

The Geometric PATZi Method for Full-Arch Reconstruction of the Atrophic Maxilla: Complete Cone-Beam Computed Tomography Coordinate Protocol, Worked Implant-Length Calculations, and a Software Reference Specification

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Abstract

Full-arch reconstruction of the atrophic maxilla increasingly relies on remote cortical anchorage, yet freehand surgery is still commonly planned without a patient-specific calculation of implant length, and operating rooms are stocked with broad implant inventories to absorb the resulting uncertainty. The conceptual rationale for coordinate-based PATZi (posterior, anterior, tilted, zygomatic) planning was recently introduced in a brief perspective article; the present report is its methodological companion and provides the complete operational protocol. We define an eleven-trajectory classification (P1-P3, A1-A2, T1-T3, Z1-Z3) in which every implant is described by a planned post-reduction entry coordinate (E) and a cortical target coordinate (X) on cone-beam computed tomography (CBCT). The entry-to-target distance is computed exactly as the three-dimensional Euclidean distance S3D, and the clinical implant length is then selected from it through explicit, recorded adjustments for landmark selection, device geometry, and safety. The article presents the anatomic definition and multiplanar evaluation of each subtype, the geometric variables and calculation rules, a step-by-step clinical protocol, worked numerical examples on schematic coordinates, a subtype-specific safety matrix, and a reference software specification that separates deterministic geometry from proposed artificial intelligence (AI) modules for segmentation, landmark proposal, and inventory prioritization. The approximate 15-mm prosthetic envelope is used to position E and is never added to

implant length. All anticipated benefits, including inventory reduction, are framed as hypotheses, and a staged validation pathway with defined primary outcomes is specified. The method is offered as a reproducible planning language and software reference for surgeons and developers, pending clinical validation.

Keywords

Atrophic Maxilla, Dental Implant Planning, Pterygoid Implant, Zygomatic Implant, Cone-Beam Computed Tomography, Artificial Intelligence

1. Introduction

Severe maxillary atrophy removes the alveolar bone that conventional implant dentistry depends on, and contemporary full-arch reconstruction answers with remote cortical anchorage: pterygoid, nasal-crest, transnasal, trans-sinus, trans-palatal, and zygomatic trajectories that borrow bone the resorptive process spares [1] [2]. The PATZi protocol organizes these options into posterior (P), anterior (A), tilted (T), and zygomatic (Z) families and has been described clinically for the moderately and severely atrophic maxilla [1] [2]. What the clinical literature has not yet supplied is a quantitative planning layer: a reproducible way to convert a chosen trajectory into a predicted implant length, angulation, and focused inventory before freehand surgery begins.

The conceptual rationale for such a geometric layer was introduced by our group in a brief perspective article [3]. The format of that report could accommodate only the premise, a classification table, and a single geometric figure. The present article is its methodological companion and contains the material a clinician or software developer actually needs to apply or test the method: the complete anatomic definition of all eleven trajectory subtypes with original multiplanar illustrations, the full set of geometric variables and calculation rules, a step-by-step clinical protocol, worked numerical examples, a subtype-specific safety matrix, a reference software specification with regulatory context, and a staged validation framework with defined outcomes. None of this content appears in the perspective, and the two reports are intended to be read as concept and method, respectively.

Two commitments run through the method. First, determinism where determinism is possible: the entry-to-target distance is an exact computation once E and X are selected, and that computation must remain auditable even when artificial intelligence (AI) assists the surrounding workflow. The clinically selected implant length, by contrast, remains conditional on landmark selection, device geometry, the surgeon-defined safety adjustment, and intraoperative changes; the method does not remove that judgment but makes each conditioning step explicit and recordable. Second, honesty about evidence: no data yet demonstrate that this planning method predicts the implant ultimately placed or reduces inventory, and

every anticipated benefit in this article is framed as a hypothesis attached to a defined validation outcome.

2. The Geometric PATZi Classification

The classification comprises eleven trajectories in four families, spanning the degrees of alveolar resorption described by Cawood and Howell [4]. Each subtype is defined by a planned entry region, a cortical target, and the multiplanar views required to evaluate its vector; the summary appears in **Table 1**.

Table 1. Geometric PATZi classification with required multiplanar evaluation.

Code	Planned entry (E)	Cortical target (X)	Primary function	Key views
P1	Residual posterior alveolus, premolar-molar region	Native alveolar bone; no remote target	Conventional axial posterior support	Cross-sectional, panoramic
P2	Edentulous ridge at the former palatal-root position of the first or second molar	Dense residual palatal-root-site bone; remains within the alveolar process	Posterior support from palatal-root-site bone	Axial + cross-sectional
P3	Tuberosity region, passing posterior to the maxilla	Medial pterygoid plate of the sphenoid (only subtype engaging the pterygoid plates)	Posterior remote anchorage	Axial + sagittal + oblique
A1	Anterior alveolus, regions 7 - 10	Pyramidal rim or dense midline crest	Conventional anterior support	Cross-sectional, sagittal
A2	Anterior alveolus	Z-point/conchal-crest transnasal target	Extended anterior remote anchorage	Coronal + sagittal
T1	Premolar region, 4/5 or 12/13	Lateral nasal crest/canine buttress, anterior to the maxillary sinus	Tilted midarch support avoiding the sinus	Oblique sagittal
T2	Residual alveolar crest, premolar region	Z-point/golden-triangle target across the sinus corridor	Trans-sinus support	Coronal + oblique
T3	Premolar or palatalized alveolar entry	Palatal cortical bone	Transpalatal support	Coronal + axial
Z1	Molar region, 2/3 or 14/15	Zygomatic buttress/body	Posterior zygomatic support	Coronal + 3D rendering
Z2	Premolar region, 4/5 or 12/13	Zygomatic buttress/body	Premolar zygomatic support	Coronal + 3D rendering
Z3	Anterior region, 7 - 10	Zygomatic buttress/body	Anterior zygomatic/A-frame support	Coronal + 3D rendering

E, planned post-reduction entry/platform coordinate; X, planned cortical target coordinate; 3D, three-dimensional. Tooth positions follow the Universal Numbering System.

2.1. Posterior Family (P1-P3)

The posterior family is subdivided by cortical target rather than by entry alone (**Figure 1**). P1 is a conventional axial implant in residual posterior alveolar bone;

its geometry is elementary, but the subtype is retained so that every implant in a full-arch plan shares the same E-X data structure and audit trail. P2 exploits a specific intraosseous target: the dense residual bone at the former palatal-root position of the first or second molar in the edentulous ridge. The implant is placed at that site and remains entirely within the alveolar process, gaining favorable bone quality without approaching the pterygomaxillary region; the label directs the surgeon and the software to locate X within the palatal-root-site bone rather than at the geometric center of the ridge. P3 is the only posterior subtype that exits the alveolar process: the trajectory passes posterior to the maxilla to engage the medial pterygoid plate of the sphenoid. Pterygoid and tuberosity fixation has a long clinical history with high reported survival, though the evidence is heterogeneous and largely retrospective [5]-[11]; CBCT planning studies emphasize prosthetically driven entry, variable sinus relationships, and the need to distinguish total implant length from the length actually engaging the target [8] [12]. For P3 the frontal projection is insufficient: the course is posterior and medial, and the vector must be confirmed in axial, sagittal, and oblique reformats, with X placed within, not beyond, the intended cortical stop.

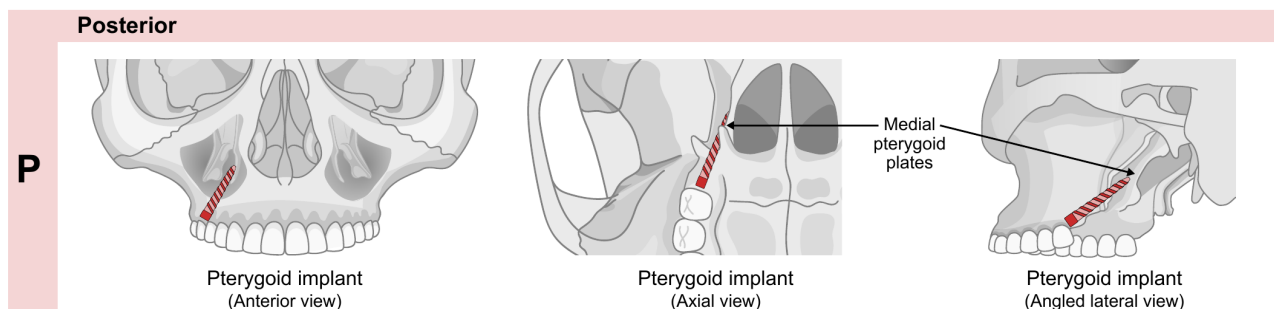


Figure 1. Posterior implant family. The artwork illustrates the P3 pterygoid trajectory in anterior, axial, and angled lateral views, engaging the medial pterygoid plates posterior to the maxilla; P1 (conventional axial) and P2 (palatal-root-site) implants remain within the alveolar process as defined in [Table 1](#).

2.2. Anterior Family (A1-A2)

A1 uses residual anterior maxillary bone with fixation at the anterior nasal spine, piriform rim, lateral nasal wall, or nasopalatine foramen region; A2 extends the concept through a transnasal corridor to a defined apical target in the Z-point/conchal-crest region, with the illustrated A2-1 to A2-3 variants sharing that target ([Figure 2](#)). Literature on nasal-floor elevation, vomer/nasal-crest fixation, nasopalatine management, and extra-long transnasal implants supports the broader principle that anterior cortical structures provide meaningful anchorage when the conventional alveolus is deficient [13]-[18]. Transnasal planning must remain anatomy-specific: the lateral nasal wall, inferior turbinate region, nasolacrimal relationship, and restorative emergence require review, and the A2 label is a planning category, not permission to cross the nasal cavity without a defined bony target and risk assessment.

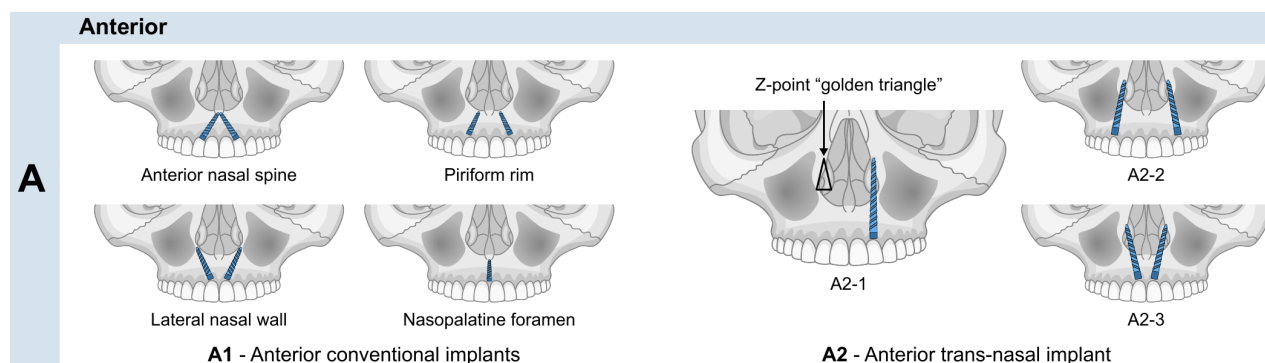


Figure 2. Anterior implant family. A1, conventional anterior implants engaging the anterior nasal spine, piriform rim, lateral nasal wall, or nasopalatine foramen region; A2, anterior trans-nasal implant directed toward the Z-point (“golden triangle”), with A2-1 to A2-3 illustrating placement variants sharing the same apical target.

2.3. Tilted Family (T1-T3)

T1 is a conventional implant deliberately tilted away from the maxillary sinus: the vector passes from the premolar region anterior to the anterior sinus wall toward lateral nasal-crest or canine-buttress bone, gaining useful length without sinus transgression (**Figure 3**). T2 is a trans-sinus vector in which the residual alveolar crest controls the entry and the apex engages an anterior buttress/Z-point target rather than floating within the sinus; case series and systematic evidence support trans-sinus treatment in carefully selected anatomy while highlighting technique heterogeneity and the need for membrane and sinus assessment [19]–[21]. T3 is a transpalatal vector intended to use palatal cortical bone; because the platform can be displaced palatally, geometric adequacy alone is insufficient, and hygiene access, screw-channel position, soft-tissue thickness, and prosthetic design must be evaluated.

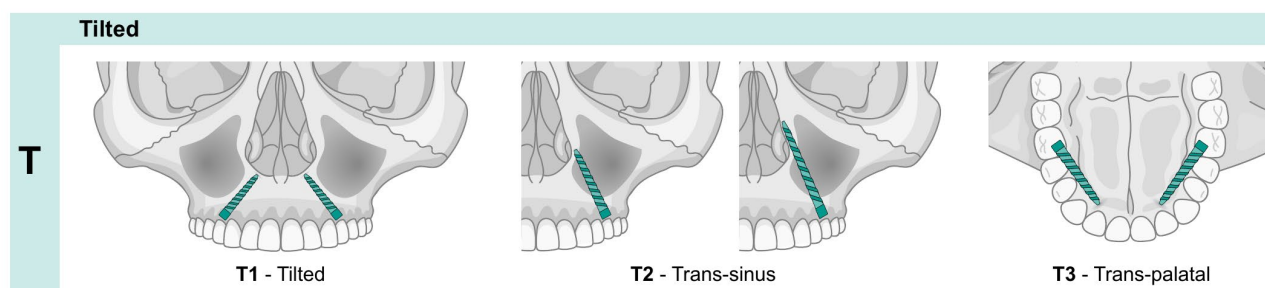


Figure 3. Tilted implant family. T1, conventional implants tilted away from the maxillary sinus; T2, trans-sinus trajectories from the residual alveolar crest toward the Z-point/golden-triangle target; T3, trans-palatal trajectories engaging palatal cortical bone (occlusal view).

2.4. Zygomatic Family (Z1-Z3)

Zygomatic implants are established rescue options for severe atrophy, supported by foundational, sinus-slot, extra-sinus, anatomy-guided (ZAGA), long-term, systematic-review, and consensus literature, which also identifies sinus disease, soft-tissue emergence, orbital and infraorbital anatomy, and prosthetic position as cen-

tral considerations [22]-[34]. In the geometric classification, Z1, Z2, and Z3 identify the planned crestal entry region (molar, premolar, and anterior, respectively) with the zygomatic buttress and body as the target (**Figure 4**); the labels organize the geometry and never replace patient-specific anatomy-guided assessment.

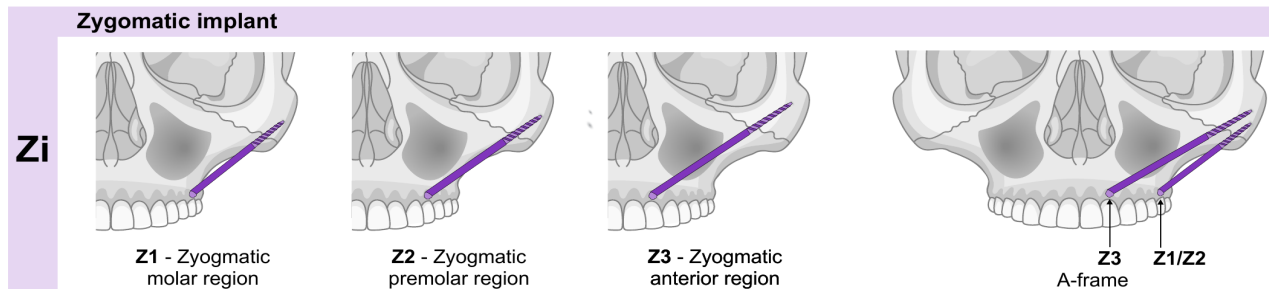


Figure 4. Zygomatic implant family. Z1, Z2, and Z3 trajectories arising from the molar, premolar, and anterior regions, respectively, and engaging the zygomatic buttress and body; the A-frame configuration combines Z3 with Z1/Z2.

3. Coordinate Geometry and the Prosthetic Envelope

The surgeon first defines the restorative envelope and the final post-alveoloplasty platform; this coordinate is designated E. The desired cortical engagement point is designated X. On a correctly oriented oblique two-dimensional (2D) reformat containing both points, the Pythagorean theorem gives the straight-line distance $S2D = \sqrt{a^2 + b^2}$. In the native CBCT coordinate system the preferred calculation is the generalized three-dimensional form, $S3D = \sqrt{(\Delta x)^2 + (\Delta y)^2 + (\Delta z)^2}$, which is mathematically exact for the straight-line distance between the two selected voxel coordinates. CBCT is the appropriate modality when three-dimensional anatomy affects management [35].

3.1. Coordinate Convention and Registration

All coordinates are reported in millimeters in the DICOM (Digital Imaging and Communications in Medicine) patient coordinate system (LPS convention: +x toward the patient's left, +y posterior, +z superior), with the origin defined by the ImagePositionPatient attribute of the acquired volume. Voxel indices are converted to millimeters using the PixelSpacing and slice-spacing attributes together with the ImageOrientationPatient direction cosines, so that E, X, and every derived quantity are expressed in physical units independent of viewer software. If the volume is reoriented, for example to align the occlusal plane, the reorientation transform must be recorded and all coordinates reported in a single, stated frame. The prosthetic plan is registered to the CBCT volume by surface or fiducial registration, and the registration transform and its residual error are recorded with the plan; a software implementation should decline to report S3D when the registration error exceeds a user-set threshold.

3.2. Standardized Endpoint-Selection Record

For every remote cortical target, X is documented with a standardized endpoint-

selection record containing four elements: 1) the intended cortical engagement depth, in millimeters within the target cortex, together with the device reference point to which the stated length applies (implant apex versus apical thread, per the manufacturer's length definition); 2) the nearest exclusion-zone structure and its measured clearance from the planned axis; 3) the position of X relative to the cortical boundary (within or at, never beyond, the intended cortical stop); and 4) the value of the surgeon-defined safety adjustment *m* for that site and its rationale. The record converts the safety review from an implicit habit into an auditable data element and is the unit the validation study analyzes.

3.3. The Prosthetic Envelope and Catalog Mapping

The frequently cited approximate 15-mm restorative space is never added arithmetically to implant length. It informs alveolar reduction, platform position, and restorative emergence, and thereby determines where E sits; once E is moved to the intended post-reduction crest, the distance from E to X is recalculated. The selected implant is then reconciled with available catalog lengths, drill-tip geometry, intended depth of cortical engagement, and a surgeon-defined safety adjustment. The clinical uncertainty of the method lies not in the distance formula but in selecting E and X, and in translating a continuous measurement into commercially available lengths; the variables are summarized in **Table 2**.

Table 2. Geometric variables and calculation rules.

Variable	Definition	Operational rule
E	Final post-reduction implant entry/platform coordinate	Define after restorative space and alveoloplasty are planned
X	Desired endpoint inside the target cortical zone	Do not place X beyond the safe cortical target
S2D	Straight-line distance on an oblique plane containing E and X	$S2D = \sqrt{a^2 + b^2}$; valid only if the plane truly contains both points
S3D	Native CBCT Euclidean distance	$S3D = \sqrt{(\Delta x)^2 + (\Delta y)^2 + (\Delta z)^2}$; preferred reference calculation
R	Restorative envelope/reduction parameter	Approximately 15 mm guides platform and reduction; never added directly to S
<i>m</i>	Surgeon-defined safety adjustment	No universal value; depends on target, system, drill geometry, and risk
L(selected)	Commercial implant selected	Map continuous S3D to the system catalog after all adjustments

CBCT, cone-beam computed tomography.

4. Step-by-Step Clinical Protocol

The method is applied as a structured preoperative worksheet in eight steps (**Figure 5**): 1) plan the prosthesis and restorative envelope first, establishing the required restorative space and occlusal scheme; 2) plan the alveoloplasty and mark

the final platform level, fixing E for each implant site; 3) assign a PATZi subtype to each site from **Table 1**, based on residual anatomy and the intended arch configuration; 4) place X within the subtype-specific cortical target using the required multiplanar views; 5) calculate S3D and record delta x, delta y, delta z, the unit direction, and the associated angulations; 6) apply the safety review in **Table 3** and complete the endpoint-selection record of Section 3.2 for each remote cortical target; 7) map the adjusted length to the implant catalog, selecting a primary implant plus a deliberately narrow backup set, typically one adjacent shorter and one adjacent longer length; and 8) record the plan, including the pre-reduction crest, planned reduction, all coordinates, and the selected inventory, so the prediction can later be audited against the implant actually placed.

In the authors' six-implant full-arch workflow, the composite (cumulative) insertion torque is defined as the arithmetic sum, in Ncm, of the final seating insertion-torque values of all implants intended to support the immediate provisional prosthesis; in the standard configuration this is all six implants, and any implant excluded from the provisional is excluded from the sum. A composite value greater than 120 Ncm supports consideration of immediate loading, always taken together with implant distribution, cross-arch splinting, per-site stability, bone quality, and prosthetic judgment; the benchmark is part of the authors' clinical routine and is not proposed as a validated universal criterion.

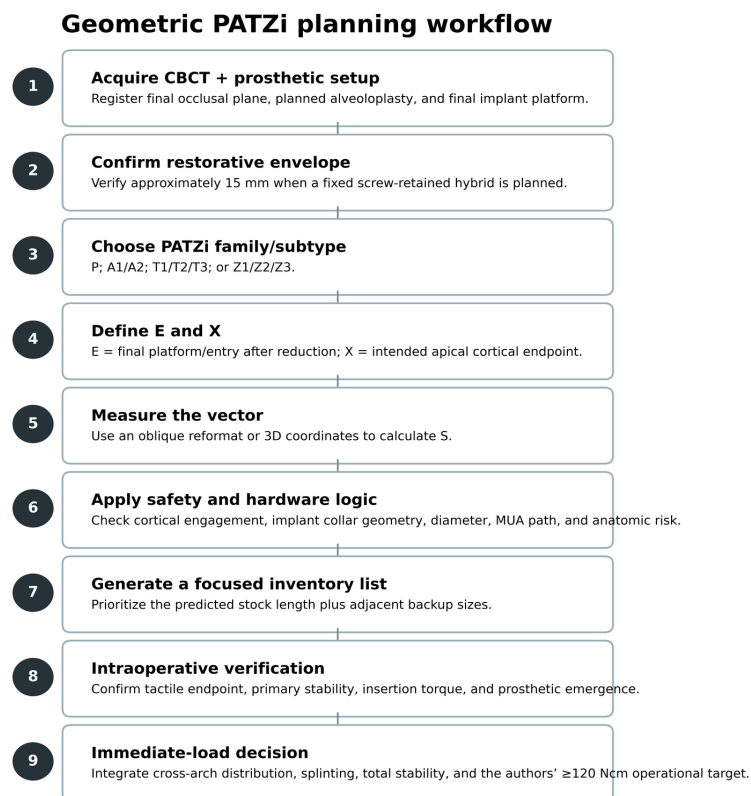


Figure 5. Geometric PATZi planning workflow linking restorative planning, subtype selection, coordinate definition, vector calculation, safety review, focused inventory, and intraoperative stability assessment.

Table 3. Subtype-specific planning checks.

Subtype	Confirm on CBCT	Key cautions
P1	Residual crest height and width, sinus-floor proximity, bone quality	Sinus encroachment; inadequate native bone volume
P2	Palatal-root-site bone volume and density, sinus-floor proximity, palatal contour	Palatal angulation and emergence; sinus encroachment; confirm the implant remains within alveolar bone
P3	Tuberosity, posterior sinus wall, pterygomaxillary junction, medial pterygoid plate, posterior vascular anatomy	Posteromedial vector; avoid superior/posterior overshoot and vascular injury
A1	Pyriform rim, nasal floor, midline crest, facial-palatal width	Nasal violation, thin facial plate, poor emergence
A2	Lateral nasal wall, conchal region, Z-point, nasolacrimal relationship	Mucosal injury, malposition, inadequate apical target
T1	Residual crest, anterior sinus wall, canine buttress/lateral nasal crest	Restorative angle; confirm the vector remains anterior to the sinus
T2	Residual crestal control, sinus membrane, anterior sinus wall, Z-point	Sinus complication and inadequate target bone
T3	Palatal cortical thickness, soft tissue, screw access	Palatal emergence and hygiene compromise
Z1-Z3	Zygomatic volume, orbit/infraorbital region, sinus, emergence	Orbital/sinus/soft-tissue complications; use anatomy-guided planning

CBCT, cone-beam computed tomography.

5. Worked Examples

Table 4 applies the calculation to four illustrative sites using schematic coordinates on a model maxilla; the values demonstrate the arithmetic and the catalog-mapping step and are not patient data. Consider the P3 example in detail. The post-reduction platform is set at $E = (58.0, 34.0, 18.0)$ mm and the target within the medial pterygoid plate at $X = (66.0, 46.0, 28.0)$ mm, giving $\Delta x = 8.0$, $\Delta y = 12.0$, $\Delta z = 10.0$ mm. Then $S3D = \sqrt{64 + 144 + 100} = \sqrt{308} = 17.5$ mm. If the surgeon's system offers 15-, 18-, and 20-mm lengths and the plan calls for engagement to, but not beyond, the cortical stop, the 18-mm implant is selected as primary with 15- and 20-mm backups, and the 0.5-mm difference is absorbed within the planned depth of cortical engagement and safety adjustment m . The same arithmetic yields a short intra-alveolar calculation for P2 and a long vector for Z1, which is precisely the point: one data structure and one equation serve every subtype, and only the coordinates change.

6. Software Reference Specification

The proposed architecture separates deterministic geometry from AI inference (**Figure 6**). A machine-learning layer may segment the maxilla, sinus, nasal cavity, orbit, pterygoid plates, zygomatic body, palatal cortex, and other exclusion zones;

Table 4. Worked examples on schematic coordinates (illustrative; not patient data).

Subtype	E (x, y, z) mm	X (x, y, z) mm	Deltas (mm)	S3D (mm)	Catalog	Backups
P2	(52.0, 30.0, 20.0)	(53.5, 32.0, 31.0)	1.5, 2.0, 11.0	11.3	11.5 mm	10, 13 mm
P3	(58.0, 34.0, 18.0)	(66.0, 46.0, 28.0)	8.0, 12.0, 10.0	17.5	18 mm	15, 20 mm
T2	(44.0, 28.0, 22.0)	(50.0, 38.0, 38.0)	6.0, 10.0, 16.0	19.8	20 mm	18, 22 mm
Z1	(60.0, 30.0, 24.0)	(80.0, 45.0, 59.0)	20.0, 15.0, 35.0	43.0	42.5 mm	40, 45 mm

E, planned entry coordinate; X, cortical target coordinate; $S3D = \sqrt{(\text{delta } x)^2 + (\text{delta } y)^2 + (\text{delta } z)^2}$. Catalog lengths are examples; each system’s actual offerings, drill-tip geometry, and the surgeon-defined safety adjustment determine the final selection.

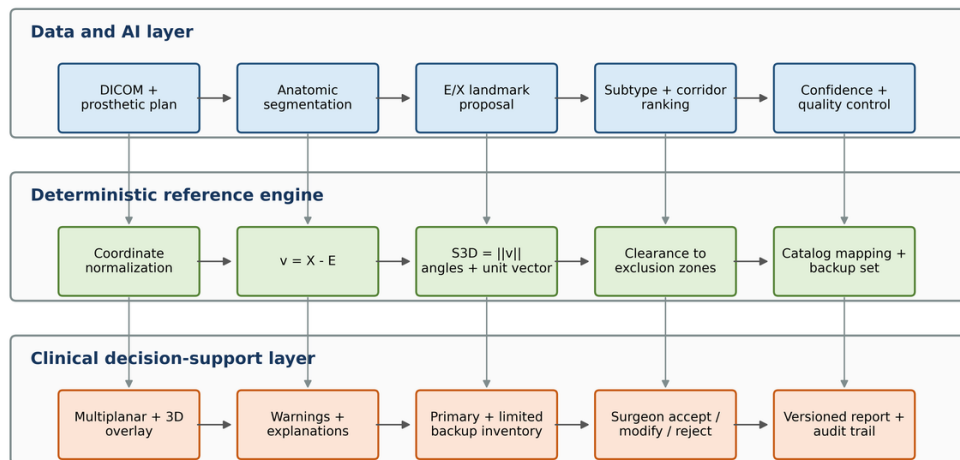
detect candidate E and X landmarks; classify the PATZi subtype; and rank feasible corridors, consistent with published evidence on AI implant planning, navigation, and robotics [36]-[39]. The normative calculation, however, remains auditable: $\text{delta} = X - E$; $S3D = \sqrt{(\text{delta } x)^2 + (\text{delta } y)^2 + (\text{delta } z)^2}$, with the unit direction vector and axial, coronal, and sagittal angulations reported alongside length. Minimum inputs are calibrated DICOM (Digital Imaging and Communications in Medicine) CBCT data with voxel spacing and orientation, the post-reduction coordinate E, the target X, catalog dimensions, planned diameter, and surgeon-defined safety constraints. Minimum outputs are subtype, coordinates, S3D, vector angles, nearest-anatomy clearances, primary catalog candidate, backup lengths, uncertainty, and an auditable overlay (Figure 7). Software claiming to implement the method should identify the algorithm version, preserve the defined variables and equations, document deviations, and cite this specification; the specification does not authorize autonomous placement or replace surgeon review.

A clinical application that analyzes patient-specific CBCT data and recommends surgical trajectories may fall within clinical decision-support or Software as a Medical Device frameworks depending on intended use and claims [40]-[43]. Development should therefore include traceable requirements, cybersecurity, dataset governance, external validation, uncertainty reporting, change control, and human-in-the-loop review. This article is a scientific specification, not a cleared medical device.

7. Anticipated Benefits and Limitations

Three benefits motivate the method, and each is a hypothesis. Dimensional discipline: virtual pterygoid planning already demonstrates that CBCT can define prosthetically driven entry, angulation, and the length actually engaging the target, with substantial individual variation [8] [12]—exactly why a patient-specific coordinate method should outperform selecting a long implant from experience alone. Inventory rationalization: a calculated plan identifies a primary implant and a deliberately narrow backup set instead of stocking a broad catalog for each freehand case; the economic benefit remains to be measured prospectively. Communication: the labels E, X, S3D, subtype, and target cortex give the surgeon, restorative dentist, laboratory, implant representative, and software developer one unambiguous vocabulary, and the same annotation scheme structures future datasets for AI development [38] [39].

Geometric PATZi Reference Software Architecture v1.0

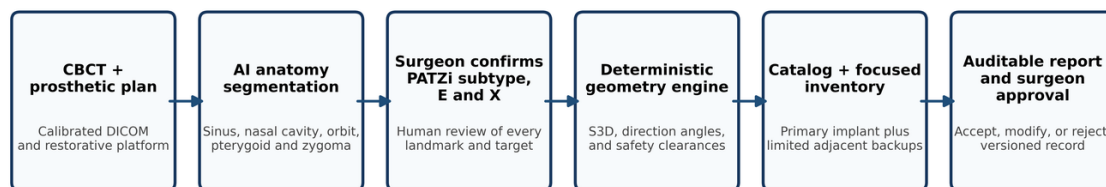


Normative principle: AI may propose anatomy and landmarks; the formula core is deterministic, transparent, versioned, and surgeon-supervised.

Research specification only - not autonomous surgical authorization or a cleared medical device.

Figure 6. Reference software architecture. AI modules perform segmentation, landmark proposal, and corridor ranking; the deterministic geometry engine calculates the entry-to-target vector, length, angulation, clearances, and catalog mapping, with every recommendation subject to surgeon review and an auditable output report.

Proposed AI-Assisted Geometric PATZi Planning and Inventory Workflow



Human-in-the-loop: AI proposes; deterministic equations calculate; the surgeon verifies, edits, accepts, or rejects.

Operational outputs: PATZi subtype, E/X coordinates, S3D, direction angles, exclusion-zone clearances, implant candidates, confidence, warnings, and audit trail.

Inventory and cost reduction remain hypotheses requiring prospective validation.

Figure 7. Proposed AI-assisted planning and inventory workflow. The inventory-reduction benefit is a hypothesis requiring prospective validation.

The limitations are equally explicit. No data yet demonstrate predictive accuracy, time savings, or inventory reduction. Error can enter through voxel size, patient positioning, metal artifact, segmentation, landmark selection, planned reduction depth, and honest disagreement about where a target should end; regional landmarks such as the Z-point and golden triangle must be defined operationally on CBCT, and interobserver agreement in assigning P1 ver-

sus P2 versus P3 must be measured. The subtype labels are planning categories, not permission, and immediate-loading decisions rest on distribution, splinting, bone quality, and prosthetic judgment [44] [45], not on any single composite torque number. Clinical validation involving patient imaging or outcomes will require institutional review board approval or exemption and appropriate consent.

8. Validation Pathway

A staged pathway is specified (**Figure 8**). Phase 1 is retrospective: independent surgeons select E and X on de-identified CBCTs of completed full-arch cases, and two co-primary comparisons are prespecified and kept distinct. The first is catalog agreement: whether the catalog length predicted from S3D (the primary candidate and, separately, the primary-plus-backup set) matches the catalog length ultimately placed. The second is coordinate-plan accuracy: the continuous difference between predicted S3D and the achieved entry-to-apex distance measured on postoperative imaging where available. Interobserver agreement on subtype, E, X, and S3D is the co-primary reliability outcome. Every case record documents intraoperative deviations—any change of trajectory subtype, endpoint, or implant system—on a structured form; the deviation rate is reported as an outcome, and the prespecified analysis presents both an intention-to-plan comparison, in which deviated cases count against the prediction, and a per-protocol comparison restricted to cases executed as planned. Angular and apical deviation, insertion torque, immediate-loading decision, inventory pulled versus used, procedural

Proposed Validation Pathway

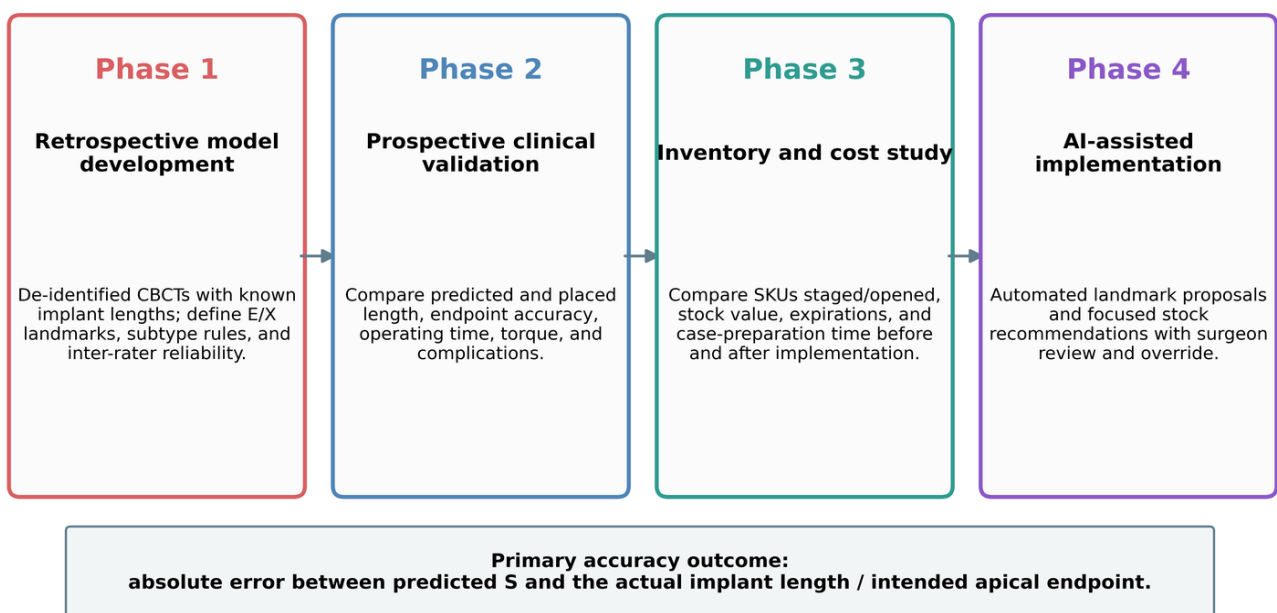


Figure 8. Proposed four-phase validation pathway: retrospective model development, prospective clinical validation, inventory/cost evaluation, and AI-assisted implementation.

Table 5. Proposed validation outcomes.

Domain	Outcome	Analysis
Catalog agreement	Predicted catalog length (primary candidate, and primary-plus-backup set) vs. catalog length placed	Percent agreement with 95% CI
Coordinate-plan accuracy	Predicted S3D vs. achieved entry-to-apex distance on postoperative imaging, where available	Mean absolute error, RMSE, Bland-Altman
Reliability	Agreement on subtype, E, X, and S3D	Weighted kappa and ICC
Position	Coronal, apical, angular, and depth deviation	3D superimposition when postoperative CBCT exists
Protocol deviations	Intraoperative change of trajectory subtype, endpoint, or implant system, on a structured form	Deviation rate; intention-to-plan and per-protocol analyses
Stability	Per-site insertion torque and composite (cumulative) torque as defined in Section 4	Descriptive and subtype-stratified analysis
Inventory	SKUs pulled, opened, and used	Pre/post implementation comparison
Efficiency	Planning and operative time	Paired or adjusted comparison
Safety	Intraoperative and postoperative complications	Prospective adverse-event capture

RMSE, root-mean-square error; ICC, intraclass correlation coefficient; SKU, stock-keeping unit; 3D, three-dimensional; CBCT, cone-beam computed tomography.

time, and complications are secondary outcomes (**Table 5**). Phase 2 compares standard versus geometric inventory preparation prospectively. Phase 3 evaluates inventory and cost at scale, and Phase 4 introduces AI-assisted planning in silent mode before any decision support is surfaced, following published AI-validation practice [38] [39] and regulatory guidance [40]-[43]. The validation study will be submitted as a full research article; the present specification defines the reference against which it will be judged.

9. Conclusion

The geometric PATZi method converts a clinically useful cortical-anchorage taxonomy into measurable CBCT coordinates: eleven subtypes, two coordinates per implant, one exact equation, and a defined path from continuous measurement to catalog selection. This article supplies the complete operational protocol, worked calculations, safety matrix, and software reference specification that the introductory perspective [3] could not accommodate. Its anticipated benefits—clearer freehand planning, rational inventory, a shared vocabulary, and a foundation for AI-assisted decision support—remain hypotheses attached to the defined validation outcomes, and the authors invite colleagues who treat the atrophic maxilla to test the framework against their own cases.

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During preparation of this work, the authors used AI-assisted writing tools for

literature organization, language editing, document formatting, and figure ideation. The authors reviewed and edited all content and take full responsibility for the content of this article.

Author Contributions

Conceptualization, A.R.E. and J.G.; methodology, A.R.E., C.H. and J.G.; visualization, C.H.; writing—original draft preparation, A.R.E.; writing—review and editing, C.H. and J.G.; supervision, J.G. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

Dr. Gonzalez is the originator of the PATZi protocol. The authors are affiliated with Kaizen Surgical Academy, which provides surgical education related to full-arch reconstruction, and are exploring planning software based on the framework described.

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