance	0.38 mm
P75	0.57 mm
P90	0.89 mm
P95	1.30 mm
P99	2.23 mm
Maximum observed distance	3.32 mm
Surface points <= 0.5 mm	67.6%
Surface points <= 1.0 mm	92.3%
Surface points <= 1.5 mm	96.4%
Surface points <= 2.0 mm	98.4%
Surface points <= 3.0 mm	99.9%

Supplementary Figure S1. Exploratory CAD-to-as-built congruence figure supplied as high-resolution image file.

Three-dimensional scan-based congruence and CAD-to-as-built comparison of the patient-specific chin-support component

