Crown of Thorns: Circlet or Helmet?

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A comprehensive forensic, engineering, and historical analysis integrating cranial wound topography, cloth–head geometry, and relic evidence

Abstract

The morphological nature of the Crown of Thorns—whether a narrow radial circlet or an encompassing cap—remains contested in Shroud studies. This article evaluates both models using convergent lines of evidence:
forensic review of cranial wound distribution and blood-transfer patterns on the Turin Shroud;
geometric constraints imposed by the ≈15–16 cm non-contact bridge spanning the vertex;
engineering and material analysis comparing construction complexity, stability, and manipulation burden;
independent cloth correlations from the Sudarium of Oviedo[3];
historical testimony and relic geometry (Paris ring); and
experimental data from physical reconstruction of a thorn circlet.

The Shroud's head imagery shows concentrated bloodstains at the brow/temples and nape, with *no* vertex transfer across the non-contact bridge, despite conditions consistent with ongoing head/face blood transfer at burial.[1] Accepting the common premise that the crown was removed shortly after the mock coronation, persistent perimeter activity would ordinarily predict at least scattered free-fall droplets in the bridge if broad vertex lesions from a helmet were still able to transfer. Their absence remains a discriminating observation. Experimental reconstruction shows a circlet with inward-pointing thorns yields rich perimeter staining, tangential entrance–exit–re-entry puncture triads from single thorns, and limited supra-band punctures 3–5 cm above the hoop plane from broken spine fragments during forced seating. Engineering analysis finds a circlet can be fabricated with one structural join and inherent hoop stability, whereas documented cap builds required ≥2 hours and complex interlacing.[7] Taken together, these strands provide moderate-to-strong support for a circlet; a helmet remains possible but demands auxiliary assumptions (e.g., selective early vertex clotting, wholly hair-contained flow) that strain geometric, forensic, and experimental constraints.

1. Introduction

Two hypotheses frame the discussion:

Hypothesis A (Circlet): A hoop-like wreath concentrating trauma around the hairline band (brow/temples) and the nape (overlap/tie).
Hypothesis B (Cap): A dome-like structure with diffuse punctures across the scalp, including the vertex, predicting broad, multifocal staining.

Terminology. "Circlet" denotes a ring/hoop; "cap" (often called "helmet") denotes an encompassing dome over the cranial vault.

Historical timing premise. The crown is commonly read as placed for the mock coronation and removed before carrying the patibulum. This widens the window for clot stabilization but does not nullify the bridge constraint: if perimeter wounds could still transfer at burial, a helmet must explain why a punctured vertex left no bridge droplets while other head wounds did.



Figure 1. Left: ring-style circlet with long outward thorns (perimeter concentration). Right: cap-like lattice covering crown/vertex (diffuse distribution).

Historically, both forms have been defended—Barbet for a pileus-like cap; Zugibe likewise for a plaited cap—yet these readings predate or downplay cloth–head geometry and experimental seating mechanics that now provide sharper tests.[24]

Research question. Does the totality of evidence better support a circlet or a helmet-like cap? A key sub-question: can "early, complete vertex clotting" plausibly account for a clean bridge given active transfers elsewhere?



Figure 2. Ziziphus spina-christi thorns (paired straight/curved spines). Source: israelandyou.com

2. Materials and Methods

2.1 Evidence Streams

- Forensic analyses of Shroud head stains (epsilon/"3" rivulet; hairline flows; occipital staining). Experimental work demonstrates that antemortem scalp blood can be re-mobilized by post-mortem handling and hair wicking, sustaining head/face transfer at burial.[1]
- Cloth–head geometry of the ≈15–16 cm non-contact vertex bridge and implications for free-flight vs. contact transfer.[2]
- Sudarium of Oviedo correspondences (occipital and frontal regions), including geometric analysis demonstrating circlet compatibility.[3,10]
- Engineering analysis comparing circlet vs. cap: construction steps, joins, stability, manipulation burden.[2]
- Physical reconstruction with a circlet on a mannequin (puncture mapping; seating dynamics; thorn breakage).[7]
- Historical/philological context (Roman parody of kingship; Greek στέφανος and πλέκω).[6]
- Competing interpretations (Barbet; Zugibe; Bucklin; Rodante).[2]

2.2 Physical Reconstruction Protocol

Materials. Low-density polyethylene (LDPE) rods (¼ inch/6.35 mm diameter) with affixed thorns of varying lengths (approximately 33.78, 45.72, 51.81, 55.88, and 67.06 mm); mannequin head (polystyrene core with silicone skin layer; scalp analog approximately 3 mm thick); latex bald cap; high-resolution photo and video recording equipment.

Procedure. (1) Form hoop by bending LDPE rod into circular configuration (diameter approximately 20 cm); (2) Observe initial placement on mannequin, noting "halo" suspension effect from inward-pointing thorns; (3) Apply downward force to seat the circlet (force magnitude not quantified); (4) Document puncture patterns through photography; (5) Remove and replace ("recrown") twice to assess repeatability and observe cumulative effects.

Measures. Count and classify puncture types (entrance-exit pairs and entrance-exit-re-entry triads from single thorn trajectories); document punctures occurring above the primary hoop plane; record concentration of punctures at posterior overlap region; observe any thorn-breakage events during forced seating.

Trials. Three total placements (initial placement plus two recrowning cycles).



Photo shows a circlet test rig: LDPE hoop with artificial thorns on a latex-capped mannequin. Inward-angled spines keep the ring suspended above the vertex, producing a halo standoff and focusing potential punctures to brow, temporal, and nape zones. It's a qualitative mechanics demo—no force, tie, puncture mapping, or botanical modulus measured—supporting circlet geometry over cap/helmet models, as burial-cloth interpretation aid.

Data availability. Raw imagery, puncture maps, and video documentation available as referenced in the conference transcript.[7]

2.3 Non-Contact Bridge Measurement

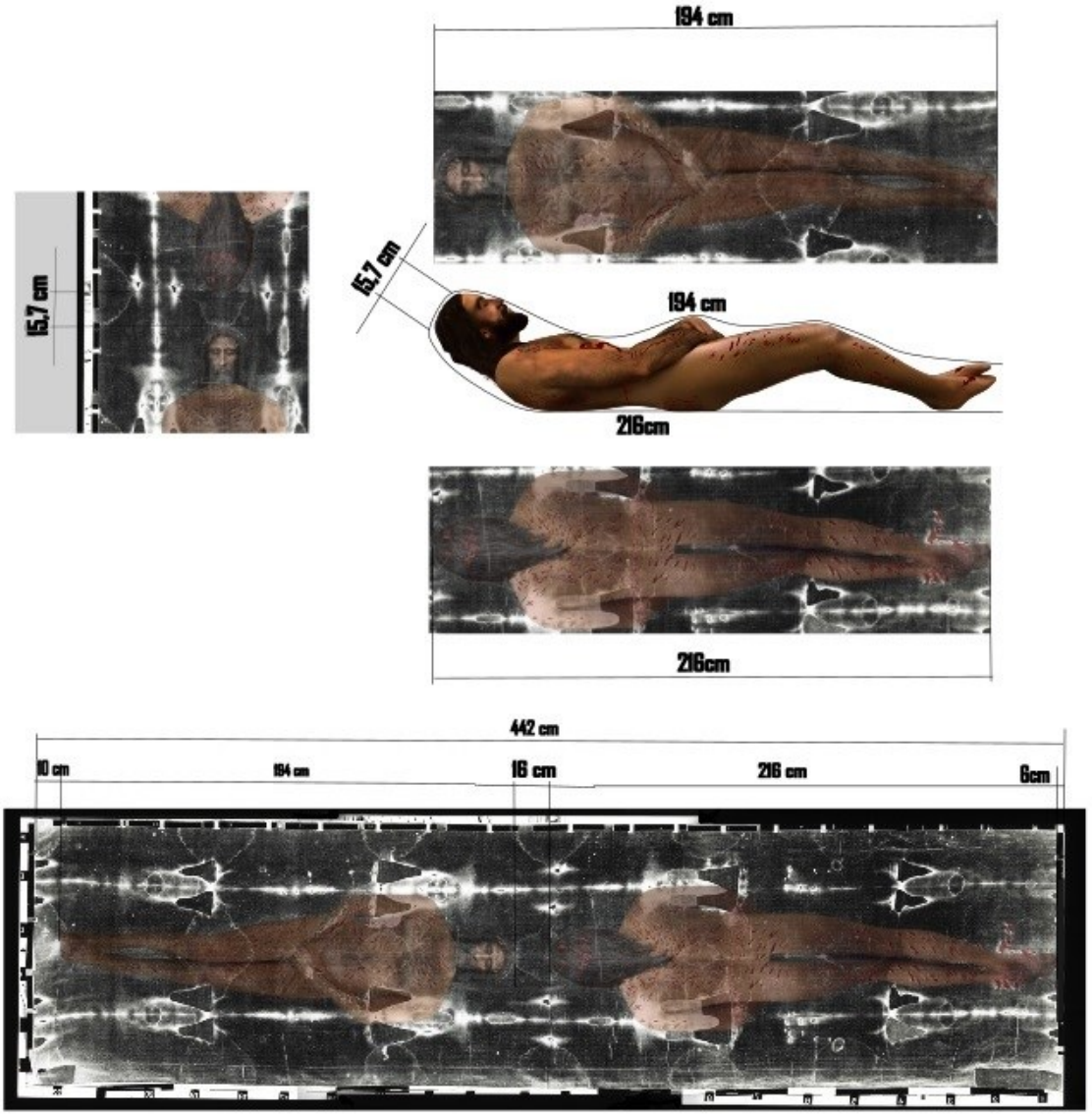


Figure 3. Shroud geometry (~442 × ~113 cm). A ≈15–16 cm non-contact vertex bridge.

Bridge length estimated from cloth length and frontal/dorsal image spans; published imagery (Enrie, Durante, Shroud 2.0) inspected at ≥300 dpi: no droplets >2 mm or smears >5 mm detected above weave/artifact noise.

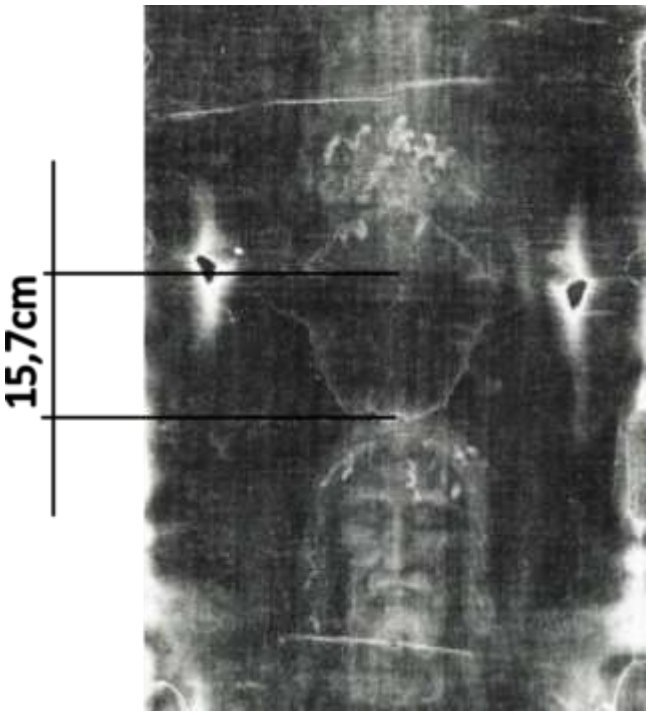


Figure 4. Vertex bridge (≈15.7 cm): arch between forehead and nape images.

2.4 Analytic Framework

Convergent-evidence reasoning: classify evidence as strongly/moderately/weakly discriminating or non-discriminating; note posture effects qualitatively based on observational data from experimental reconstruction.

2.5 Assumptions and Limitations

Vertex bleeding at burial would reach the bridge only via free-fall. Absence there could reflect early vertex-specific clotting or shallower vertex lesions. Resolution limits and hair may obscure micro-marks <2 mm. Blood transfer depends on viscosity, temperature, pressure, hair wicking, and handling. Mannequin tests approximate mechanics, not in-vivo hemodynamics. Laboratory simulations show dried scalp blood can be re-mobilized by post-mortem washing/oiling and hair wicking, sustaining facial/hairline transfer without active vertex bleeding.[1]

2.6 Mathematical Methods: Point-Cloud Registration and Shape Metrics

Following the public "mathematical path" presentation (used with permission), we combined forehead (Shroud) and occipital (Sudarium) stains into a unified 3D point cloud.

Workflow (abridged): select/normalize candidate centroids on common grids; mirror Sudarium outer side to restore anatomical laterality; align occipital (Sudarium) with forehead (Shroud); fit parabolic trend along occipital series ($R^2 = 0.718$); estimate z via parabolic regression constrained by adult male cranial distances; quantify similarity by Procrustes disparity and Mahalanobis distance; summarize with centers of mass and inertia ellipses.

Sample: **54 stains** (forehead + occipital). Angles/forces/binding pressures not measured; depths are model estimates.

3. Results

3.1 Cranial Wound Topography

3.1.1 Distribution

Stains cluster around a circumferential band (brow/temples; nape). No vertex droplets are detected at ≥300 dpi; micro-lesions may be obscured. A ring source suffices; a cap is not required.

3.1.2 Shroud–Sudarium Morphometrics

Unification yielded: parabolic occipital arc ($R^2 = 0.718$); Procrustes disparity 0.0143 (occipital) and 0.0176 (forehead); Mahalanobis ≈1.10 (occipital) and ≈1.42 (forehead); overlapping centers of mass and aligned inertia ellipses. Projected on an anatomical model, points trace a narrow *perimeter band*, consistent with both cloths recording the *same head* and inconsistent with a vertex-saturating field. Mean absolute deviations: ≈0.19 cm (posterior) and ≈0.31 cm (anterior).

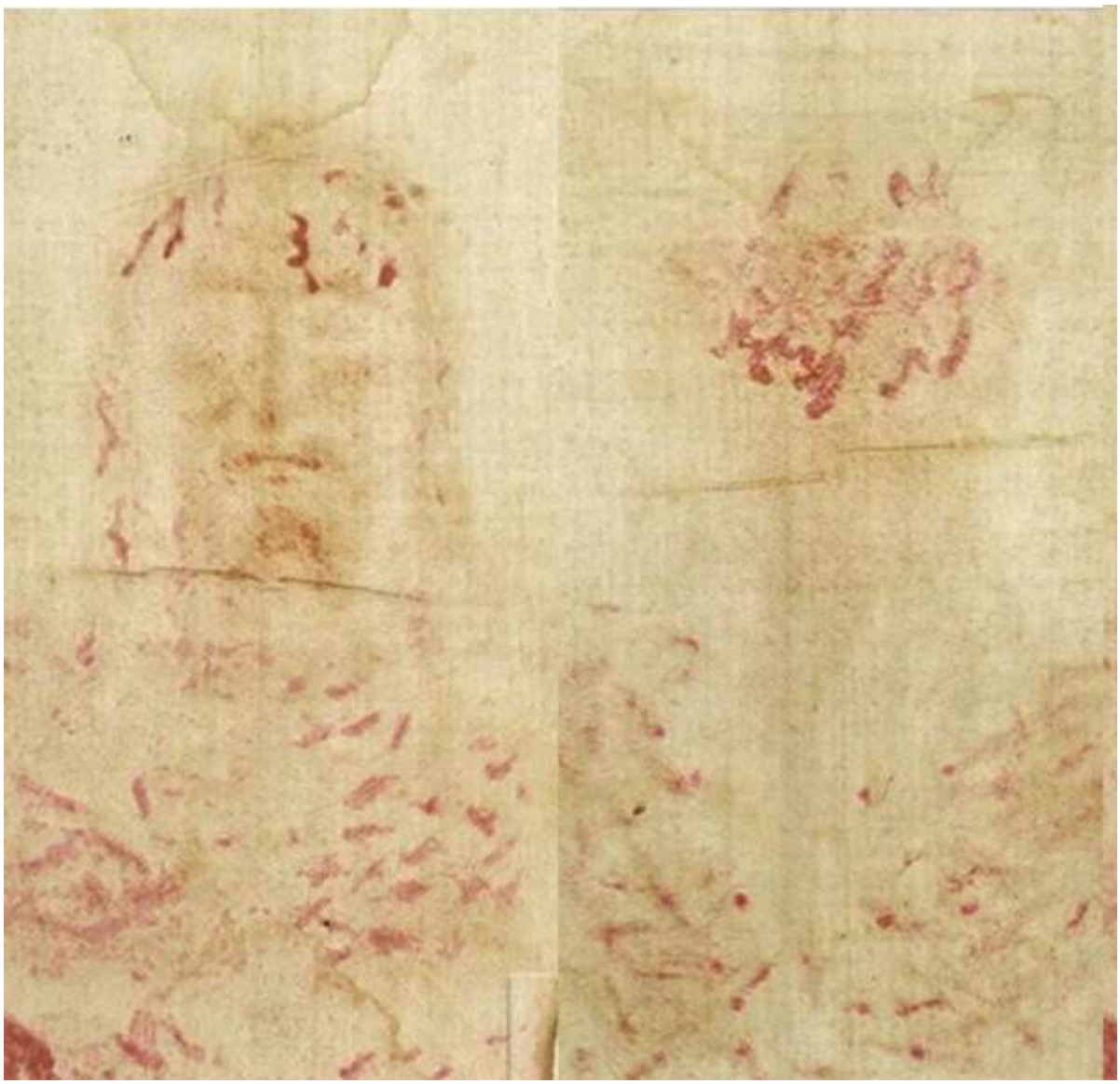


Figure 5. Shroud head region. A clean vertex bridge separates frontal/dorsal head images; stains cluster at brow and nape. Source: raydowning.com

3.2 Circlet vs. Helmet

3.2.1 Blood-pattern logic

The bridge is non-contact; vertex transfer would appear only as free-fall droplets. Given ongoing head/face transfer is experimentally plausible at burial,[1] a helmet with many vertex punctures should leave at least a small constellation of droplets. The bridge is clean. Hair-wicked streaks expected from vertex contact are likewise absent there.

3.2.2 Experimental circlet mechanics

Observed phenomena during physical reconstruction: initial "halo" suspension effect created by inward-pointing thorns preventing the circlet from resting directly on the scalp surface (height not measured); thorn breakage events during forced seating; single-thorn tangential penetration tracks producing entrance–exit pairs and entrance–exit–re-entry triads where a single thorn created multiple puncture points along its trajectory; limited supra-band punctures occurring 3–5 cm above the primary hoop plane, attributable to broken thorn fragments driven inward during compression; observational evidence suggesting that forward head flexion (posture variation) would shift posterior contact points cranially, making "high" posterior wounds compatible with nuchal (nape) loading patterns.[7] These mechanics align with Sudarium bloodstain patterns favoring a circlet configuration through geometric projection analysis.[10]

3.2.3 Cloth correlations

Bridge review (≥300 dpi): no >2 mm droplets or >5 mm smears. Sudarium analysis by Rocamora demonstrates concentrated frontal and occipital bands with geometric projection patterns consistent with a perimeter band source rather than vertex-wide injury distribution, providing independent corroboration of circlet morphology.[10] A helmet must add "perfect, early vertex drying" or "complete hair containment" while other head wounds remained transferable—conditions not required by a circlet.

3.2.4 Engineering comparison

Circlet: 1–2 branches; one structural join; inherent hoop stability from circular geometry.
Helmet: 3-D lattice structure; many members (≈8–14) and joins (≈10–22); extended thorn-adjacent handling during construction; documented builds requiring ≥2 hours of construction time.[7] Even allowing for skilled soldierly craft, sequential fabrication steps limit parallelization; under an execution timeline with time constraints, a circlet represents the more plausible construction option.

3.2.5 Botanical context

Danin's image-based botanical analysis constrains provenance and seasonality (Jerusalem-Hebron corridor; March–April timing) but does not independently determine crown geometry.[9] Pollen claims remain uncertain and are treated as non-discriminating evidence for shape determination.

3.2.6 History/philology

Ancient crowns (Roman civic/triumphal wreaths; Greek στέφανος) are wreath-like bands; πλέκω commonly denotes plaiting a ring structure. The mock regalia ensemble (robe, reed scepter, "crown") coheres most naturally as a wreath parody. The Notre-Dame relic presents a ring form, though interpretive cautions apply (see section 4.5).[58]

3.2.7 Why the cap needs extra assumptions

A cap predicts vertex-heavy puncture distribution and, given the findings in [1] regarding blood transfer potential at burial, would still anticipate some bridge droplets unless vertex wounds uniquely dried or were completely hair-contained. The circlet explains the same observations with fewer auxiliary assumptions.

3.2.8 Preliminary binding hypothesis

Multilevel thresholding analysis on the Sudarium repeatedly reveals linear high-intensity ridges near nose–mouth regions and laterally. Some features are identifiable as folds; others

exhibit characteristics compatible with pressure tracks from a securing band. This analysis remains at an early stage; material composition, width, and knotting configuration remain undetermined.

4. Addressing Alternatives

4.1 Barbet—Posterior blood flows can arise from a tight posterior band at the overlap/tie point. With the bridge constraint added to the analysis, the cap inference weakens.[2]

4.2 Zugibe—Forehead flows are non-discriminating between models; tangential circlet penetration tracks can reproduce them without invoking a helmet-wide puncture field.[4]

4.3 "High vertex" reports—Explained by posterior tying/overlap concentration, forward head flexion effects observed during experimentation, and limited supra-band punctures from broken inward-pointing thorns.

4.4 Poor Clares & de Fleury—Nuchal emphasis (Poor Clares observations) and a 210 mm diameter "Paris ring" (de Fleury measurements) have been interpreted as supporting cap superstructure; however, experimental "halo" seating effect already demonstrates that a circlet remains suspended off the shoulders before compression; the clean bridge remains a challenge for any vertex-wide puncture field.[6,7]

4.5 The Paris ring—cautions
Provenance and multiplication issues complicate interpretation; material–function paradox exists (soft rush material unlikely to independently bear thorns). Plausible roles include: flexible base structure for inserted thorn branches; devotional container/reliquary; basal band component for a cap construction (though still facing time and complexity constraints). Reported cleanliness may reflect non-contact/container status or later cleaning practices. Non-destructive residue testing (plant gums, thorn tissues, heme by-products) could clarify functional history.[8,6]

4.6 Clotting hypothesis—appraisal
Scalp vascularization supports persistent bleeding from penetrating wounds; selective, complete vertex drying while brow/nape regions remained transferable adds explanatory burden. Post-mortem re-mobilization and hair wicking can sustain facial/hairline transfer without requiring active vertex bleeding,[1] but this strengthens—not weakens—the bridge as a discriminator against vertex-wide injury patterns.

4.7 Parsimony
Circlet model: single loop construction; inward-pointing thorns; forced seating mechanics; posture-driven posterior elevation effects; recent exudation at brow/nape (transfer mechanism consistent with [1]).
Helmet model: woven dome structure; widespread vertex punctures; no bridge marks despite transfer potential (requiring perfect vertex-only drying or complete hair containment); extended fabrication time; reconciliation challenges with cloth evidence. The circlet model requires fewer unsupported auxiliary assumptions.

4.8 Integrated weighing
Strongly discriminating: clean non-contact bridge + engineering time/complexity differential (favor circlet).

Moderately discriminating: perimeter topography; reproducible tangential/supra-band lesion patterns from circlet reconstruction; Sudarium perimeter banding evidence.
Weak/ambiguous: historical testimonies; Paris ring interpretation; botanical evidence. Clotting hypothesis keeps helmet model "possible," but only via added conditional assumptions.

Mathematical path—scope. Shape metrics (R^2 trend fitting, Procrustes analysis, Mahalanobis distance, mass centers, inertia ellipses) strengthen the same-head hypothesis and delineate a narrow injury perimeter. These metrics do not, in isolation, decide circlet vs. cap; however, when combined with bridge analysis and engineering considerations, they align more naturally with circlet morphology.

5. Conclusion

Shroud head-stain mapping, a clean vertex bridge amid otherwise active head/face transfer potential (consistent with [1]), experimental inward-spine mechanics, posture-driven posterior elevation, and the build-time/manipulation differential together provide support for a circlet over a cap. A circlet can produce complex puncture patterns—including limited "higher" lesions from broken thorn fragments—without invoking a helmet-wide puncture field. Vertex-focused high-resolution imaging and residue studies on the Paris ring could further refine this judgment; present evidence favors the circlet model.

Key points favoring a circlet

- Non-contact bridge: no vertex droplets or smears despite conditions allowing head/face transfer at burial.[1]
- Engineering economy: one join vs. many members/joins and prolonged thorn-adjacent handling.
- Experimental mechanisms: tangential thorn trajectories and broken inward thorns yield entrance–exit–re-entry triads and limited supra-band punctures.
- Sudarium evidence: perimetral band distribution with geometric projection patterns consistent with band-like pressure, not vertex-wide punctures.[10]
- Nuchal concentration: posterior overlap/tie naturally intensifies nape lesions.
- "Halo effect": inward thorns suspend the ring above the scalp until forced seating, countering "shoulder-resting" objections.
- Quantitative shape analysis: low Procrustes disparity (≈0.014–0.018) and narrow band-like perimeter inconsistent with diffuse vertex injury.

Status of the cap model. Not excluded, but requires widespread vertex punctures that either clotted exceptionally early and completely or were entirely hair-contained without bridge transfer, alongside a more complex, time-consuming construction process. The circlet remains the more parsimonious account.



Figure 6. Illustrative circlet reconstruction: perimeter loading at brow/nape; limited supra-band punctures from broken inward thorns during seating; hairline rivulets.

Evidence Category	Circlet	Cap	Notes
Vertex bridge (clean)	+++	–	Strong discriminator
Engineering complexity	+++	––	Build time/joins
Perimeter topography	++	+	Both compatible; circlet more direct
Experimental tangential tracks	++	0	Circlet reproduces observed patterns
Sudarium correspondence	++	+	Perimeter band favors circlet[10]
Historical testimonia	+	+	Ambiguous/conflicting
Paris ring geometry	+	+	Multiple interpretations possible
Botanical evidence	0	0	Non-discriminating for shape
Clotting hypothesis	0	+	Keeps cap possible but adds assumptions
Total Score	**+14**	**+2**	**Circlet is the winner based on higher total score**

References

1. Fanti, G. (2024). New Insights on Blood Evidence from the Turin Shroud Consistent with Jesus Christ's Tortures. Archives of Hematology Case Reports and Reviews, 9(1), 001-015. Link. (Comprehensive analysis of bloodstains on the Turin Shroud, establishing consistency with wounds including those from the crown of thorns, and discussing blood-transfer mechanics that distinguish between circlet and helmet models.)

2. Barbet, P. (1963/2017 ed.). *A Doctor at Calvary*. Allegro/Muriwai. Link. (Classic surgical analysis proposing a cap-like crown based on posterior blood flows and testimonia, establishing the interpretive framework for the helmet hypothesis that this study critiques.)

3. Sánchez Hermosilla, A. (2015). Commonalities between the Shroud of Turin and the Sudarium of Oviedo. *SHS Web of Conferences*, 15. Link. (Forensic comparison documenting occipital and select frontal blood correspondences between the two cloths, supporting localized band pressure rather than diffuse helmet coverage.)

4. Zugibe, F. T. (2005). *The Crucifixion of Jesus: A Forensic Inquiry*. M. Evans. Link. (Forensic medical examination of crucifixion trauma providing context for wound interpretation and blood-flow patterns relevant to Crown of Thorns analysis.)

5. Barta, C. (2015). New coincidence between Shroud of Turin and Sudarium of Oviedo. *SHS Web of Conferences*, 15. Link. (Additional cross-cloth correspondence analysis reinforcing occipital region matches consistent with circumferential band configuration.)

6. Rohault de Fleury, C. (1870). *Mémoire sur les instruments de la Passion*. Paris. Link. (Nineteenth-century comprehensive study of Passion relics including detailed measurements and construction analysis of the Paris ring, providing inner diameter specifications and structural documentation of the Notre-Dame crown artifact.)

7. Fisher, M. (2024). Christ's Crown of Thorns: The Nature of Its Wounds. *YouTube/Shroud Encounter*. Link. (Experimental physical reconstruction demonstrating circlet mechanics, including halo suspension effect, forced seating with audible thorn breakage, tangential wound production, supra-band punctures from broken thorns, and recrowning effects; includes construction time comparison with helmet attempts.)

8. Associated Press. (2024). Crown of Thorns returns to Notre-Dame Cathedral for public veneration. Link. (Contemporary news documentation of crown-of-thorns relic custody and veneration continuity, establishing ongoing historical tradition and current status of primary physical artifact at Notre-Dame Cathedral following restoration.)

9. Danin, A. (2010). Botany of the Shroud of Turin. Link. (Documents plant *images* near the head; Jerusalem–Hebron localization; March–April seasonality; reports Prof. Litt's finding that Frei's pollen grains cannot be securely identified to genus/species.)

10. Rocamora, P. (2023). Two Cloths, One Geometry: Crown Projection, Morphometrics, and Binding Strip Analysis. *YouTube*. Link. (Geometric and morphometric analysis comparing crown projection patterns between Turin Shroud and Sudarium of Oviedo, with binding strip configuration assessment supporting band-type crown hypothesis and demonstrating circlet compatibility.)

Appendix A: Blood-transfer mechanics

A.1 Contact vs. free-flight
Contact transfer reproduces contacting geometry; free-flight yields circular/elliptical droplets. The vertex bridge is non-contact: absent droplets/smears implies no active vertex transfer or complete hair containment at burial.

A.2 Post-mortem dynamics
Clotting initiates within minutes; fibrinolysis and handling can re-mobilize dried blood, especially via hair wicking, sustaining head/face transfer without active vertex bleeding.[1]

A.3 Hair as capillary medium
Hair can wick and print when pressed; the bridge shows none.

Appendix B: Botanical and material notes

B.1 Candidate species
Ziziphus spina-christi, Paliurus spina-christi, Gundelia tournefortii, etc.—provenance/seasonality constraints but not geometry-decisive.[9]

B.2 Material properties and experimental limitations
The experimental reconstruction employed LDPE (low-density polyethylene) rods with affixed thorns to model seating mechanics, including the halo suspension effect and forced seating dynamics. The experimental setup successfully demonstrated tangential puncture patterns and thorn breakage phenomena. However, no quantitative force measurements were recorded during the experiments; observations of seating force and compression dynamics remain qualitative. The LDPE construction allowed for controlled documentation of puncture patterns and recrowning effects while maintaining structural integrity throughout multiple trial cycles.[7]

B.3 Availability
Thorny brushwood plausible in praetorium fuel stores; relic veneration provides historical continuity context.[8]

Appendix C: Historical/philological context

C.1 Roman crowns & Greek usage
Wreath-form tradition; πλέκω commonly of rings.[5]

C.2 Parody of kingship
Robe, reed, crown cohere as a wreath parody; the circlet aligns with 1st-century expectations.[7]

Appendix D: Assessment framework
Convergent-evidence approach (not full Bayesian). Principal uncertainties: precise bridge geometry; vertex clotting dynamics; micro-lesion detection limits; Roman construction skill/timeline. Future work: formal likelihood ratios for each stream.

Appendix E: Acknowledgments and Corrections

This paper incorporates experimental data from physical reconstruction presented at the 2024 Shroud Encounter conference in St. Louis. The author gratefully acknowledges the presentation by M. Fisher,[7] which provided valuable insights into circlet mechanics and construction dynamics.

Notes on AI assistance: This paper was developed with AI assistance. The correction process underscores the necessity of rigorous human review and source verification for any AI-augmented academic work, particularly when incorporating technical details from conference presentations, experimental protocols, or specialized forensic analyses.

Further references:

From the St Louis Conference 2025.

For the wounds to the heels and the crown of thorns as a deep crown:

Moon Pam; The Shroud of Turin: Unveiling the Medical and Spiritual Significance; Shroud of Turin International Conference 2025; St Louis; Available online: Symposium and Educational Endeavours Corporation; https://www.youtube.com/watch?v=jgrPw1N3Mko

For the debate between the Image of Edessa/ Holy Mandylion and the Image of Camuliana and St. Mary Blachernae and the folding patterns for the *Man of Sorrows*:

Moon Pam; Folding Patterns and the History of the Shroud; Shroud of Turin International Conference 2025; St Louis; Available online: Symposium and Educational Endeavours Corporation; https://www.youtube.com/watch?v=Boq_Ufe7s7o

A few additional papers:

The crown of thorns as a deep crown rather than a circlet:

Moon P: *THE LIER SHROUD AND LUCAS CRANACH THE ELDER*; British Society for the Turin Shroud; Newsletter 79; June 2014; Available online: https://www.shroud.com/pdfs/n79part6.pdf; page 30-32

Wounds to the heels and Genesis 3:15:

Moon P; *Spiritual reflections on the heel injury of the Man of the Holy Shroud*, Lent 2024; Available online:

https://www.academia.edu/115675406/Spiritual_reflections_on_the_heel_injury_of_the_Man_of_the_Holy_Shroud

St Mary Blachernae:

Moon P; *The Folding Patterns of the Shroud of Turin*; 7th January, 2025; Available online:

https://www.academia.edu/126895116/The_Folding_Patterns_of_the_Shroud_of_Turin

Numbers 5 and 6

Other papers include:

Moon P; *Three treasures of Constantinople*; Science, Theology and the Holy Shroud; ed. R Gary Chaing and Evelyn M White; Edited papers of 2019 International Shroud Conference; Doorway Publications 2020: Available Online: https://www.academia.edu/42642715/Three_Treasures_of_Constantinople_The_Holy_Blood_of_Bruges_a_relic_the_Limburg_Staurotheke_a_reliquary_and_the_Madrid_Skylitzes_an_illustrated_manuscript_all_provide_historical_evidence_that_the_Shroud_of_Turin_is_much_older_than_the_1988_radiocarbon_dating_suggests