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Review

The PATZi Protocol for Full-Arch Rehabilitation of the Atrophic Maxilla: A Narrative Review of the Literature

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Abstract

Immediate, graftless full-arch rehabilitation of the atrophic maxilla is constrained by alveolar resorption, sinus pneumatization, and poor posterior bone quality, and conventional four-implant configurations may end in a shortened dental arch, a long distal cantilever, or an unplanned change in strategy during surgery. The PATZi protocol (pterygoid, anterior, tilted, zygomatic implants) was proposed in 2023 as a stepwise algorithm that sequences implant techniques by maxillary region, reserves zygomatic implants for regions in which no other anchorage can be obtained, and codes each configuration with the aim of describing complexity and planning salvage. This narrative review, conducted without formal risk-of-bias assessment or data pooling, describes the algorithm, appraises evidence for its components and the protocol as a whole, and identifies the limitations of its clinical application. Systematic reviews report cumulative survival of 92.5–95.5% for pterygoid implants and about 95–97% for zygomatic implants; for tilted implants, most studies found no statistically significant difference from axial implants, although one meta-analysis found more failures in the maxilla. Nasopalatine, transnasal, and trans-sinus anchorage rest largely on small series. These results concern individual techniques and cannot be extrapolated to the algorithm. Evidence on the protocol itself is limited to its original description, 142 rehabilitations performed over the course of one year and reported only in terms of immediate loading and prosthetic arch length, a 2025 extension to the moderately atrophic maxilla, and one case report. PATZi is a coherent, prosthetically driven framework that has not been clinically validated; prospective comparative studies with long-term follow-up are needed to establish its outcomes.

Keywords: PATZi protocol; atrophic maxilla; full-arch rehabilitation; pterygoid implants; tilted implants; zygomatic implants; transnasal implants; immediate loading

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1. Introduction

Full-arch fixed implant rehabilitation is performed increasingly often, and as life expectancy rises, the number of edentulous patients, together with their expectation of a fixed prosthesis delivered on the day of surgery, is expected to grow further [1]. The maxilla is where this expectation meets its anatomical limits. Once the teeth are lost, the alveolar process resorbs while the maxillary sinus pneumatizes, and the bone that remains in the posterior segments is often of low density [2]. Where resorption and pneumatization are advanced, the bone left below the sinus may be too low to receive conventional axially placed implants in the molar region without augmentation [2]. This limitation applies to the moderately and severely atrophic maxilla and not to every edentulous patient, and the bone available varies from one region of the arch to another. Rehabilitation of the severely resorbed maxilla is widely regarded as one of the most demanding tasks in implant surgery [2].

For many years, the answer was extensive grafting [3,4]; Le Fort I downfracture, onlay grafts, and sinus floor augmentation have all been used to create bone for implants [5]. Grafting followed by delayed implant placement, however, is generally considered to carry more morbidity, a longer treatment time, and a higher cost than graftless alternatives [1,3,4]; meanwhile, graftless concepts have gained ground accordingly. The best-known approach is the four-implant arrangement with distally tilted posterior implants. When the sinuses are extensively pneumatized, the posterior implants of this arrangement may emerge no further back than the first premolars; the anteroposterior (AP) spread is then small and the prosthesis requires either a distal cantilever or a shortened arch [1]. The developers of PATZi regard both as compromises and argue that a shortened arch impairs quality of life [1]. That argument should be treated with caution. In partially dentate patients, a systematic review found oral health-related quality of life with a shortened dental arch to be similar to that obtained after restoration with removable partial dentures [6]. These data cannot simply be transferred to implant-supported full-arch prostheses, but they do not support the assumption that a shortened arch necessarily impairs quality of life, and, to our knowledge, patient-reported outcomes have not been compared between 10-tooth and 12–14-tooth implant-supported maxillary prostheses. Should one of the four implants be lost, the prosthesis may have to function on three [1].

Clinicians have therefore turned to remote anchorage in the vertical buttresses of the facial skeleton: pterygoid implants in the pterygomaxillary buttress, transnasal implants along the lateral nasal wall and zygomatic implants in the zygomaticomaxillary buttress [1]. Several decision schemes guide the choice among these options, most of them organized around the maxillary zones described by Bedrossian (zone I, premaxilla; zone II, premolar region; zone III, molar region) and the bone available in each (Figure 1) [7,8]. Even with careful planning, intraoperative findings such as poor bone quality, low insertion torque, or lack of primary stability can force the surgeon to improvise [1].

The PATZi protocol, published by Ponnusamy, Gonzalez, and Holtzclaw in 2023, is an attempt to give that improvisation a structure [1]. It grew out of a restoratively driven approach to zygomatic implants described earlier by its first author [9] and was extended in 2025 to the moderately atrophic maxilla with a grading and staging classification [10]. Its clinical scope, as published, is the atrophic maxilla that is to be restored with an immediately loaded fixed full-arch prosthesis: the original description covers the full range of configurations, including those that require one or more zygomatic implants [1], and the 2025 paper applies the same sequence to moderate atrophy and gives example configurations for moderate and advanced atrophy [10]. In an edentulous maxilla with little or no atrophy, in which the first-line options are all feasible, the fallback steps that distinguish the algorithm do not come into play. Outside this scope, the indexed literature contains a single case report, in an adult with Goldenhar syndrome [11]. One case shows that the

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sequence can be followed in a congenitally asymmetric maxilla; it does not permit any conclusion about congenital or acquired defects in general, and no report of the protocol in maxillae resected for tumor, in patients with clefts, or in irradiated bone was identified.

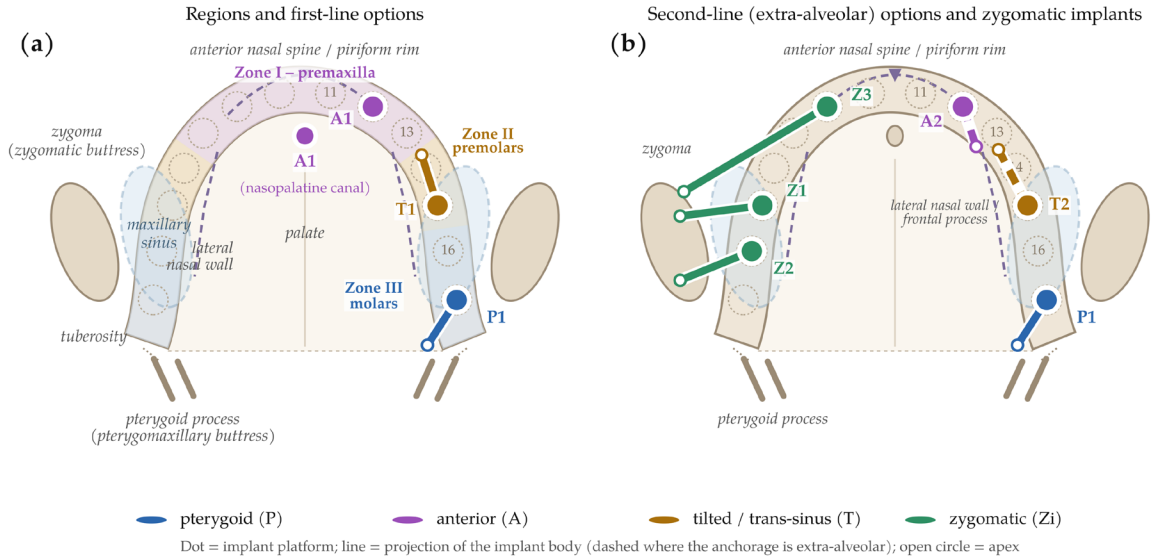


Figure 1. Schematic occlusal view of the edentulous maxilla showing the regions and anchorage sites used in the PATZi protocol. (**a**) Bedrossian zones I–III and the first-line options: a pterygoid implant (P1) in the molar region, whose platform lies in the tuberosity and whose apex engages the pterygoid process, a tilted implant (T1) in the premolar region, and anterior implants (A1) engaging the piriform rim or the nasopalatine canal. (**b**) Second-line options: transnasal (A2) and trans-sinus (T2) implants, drawn with dashed bodies to indicate extra-alveolar anchorage, and the three orientations of zygomatic implants (Z1, premolar platform; Z2, molar platform; Z3, anterior platform), all directed to the zygomatic body. Z1 and Z2 are drawn together for illustration only; they are not combined in the original description [1]. Dots mark the implant platform; lines mark the projection of the implant body in the occlusal plane, and open circles mark the apex. Drawings are created by the authors and are not to scale.

Two questions remain unresolved after the 2023 and 2025 publications. The first is whether the protocol as a whole, as distinct from the implant techniques it combines, is supported by clinical evidence: both papers are descriptive, both come from the developers of the protocol, and neither reports implant or prosthesis survival, complications, or patient-reported outcomes [1,10]. The second is how far each decision of the algorithm (its order, its fallback options and its criteria for moving to zygomatic anchorage) agrees with the independent literature on the individual techniques, which has not so far been set against the algorithm in a single appraisal. The objectives of this narrative review were therefore (i) to describe the algorithm and its coding system; (ii) to evaluate the evidence supporting each of its components—namely pterygoid, anterior, tilted, and zygomatic implants—in the rehabilitation of the atrophic maxilla; (iii) to analyze the data available on the protocol as a whole; and (iv) to identify the limitations of the evidence and of the clinical application of the protocol.

2. Literature Search and Selection Methods

This article is a narrative review. The search and the screening of records are reported below so that readers can judge how the sources were assembled, but the review was not registered, the flow of records is not reported, no formal assessment of the risk of bias was

undertaken, and no data were pooled. It should not be read as a systematic review, and its conclusions should be weighed with that in mind.

The initial search was carried out in MEDLINE (via PubMed), and its final run was on 20 September 2026. During the revision of the manuscript, the search was extended to two further sources, Web of Science and Google Scholar. The search combined the terms "PATZi", "pterygoid implant", "tilted implant", "zygomatic implant", "transnasal implant", "nasopalatine canal", and "atrophic maxilla". No limit was placed on the year of publication, and no language restriction was applied; all but one of the sources cited were published in English, the exception being a study published in Chinese with an English Abstract. The reference lists of the PATZi publications and of the systematic reviews retrieved were screened for further sources. Relevant publications may nevertheless have been overlooked, in particular reports in journals that are not indexed in MEDLINE or Web of Science, continuing-education articles, book chapters and conference proceedings.

Titles and Abstracts were screened against written eligibility criteria by three of the authors (B.F., M.B.-S., and N.M.A.). Publications were eligible if they addressed the PATZi protocol or related implant-supported techniques for the rehabilitation of the severely atrophic maxilla. Original clinical studies, whether prospective or retrospective, case series, case reports, systematic reviews, narrative reviews, and relevant technical reports were eligible, and publications dealing with surgical technique, anatomical considerations, treatment planning, implant survival, prosthetic rehabilitation, clinical outcomes, or associated complications were considered relevant. Publications were excluded if they dealt exclusively with conventional dental implants without relevance to the protocol or its individual components, addressed mandibular rehabilitation only, or lacked sufficient clinical or technical information for the objectives of the review; animal studies, in vitro investigations, and unrelated experimental studies were also excluded. The PubMed records were screened in two independent passes. Where the two passes disagreed, the record was decided against the criteria, with two further authors (A.A.B. and O.E.A.T.) acting as third reviewers, and two others (R.A.-Q. and D.A.-W.) carried out the final checks. Among the eligible publications on each technique, systematic reviews and meta-analyses were given precedence, followed by cohort studies; technical reports and case reports were retained only for techniques for which no higher-level evidence was found.

Data were extracted in narrative form, without a standardized extraction sheet. For each source, we noted the study design, the numbers of patients and implants, the follow-up, the outcome reported (implant survival, implant success, implant failure, marginal bone loss or complications) and the definition used for it. Survival and success rates are reported as published and were not pooled. No formal assessment of the risk of bias or of the certainty of the evidence was undertaken. Sources were weighed informally according to their design, their directness to the population of interest (full-arch rehabilitation of the atrophic maxilla), their size and follow-up, and their independence from the developers of the protocol; where the authors of a systematic review had themselves rated the risk of bias or the certainty of their evidence, their rating is reported. The sources cited therefore differ considerably in reliability and should not be regarded as equivalent, and the type of study is stated for each of them in the text.

A supplementary, targeted search was carried out in November 2026—during the revision of the manuscript—on four topics that the initial search had not addressed specifically: the complications and long-term outcomes of zygomatic implants, trans-sinus implants, and nasopalatine and transnasal implants in full-arch rehabilitation, as well as the effect of a shortened dental arch on quality of life. Seven sources were added as a result [6,12–17]; they were chosen for their relevance to these topics and did not pass through the screening described above.

3. Pterygoid Implants (P)

The first step of the algorithm deals with the molar region (Bedrossian zone III). In the original paper, the letter P stood for "posterior", with the pterygoid implant as the technique for that region (P1) [1]; later descriptions simply name the step after the implant [10]. Conventional axial implants are not among the options for this region, because the developers consider them rarely feasible there for want of bone volume and density [1]. A pterygoid implant enters through the maxillary tuberosity and runs posteriorly, superiorly, and medially to seat its apex in the dense bone of the pterygomaxillary junction [1]. Terminology in this region is inconsistent, and three terms need to be kept apart. Gaur et al. pointed out that many implants described as pterygoid are in reality tubero-pterygoid implants and that the intended target is the pterygoid pillar formed by the tuberosity, the pyramidal process of the palatine bone and the pterygoid process of the sphenoid [18]. In this review, "pterygoid implant" denotes an implant intended to engage the pterygoid process, whether or not its authors call it tubero-pterygoid, and "tuberosity implant" an implant that is confined to the tuberosity and does not engage the pterygoid plates. The P1 implant of PATZi is defined by apical engagement of the pterygomaxillary junction [1] and belongs to the first group; results obtained with tuberosity implants are reported below only where a source analyzed them separately, and they are not evidence for P1. The anatomical data compiled by Gaur et al. give a bone density in the pterygoid plate roughly 139% higher than in the tuberosity, which is the rationale for seeking primary stability at this site [18].

Several placement techniques have been described, among them preparation with osteotomes at the pterygoid process or the pterygomaxillary site [19] and flapless placement of single-piece implants [18]. They are not detailed here, because this review is concerned with the place of the pterygoid implant in the algorithm and with its clinical outcomes, not with surgical technique. Broumand and Kirchhofer regard pterygoid implants as a valid resource for the posterior atrophic maxilla and as an alternative to augmentation [2].

Three systematic reviews report the outcomes of implants in this region, but they use different outcome measures over different periods, and their figures are not directly comparable. The review by Candel et al. of 13 articles (676 patients, 1053 pterygoid implants followed for at least 12 months) gave a weighted mean success rate of 90.7%, that is, an average of the success rates published in the primary studies as their authors defined success; marginal bone loss was 0–4.5 mm, which the authors considered comparable with conventional implants, and there were no complications beyond those seen with conventional implants [19]. Bidra et al. restricted their analysis to roughened-surface implants and reported survival, not success: 10 studies with 911 pterygoid implants and up to 6 years of follow-up yielded 39 failures—37 of them within the first year, and 30 before loading—for a cumulative survival of 95.5% [20]. The largest review so far, by Raouf and Chrcanovic, pooled 38 studies with 2245 patients and 3446 implants followed for a mean of 61.0 months; it applied the same distinction between pterygoid and tuberosity implants and analyzed the two separately (3053 and 393 implants, respectively) [21]. Cumulative survival at 10 years was 92.5% for pterygoid implants, significantly lower than the 96.9% recorded for tuberosity implants ($p = 0.006$); most failures occurred within the first year, and three-quarters of the pterygoid implants, as against one-third of the tuberosity implants, supported full-arch prostheses, so that the two groups differed in more than the implant site [21]. A mean success rate at 12 months or more, a cumulative survival over up to 6 years, and a cumulative survival at 10 years are estimates of different quantities; they should not be set side by side as if they measured the same thing, nor read as a trend.

In the review of Raouf and Chrcanovic, immediately loaded implants had higher survival than those loaded early or late ($p < 0.001$) [21]. This association should not be taken

as an effect of the loading protocol. Implants are selected for immediate loading when their primary stability is high; almost all of the immediately loaded implants in the review were splinted in full-arch fixed prostheses, and the authors themselves pointed to high insertion torque and to the clinician's judgment as possible explanations and cautioned that confounding factors could not be separated in retrospective, unbalanced data [21]. Few complications were reported, and they were listed without frequencies: displacement into the pterygoid fossa, sinus membrane perforation and sinusitis, bleeding, postoperative pain, transient palatine nerve paresthesia, and peri-implant mucositis [21]. A 2026 meta-analysis by Diniz et al. comparing pterygoid with conventional implants in complete-arch maxillary rehabilitation (6 studies; 904 pterygoid and 2940 conventional implants) reported survival of 95.25% and 97.88%, respectively, with a higher risk of loss for pterygoid implants (risk ratio for implant loss 1.54; 95% confidence interval 1.05–2.24), and concluded that pterygoid implants are a viable option whose survival is slightly below that of conventional implants [22].

Individual series are consistent with these figures but, being retrospective and uncontrolled, add little to their certainty. At the University of Connecticut, 102 pterygoid implants in 69 patients followed for a mean of 34.35 months had a cumulative survival of 94.74%; all five failures occurred before functional loading, and only one minor postoperative complication was recorded [23]. Cea-Arestín et al. reported success, not survival, in 175 of 178 pterygoid implants (98.3%) placed in 113 patients over two decades [24]. In 25 patients rehabilitated with full-arch maxillary prostheses on anterior and pterygoid implants, Wu et al. found 1-year survival of 96.5% for the anterior and 97.8% for the pterygoid implants, with similar marginal bone loss (about 0.6–0.7 mm), similar peri-implant soft-tissue parameters, and high patient satisfaction [25]. Berniūtė et al. recorded no failures among 47 pterygoid implants in 37 patients followed for 6 to 96 months, although plaque around these distal implants was associated with smoking, older age, and thinner keratinized tissue, a reminder that they are harder to clean and need regular professional maintenance [26]. Pterygoid anchorage has also been built into patient-specific subperiosteal implants for extreme (Cawood and Howell class V–VI) atrophy [27]. This is a different device, a custom framework fixed to the surface of the bone with screws, and reports on it cannot be used as evidence for the efficacy of endosseous pterygoid implants.

PATZi places pterygoid implants first because, in the view of its developers, they lengthen the AP spread and allow molar occlusion without grafting [1]. If a pterygoid implant is not feasible, or cannot be seated with adequate primary stability, the posterior region is recorded as null (Px) and posterior support is obtained later in the algorithm from a zygomatic implant emerging in the molar area (Z2) [1]. The outcome data call for one qualification. Most failures of pterygoid implants occur early, many of them before loading [20,21,23]. These were implants that had been judged stable enough to be left in place, so that early loss cannot be attributed solely to insufficient stability at the time of surgery, and satisfactory insertion torque or clinical stability at placement does not by itself guarantee osseointegration. The intraoperative check built into the algorithm can be expected to exclude implants that are manifestly unstable, not to prevent early failure. The combination of zygomatic and pterygoid implants is likewise recognized in other decision schemes as a configuration (type 2B) for the severely atrophic maxilla [7].

4. Anterior Implants (A)

Once the posterior region has been dealt with, attention turns to the premaxilla (Bedrossian zone I) [1]. The first option (A1) is an intra-alveolar implant whose apex engages cortical bone, and several configurations are possible: the piriform rim, the anterior nasal spine, the lateral nasal wall, or the nasopalatine canal [1]. If an A1 implant is not feasible, the algorithm moves on to the extra-alveolar transnasal implant (A2), whose

body and apex are engaged in the thick cortical bone of the lateral nasal wall and the frontal process of the maxilla [1]. Only when a transnasal implant is also impossible is the anterior region recorded as null (Ax) and anterior anchorage obtained from an anteriorly positioned zygomatic implant (Z3) [1]. The preference for an extra-long transnasal implant over an anterior zygomatic implant is a premise of the original algorithm: its developers regard the transnasal implant as the less invasive of the two and wish to avoid a quad zygoma configuration [1]. It is not a demonstrated means of reducing surgical trauma. No study comparing the morbidity, the complications, or the survival of transnasal and anterior zygomatic implants was identified, and a clinical advantage of A2 over Z3 has not been established.

The nasopalatine canal is a much-discussed site in the atrophic premaxilla, and the clinical literature on it has been summarized in a scoping review of 29 studies [28]. The procedures grouped under this heading differ in purpose and in their relevance to PATZi, and four should be distinguished. The first is the use of the canal itself as an implant site: the neurovascular contents are removed, and the implant is placed within the canal to support the prosthesis. This is the situation of the nasopalatine implant in PATZi. In the one series identified in which it was used for the rehabilitation of severely atrophic maxillae, Peñarrocha et al. placed a nasopalatine implant in each of 13 patients with Cawood and Howell class V atrophy, together with implants at other sites; two of the 13 implants failed before loading and none thereafter, a success rate of 84.6% after a mean of 70 months, and six patients reported a slight loss of sensation in the anterior palate that resolved within weeks [12]. Particulate bone graft was packed into the canal before the implant was inserted, so that the technique was not strictly graftless [12]. The second is obliteration of the canal, in which the contents are removed, and the canal is grafted so that an implant can be placed in the incisor region. The pilot study of Bodereau et al. is of this kind: in 10 patients with a missing central incisor and a wide canal, the neurovascular contents were removed, the defect was grafted, and implants were placed, all of which were retained over 2 to 9 years with normal sensation [29]. It concerns the replacement of a single tooth with bone grafting and does not validate the use of the canal for anchorage in a graftless full-arch protocol. The third is repositioning of the neurovascular contents, which preserves them while an implant is placed in or beside the canal; it is applicable in principle to a nasopalatine implant, but only three studies report it [28]. The fourth is an implant driven through the canal to engage the anterior nasal spine, as in the Goldenhar syndrome case treated according to PATZi [11]; the evidence for this variant is that single case.

Pooled outcomes are available only for obliteration and repositioning. Yeo et al. found that implants placed after obliteration of the canal (16 studies; 92 implants) survived in 95.6% of cases, whereas implants placed after repositioning of the canal contents (3 studies; 57 implants) survived in 100%. Neurosensory disturbance of the anterior palatal mucosa, however, was more frequent after repositioning (34.6%) than after obliteration (9.6%), and persistent altered sensation was reported only in the repositioning studies [28]. These figures come from studies with differing indications and prosthetic designs, and how far they apply to graftless full-arch rehabilitation is uncertain. The protocol suggests an additional nasopalatine implant, when feasible, in the configurations in which the posterior region and at least one other region are null [1].

Transnasal implants have been described in several variants. In a case report, Oh et al. used “Z-point” transnasal implants anchored in the bone between the lateral nasal wall and the medial sinus wall at the level of the inferior turbinate; for their technique, they required at least 3 mm of bone at the Z-point and at least 4 mm from the crest to the nasal floor, and advised against it in very wide nasal fossae [30]. Combined with zygomatic, pterygoid, and nasopalatine implants, the fixtures in that patient reached an insertion torque above 80 Ncm, were loaded on the day of surgery, and the anterior cantilever was

removed [30]. These dimensions and this torque value are parameters of one technique in one patient. They are not validated criteria for selecting patients or for immediate loading. The largest series identified, a retrospective multicenter study by Gelpi et al., reported 52 nasal or transnasal implants in 31 patients with Cawood and Howell class V–VI atrophy of the anterior maxilla. All 52 implants were classed as successful after a healing period of 16 weeks, on criteria that included insertion torque, the absence of crestal bone resorption, and the feasibility of the planned prosthesis, and loading was immediate in the 17 patients (55%) in whom insertion torque reached 50 Ncm and delayed in the others [13].

The safety of the anterior options has been assessed less fully than their survival. For the nasopalatine canal, the best-documented adverse effect is sensory disturbance of the anterior palate, which was transient in the series of atrophic maxillae [12] and was more frequent, and in some patients persistent, when the neurovascular contents were repositioned than when the canal was obliterated [28]. For transnasal implants, the reports identified describe primary stability and implant success over the healing period [13,30]. They do not provide systematic information on nasal complications, such as obstruction, rhinosinusitis, epistaxis or exposure of the implant in the nasal cavity, on the long-term condition of the nasal mucosa and of the peri-implant soft tissues, or on implant survival in the longer term. The evidence for anterior extra-alveolar anchorage thus consists of technical descriptions, case reports and one short-term retrospective series, and its long-term outcomes, and its safety relative to anterior zygomatic implants, are not yet known.

5. Tilted Implants (T)

The T step deals with the premolar region (Bedrossian zone II) [1]. A conventional tilted implant (T1) is placed parallel and anterior to the anterior sinus wall, which lets the platform emerge further distally and increases the AP spread without sinus augmentation [1]. If a T1 implant is not feasible, a trans-sinus implant (T2) is considered; this implant crosses the anterior part of the maxillary sinus to seat its apex in the lateral nasal wall [1]. If neither is possible, the region is recorded as null (Tx) and a zygomatic implant emerging in the premolar area (Z1) is indicated [1]. The authors note that Z1 is the zygomatic implant they need most often, because extensive sinus pneumatization frequently rules out an intra-alveolar implant in the premolar region [1]. The evidence for T1 and for T2 is of a different order, and the two are considered separately below.

Conventional tilted implants (T1) are the best-documented element of the protocol. The reviews summarized here compare tilted with axial (upright) implants; they were not designed to evaluate trans-sinus implants, and their results are taken as evidence for T1 only. Del Fabbro et al. reviewed 10 studies of immediately loaded rehabilitations of edentulous jaws, maxillary and mandibular, with 462 patients and 1992 implants, and found 25 failures (1.25%) in the first year, nearly all in the maxilla, with no difference between tilted and upright implants and no loss of a prosthesis [31]. Confining the analysis to the immediately loaded maxilla, Menini et al. pooled 11 studies (324 patients, 1623 implants) and reported first-year failure of 2.19% for tilted and 1.89% for upright implants (risk ratio for implant failure 1.23; 95% confidence interval 0.66–2.30) and no difference in marginal bone loss (mean difference 0.02 mm) [32]. Ata-Ali et al. likewise found no difference in success between tilted and axial implants in either retrospective or prospective studies, and very similar marginal bone loss [33].

The largest meta-analysis, by Chrcanovic et al., covered 44 studies in either jaw comparing 5029 tilted with 5732 axial implants; failure rates were 1.63% and 1.81% (risk ratio for implant failure 1.14; 95% confidence interval 0.84–1.56) and marginal bone loss did not differ (mean difference 0.03 mm) [34]. When the analysis was restricted to the maxilla, however, tilted implants failed significantly more often than axial implants (risk ratio for implant failure 1.70; 95% confidence interval 1.05–2.74), whereas no difference was found

in the mandible. The authors cautioned that confounding in non-randomized studies makes these estimates uncertain [34]. Lin and Eckert, reviewing 42 studies on full-arch prostheses for a consensus conference of the International Team for Implantology (ITI), could not pool the data because of heterogeneity; descriptively, there was no difference in clinical performance, and fracture of the interim acrylic prosthesis and screw loosening were the commonest complications [35]. For the edentulous maxilla specifically, Mehta et al. reported 3-year survival of 99.41% for tilted and 100% for axial implants (risk ratio for implant survival 1.00; 95% confidence interval 0.98–1.01) with no difference in bone loss, although the certainty of the evidence was rated very low to low [36]. In fixed partial dentures, Batista et al. also found no difference in implant failure (2.23% versus 1.79%; $p = 0.81$) but slightly more marginal bone loss around tilted implants (mean difference 0.12 mm; $p = 0.001$), a difference they judged unlikely to matter clinically [37].

Three points govern the interpretation of these reviews. First, they are not independent of one another. They were published between 2012 and 2024, address the same question and draw on the same limited pool of largely non-randomized clinical studies, so that many primary cohorts are likely to contribute to more than one of them. We did not map this overlap formally, but agreement between the reviews should not be counted as repeated, independent confirmation. Second, they differ in how directly they apply to full-arch rehabilitation of the atrophic maxilla. The analyses confined to the maxilla [32,36] and the maxillary subgroup of the largest meta-analysis [34] are the most relevant. The reviews that are not confined to the maxilla [31,33,35] are less direct, and the review of fixed partial dentures [37], in which the implants are splinted over a short span and not across the arch, bears only indirectly on the protocol. Third, the comparison most relevant to PATZi, the maxillary subgroup of the largest meta-analysis, found a risk of failure about 70% higher for tilted than for axial implants, with a confidence interval that excludes equality [34]. The absolute failure rates were low, and the estimate was open to confounding. However, the two maxillary analyses that found no significant differences were smaller and cannot exclude such an increase in size: the upper confidence limit of the risk ratio for failure reported by Menini et al. was 2.30 [32]; Mehta et al. rated their own evidence as very low to low certainty [36]. Therefore, it is accurate to say that most of the reviewed studies found no statistically significant differences between the tilted and axial implants; however, it is not accurate to say that the two are equivalent in the maxilla.

Trans-sinus implants (T2) have a much smaller evidence base. A systematic review by Gianfreda et al. identified 10 studies of full-arch rehabilitation with trans-sinus implants; in its meta-analysis, 5 of 232 trans-sinus implants failed, as against 5 of 675 axial or conventionally tilted implants (risk ratio for implant failure 2.80; 95% confidence interval 0.89–8.77; $p = 0.076$) [14]. The difference was not statistically significant, but the confidence interval is wide and is compatible with a substantially higher risk of failure, so that the results obtained with conventional tilted implants cannot be assumed to hold for trans-sinus implants. The authors of the review themselves called for controlled trials with longer follow-up [14].

6. Zygomatic Implants (Zi)

Zygomatic implants were introduced by Brånemark to give posterior anchorage in the maxilla and to shorten rehabilitation, and they have been used both for the atrophic edentulous maxilla and for maxillectomy defects [38]. These are different indications, and only the first is the subject of PATZi and of this review. For severe maxillary atrophy, zygomatic implants are now regarded as a stable and predictable alternative to extensive grafting [3,4], and their history, anatomy, placement techniques, stabilization, and prosthodontic management have been reviewed in detail [5]. In a systematic review of indications, Polido et al. included 10 studies with 209 patients and 622 zygomatic implants

followed for a median of 28.5 months; mean implant survival was 97% (range 89–100%) [39]. The population was mixed: 181 patients were treated for extreme atrophy, after failed grafts or implants, or to avoid staged grafting; 16 were treated after benign or malignant maxillary resection; 7 were treated for cleft palate; and 5 were treated for other medical reasons. The survival figure refers to all of them together [39]. Resected maxillae results should not be transferred to the atrophic maxilla. In the updated review of Chrcanovic et al. (68 studies, 4556 zygomatic implants, 12-year cumulative survival 95.2%), the five studies of rehabilitation after maxillary resection showed lower survival [15]. In the long-term meta-analysis of Brennand Roper et al. (18 studies, 1349 zygomatic implants followed for at least 3 years; mean survival 96.2%, 95% confidence interval 93.8–97.7), resection patients were included but were too few to be analyzed separately [17]. Mouth opening below 30 mm, acute sinusitis, and irradiation above 70 Gy were listed by Polido et al. as contraindications, and the authors stressed that the procedure belongs in experienced hands and that three-dimensional imaging and prosthetic planning are mandatory [39].

Surgical technique has moved from the original intrasinus approach, which gains anchorage in up to four cortical layers but emerges on the palate and produces a bulky prosthesis, towards extrasinus or extramaxillary approaches that are prosthetically driven and emerge at the crest [8]. These approaches are often said to carry a lower risk of sinusitis [8], but the evidence for this is indirect. In the systematic review of Kämmerer et al. (24 studies, 918 patients, 2194 zygomatic implants), the probability of sinusitis was 9.53% with the original surgical technique and 4.39% with anatomy-guided approaches, and soft-tissue infection, paresthesia, and oroantral fistula were also less frequent with the latter. Only one of the included studies compared the techniques directly; however, no statistical comparison was made; the two groups of studies differed in period, follow-up, and loading protocol; and the authors noted that complications were probably under-reported [16]. A lower risk of sinusitis with extrasinus placement is therefore plausible but has not been established by direct comparison. Aparicio et al. reviewed the outcomes of the zygoma anatomy-guided approach (ZAGA) and proposed the Zygomatic Success Code, which judges a zygoma-anchored rehabilitation not by implant survival alone but by implant stability, associated sinus pathology, the condition of the peri-implant soft tissues and the prosthetic offset [38]. Alterman et al. recommended at least 7 mm of zygomatic anchorage, ideally bicortical, an insertion torque of 35–45 Ncm, a distance of at least 5 mm between the apex of an anterior zygomatic implant and the inferolateral orbital rim, and coverage of extramaxillary implants with the buccal fat pad; they cited survival of 95.8–99.9% from earlier reviews and listed bleeding, orbital injury, sinus damage and fracture among the complications [8]. These values are the recommendations of one group of authors. They are reported here as such and should not be read as validated thresholds of safety, for which separate evidence would be required. From the restorative side, Ponnusamy and Miloro proposed the Restoratively Aimed Zygomatic Implant Routine, in which the implant head is positioned as close as possible to the central fossae and cingula of the planned teeth so as to avoid the buccopalatal cantilever, speech problems, and hygiene difficulties of palatally emerging implants [9]. Other schemes combine zygomatic implants with anterior implants (type 2A) or with pterygoid implants (type 2B), or use quad zygoma when the premaxilla has resorbed to the nasal floor [7].

Implant survival is only part of the outcome of a zygoma-anchored rehabilitation. Sinusitis, soft-tissue complications, prosthetic complications, and patient-reported outcomes have been pooled in reviews of case series [15–17]; they are considered, together with the corresponding outcomes of the other techniques, in Section 8.3.

In PATZi, unlike the first three letters, Zi denotes a type of implant rather than a region, and its use is dictated entirely by the null classifications assigned earlier in the sequence [1]. If no region is null, no zygomatic implant is placed (Z0). A Tx classification

calls for a Z1 implant, with its platform in the premolar region and its apex at the posteroinferior aspect of the zygoma; a Px classification calls for a Z2 implant, with its platform in the molar region and its apex likewise posteroinferior; and an Ax classification calls for a Z3 implant, whose platform emerges anteriorly and whose apex sits in the anterosuperior part of the zygoma [1]. Z1 and Z2 thus share the same apical position and differ only in where the platform emerges, and in the table of combined null classifications and the decision tree of the original description, they never appear together, whereas Z3, which occupies a different part of the zygoma, is combined with either [1]. Keeping the apices of Z1 and Z2 implants low and posterior is intended to preserve the rest of the zygomatic body for a second or a salvage implant [1]. When more than one region is null, as in severe atrophy, the indications are therefore not simply added together. A posterior and a premolar deficit are compensated by a Z2 implant alone, with additional anterior anchorage recommended where possible; an anterior and a premolar deficit by Z1 and Z3, a quad zygoma configuration with pterygoid support; and a posterior and an anterior deficit, with or without a premolar deficit, by Z2 and Z3, the conventional quad zygoma configuration. Where the posterior region is among the null regions, an additional nasopalatine implant is suggested if possible (Table 1) [1]. The Goldenhar syndrome case is an example of the sequence applied to an asymmetric maxilla: in a patient whose left zygoma was only 6.5 mm high, two pterygoid implants, one nasopalatine implant, and two zygomatic implants were placed; the composite insertion torque exceeded 300 Ncm; the prosthesis was loaded immediately; and the result was reported as stable, with minimal bone loss, for almost 5 years [11].

Table 1. Decision pathways of the PATZi protocol and the resulting indication for zygomatic implants, compiled from Ponnusamy et al. [1].

Pterygoid	Anterior (A1 or A2)	Tilted (T1 or T2)	Zygomatic Indication [1]
P1	Yes	Yes	None (Z0)
P1	Yes	No (Tx)	Z1
P1	No (Ax)	Yes	Z3
P1	No (Ax)	No (Tx)	Z1 + Z3
Px	Yes	Yes	Z2
Px	Yes	No (Tx)	Z2 ± nasopalatine implant [2]
Px	No (Ax)	Yes	Z2 + Z3 ± nasopalatine implant
Px	No (Ax)	No (Tx)	Z2 + Z3 ± nasopalatine implant [2]

Note. [1] Z1: platform in the premolar region, apex at the posteroinferior aspect of the zygoma; Z2: platform in the molar region, apex at the posteroinferior aspect of the zygoma; Z3: platform in the anterior region, apex at the anterosuperior aspect of the zygoma. [2] Z1 and Z2 share the posteroinferior apical position and are not combined in the original description: when both the posterior and the premolar regions are null, Z2 is indicated, and Z1 is not added; for Px with Tx alone, additional anterior anchorage is recommended where possible. According to the developers, surgical difficulty and technique sensitivity increase from the first row to the last; this grading has not been validated.

The composite (or cumulative) torque value quoted in that report is the arithmetic sum of the insertion torques of all the implants that support the prosthesis. It is used as an arch-level surrogate for primary stability, and the case report cites 120 Ncm as a proposed threshold for immediate loading of a full arch [11]. The measure has inherent limitations. It rises with the number of implants, so that values from configurations of different sizes are not comparable; a high total can conceal an implant with poor individual stability; and insertion torque reflects resistance to rotation at the moment of placement, which depends on implant design, site preparation, and bone density, not the behavior of the implant under functional load. No threshold has been validated against clinical

outcome for prostheses on remote anchorage, and a single case with a favorable course cannot serve as evidence that immediate loading is safe above a given value.

7. The PATZi Protocol

PATZi is an ordered decision algorithm in which specific implant techniques are assigned to specific regions of the maxilla: posterior (pterygoid), anterior, tilted (premolar), and zygomatic (Figure 2) [1]. The goal is a provisional fixed prosthesis of adequate arch length that can be loaded immediately, obtained with the techniques that its developers regard as least invasive [1]. Its developers present it as both a preoperative and an intraoperative workflow [1]. The original paper words the sequence largely in terms of attempts: an implant that does not achieve primary stability or sufficient insertion torque (less than 35 Ncm is given as insufficient) is abandoned, and the next technique in the sequence is used [1]. It does not, however, require every option to be attempted surgically before the next is considered, and its own cases show both situations. In Case 5, the transnasal implant was passed over because its indications were not met, and intra-alveolar anterior and tilted implants were judged not to be possible; in Cases 2 and 3, by contrast, tilted and pterygoid implants, respectively, were attempted and abandoned [1]. We therefore read the sequence in a double sense. Before surgery, the regions are assessed in the order given, and an option that is anatomically unavailable is passed over without being attempted; during surgery, the same order supplies the fallback when a planned implant cannot be stabilized. The published code does not show which decisions were taken before and which during surgery, and this should be reported in future clinical studies. Nor do all regions have the same number of options. The anterior and premolar regions each have a first-line intra-alveolar option (A1, T1), a second-line extra-alveolar option (A2, T2), and a null classification (Ax, Tx). The posterior region is the exception: it has a single option, the pterygoid implant (P1), whose platform lies in the tuberosity and whose apex is anchored beyond the alveolar process, and a null classification (Px). The original description is not consistent about the class to which this implant belongs: its diagram of the algorithm labels only the anterior and tilted options as intra-alveolar or extra-alveolar; its Discussion counts pterygoid implants among the extra-alveolar implants; and the legend of Case 1, in which pterygoid implants were placed, describes every section as filled with intra-alveolar implants [1]. In this review, the two labels are applied, as in that diagram, to the anterior and tilted options only, and the pterygoid implant is described by its anatomy. There is no second-line posterior implant, and a posterior deficit is compensated only at the zygomatic step. A removable denture, grafting with delayed implant placement, or a patient-specific subperiosteal implant are considered only when the whole algorithm, including the zygomatic step, cannot deliver adequate stability, composite torque value, and AP spread [1].

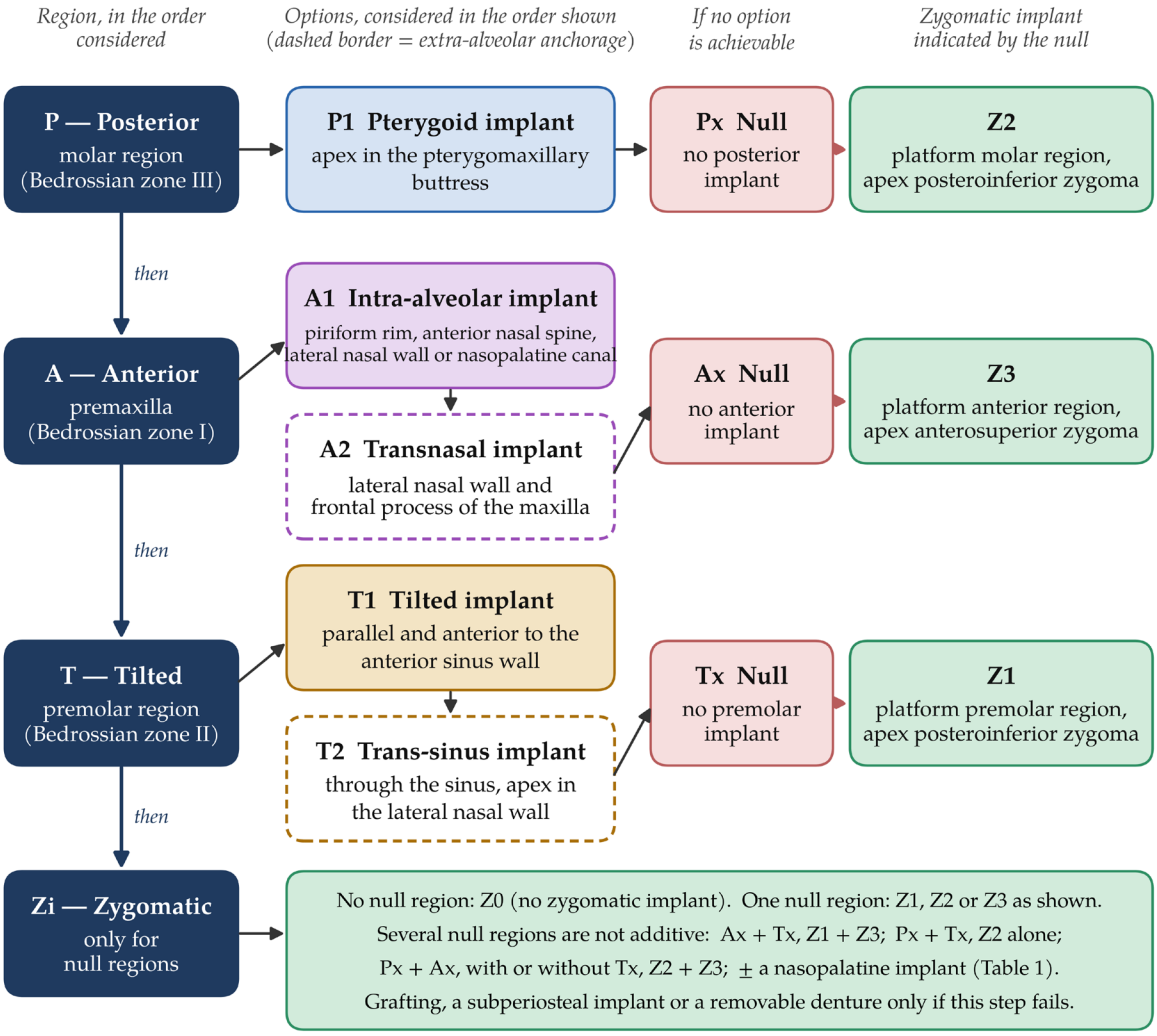


Figure 2. Decision sequence of the PATZi protocol. The regions are considered in the order shown on the left, at the planning stage and, if a planned implant cannot be stabilized, during surgery; an option that is anatomically unavailable is passed over without being attempted. In the anterior and premolar regions, the intra-alveolar option (A1, T1) is considered first and the extra-alveolar option (A2, T2) second; the posterior region has a single option (P1). A region in which no option is feasible is recorded as null (Px, Ax, or Tx). The right-hand column shows the zygomatic implant that corresponds to each null classification taken singly (Z2, Z3, or Z1). Combined null classifications are not additive: Z1 and Z2 share the posteroinferior apical position and are not combined in the original description; the combinations are listed in the bottom box and in Table 1. Solid arrows show the order in which the options are considered; dashed arrows show the zygomatic implant indicated by a null classification. Box colours follow the region (blue, posterior/pterygoid; purple, anterior; amber, tilted; green, zygomatic; red, null); dashed borders mark the options labeled extra-alveolar in the original diagram (A2, T2). Drawn by the authors from the description by Ponnusamy et al. [1].

The criteria for immediate loading operate at different levels and are set out separately here. At the level of the individual implant, the criteria are primary stability and insertion torque, a torque below 35 Ncm being regarded as insufficient; an implant that does not meet them is replaced by the next option for its region [1]. At the level of the arch, the developers refer to the AP spread and to the composite torque value, and give a numerical threshold for neither [1]; a composite torque of 120 Ncm is cited as a proposed threshold in the case report, in which more than 300 Ncm was recorded [11]. At the level

of the prosthesis, the implants are splinted across the arch by a provisional fixed prosthesis of full arch length, designed without a distal cantilever wherever the configuration allows [1]. The original description does not state how these elements are to be weighed against one another, for instance whether a high composite torque can offset one poorly stable implant, or what the minimum number of anchors is for a given distribution [1]. To our knowledge, none of the thresholds has been validated for the configurations that the protocol generates: no study has related individual or composite torque, the number of anchors, or their distribution to the outcome of prostheses delivered under PATZi.

PATZi is also proposed as a classification. Each configuration is written as an alphanumeric code: P1A1T1Z0, for instance, denotes pterygoid, intra-alveolar anterior, and tilted implants without zygomatic implants—the configuration otherwise known as the pterygoid fixated arch stabilization technique (PFAST). In contrast, P1AxTxZ1,3 denotes pterygoid implants combined with premolar- and anterior-oriented zygomatic implants [1]. The code records the type of anchorage used in each region, not the number of implants. In the five published examples, a single code is given for the whole arch [1], and, as drawn in Figure 3, each element of the code stands for one implant on each side; the number of implants can be inferred from the code only on that assumption. The original description gives no convention for writing an asymmetric arch [1]. Nor does the code show an additional nasopalatine implant: the nasopalatine canal is one of the A1 sites, yet a nasopalatine implant is also suggested as an adjunct in combined null configurations, including those in which the anterior region is itself coded null (Ax) [1]. Because the bone available often differs between the two sides, we suggest that the sides be coded separately when they differ (for example, right P1A1T1Z0, left P1A1TxZ1) and that the number and sites of the implants, adjunctive implants included, be reported alongside the code. According to its developers, the code conveys how resorbed the maxilla is and how demanding the surgery was, gives the surgeon and the restorative dentist a common language, and makes it easier to plan salvage should an implant fail [1]. These functions are plausible but have not been tested: no study of the reproducibility of the code, or of its relation to operating time, morbidity, or outcome, was found. The decision pathways are summarized in Table 1.

The original publication illustrated the protocol with five maxillary arches (Figure 3) [1]. In Case 1 (P1A1T1Z0), pterygoid implants, intra-alveolar anterior implants engaging the piriform rim, and conventional tilted implants gave adequate stability, and no zygomatic implant was needed. In Case 2 (P1A1TxZ1), an attempt to place tilted implants was unsuccessful for lack of bone, and Z1 zygomatic implants were placed with their apices kept inferolateral in the zygoma to preserve bone for a possible future implant. In Case 3 (PxA1T1Z2), the pterygoid implants failed to achieve primary stability; stopping at four implants would have meant a shortened arch or a long cantilever, and Z2 zygomatic implants restored first-molar occlusion. In Case 4 (P1A2TxZ1), bilateral transnasal implants took the place of anterior zygomatic implants, illustrating the preference of the protocol for the transnasal option. In Case 5 (P1AxTxZ1,3), intra-alveolar anterior and tilted implants were not possible, and the indications for transnasal implants were not met; the resulting null classifications in the anterior and the premolar region required Z1 and Z3 zygomatic implants, while the successful pterygoid implants still allowed a full-length arch without a cantilever [1]. These cases were chosen by the developers to show how the algorithm and the code are applied; they are illustrations, not evidence of clinical outcome.

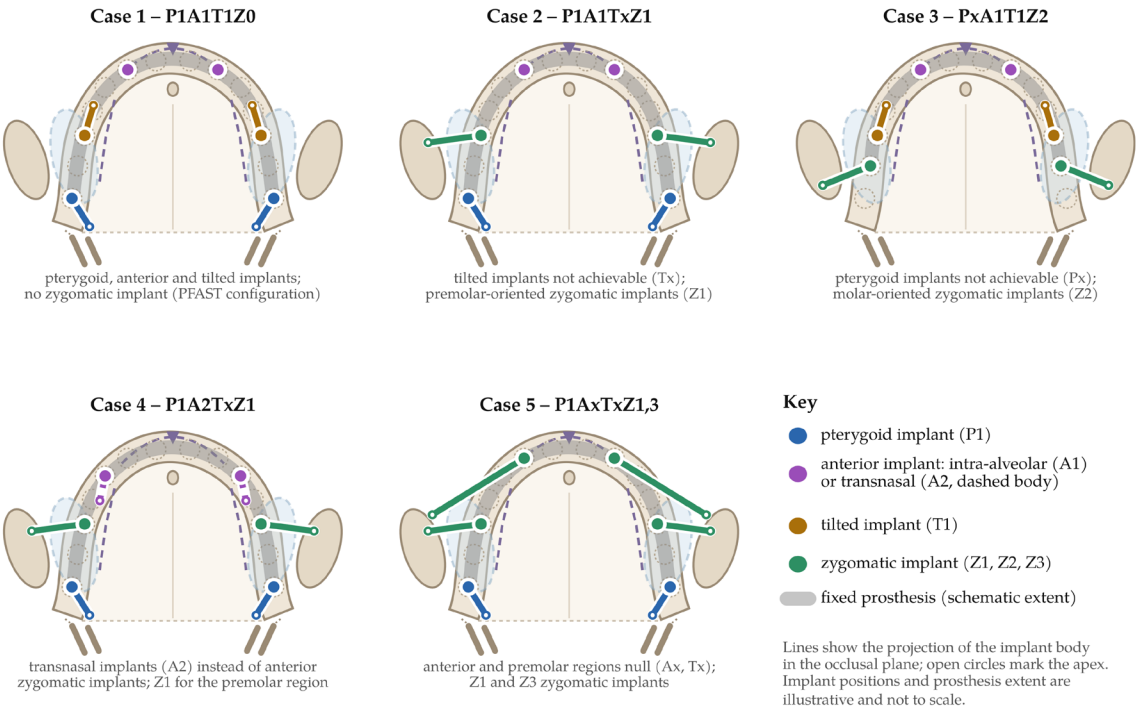


Figure 3. Occlusal schematics of the five implant configurations reported in the original description of the protocol [1]: Case 1, P1A1T1Z0; Case 2, P1A1TxZ1; Case 3, PxA1T1Z2; Case 4, P1A2TxZ1; Case 5, P1AxTxZ1,3. The grey band indicates the schematic extent of the fixed prosthesis, which reaches the first molars in Case 3 and the second molars where the pterygoid implants are present. Implant positions and prosthesis extent are illustrative and not to scale.

To describe arch-length outcomes, the developers introduced the Full-Arch Ratio (FAR) (Figure 4). As defined in the text of the original paper, the number of cantilevered arches is divided by the number of zero-cantilevered arches, the quotient is subtracted from 1, and the result is multiplied by 100—that is, FAR = [1 − (cantilevered arches/zero-cantilevered arches)] × 100. The equation itself is printed with the brackets around the quotient only [1]. A cantilevered arch is a prosthesis with a distal cantilever of at least one tooth or with fewer than 12 teeth; the index runs from negative infinity to 100, 100 is the goal, and cases of division by zero are to be disregarded [1]. The developers reported that, among 142 maxillary full-arch rehabilitations performed over the course of one year under the protocol, all of them were immediately loaded, nine final prostheses incorporated a distal cantilever and/or a reduced number of teeth, and they gave the FAR as 94 [1]. The one-year period is the period over which the patients were treated, not a period of follow-up: no follow-up interval and no implant or prosthesis survival were reported for this series [1]. The restorative target is a prosthesis of 12 to 14 teeth, as against the 10-tooth design often associated with conventional four-implant configurations [1].

Three observations on the FAR are our own interpretation and form no part of the original report. First, the published formula and the published result do not coincide. Nine cantilevered arches among 142 leave 133 zero-cantilevered arches, and the formula, as published, then gives [1 − (9/133)] × 100 = 93.2; the reported value of 94 is obtained by rounding from 93.7 only if the total number of arches is used as the denominator, [1 − (9/142)] × 100. We reproduced the published definition and value unchanged, and we do not know which denominator the developers intended. The numerical difference is small here, but the two versions diverge as the proportion of cantilevered arches rises, and only the published version can take negative values. Second, the two categories are not

described consistently in the original paper. The definition of a cantilevered arch as a prosthesis of fewer than 12 teeth is not matched by the wording of the results, which refers to 12 teeth or fewer, and the legend of the figure that illustrates the categories assigns the cantilevered designs to the denominator and the zero-cantilevered designs to the numerator, the reverse of the formula [1]. The two wordings of the tooth count are not equivalent, since a 12-tooth prosthesis without a cantilever is a zero-cantilevered arch under the first wording and a cantilevered arch under the second. Because the stated restorative target is 12 to 14 teeth, and the same legend describes the zero-cantilevered arch as a design of 12 teeth or more, we take "fewer than 12 teeth" to be the intended definition and keep to the formula for the numerator and the denominator in this review and in Figure 4. Third, the cantilevered arch category combines two distinct features. A distal cantilever is a question of load: it applies a bending moment to the most distal implants and to the framework. A reduced number of teeth is a question of arch length: it shortens the occlusal table, and may do so without any cantilever. A prosthesis can have either feature without the other; the length of a cantilever is not taken into account, and the index does not distinguish between them. For clinical interpretation, the number of teeth and the presence and length of a distal cantilever should be reported separately. Lastly, the FAR describes the design of the prosthesis at delivery; it is not a measure of clinical outcome.

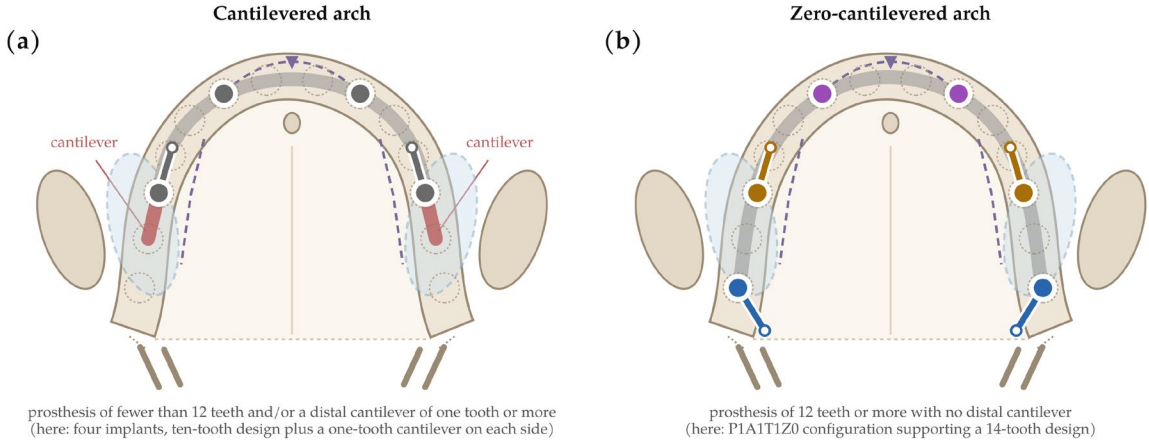


Figure 4. The two prosthetic categories that define the Full-Arch Ratio (FAR). (**a**) A cantilevered arch: a prosthesis of fewer than 12 teeth and/or with a distal cantilever of at least one tooth, illustrated by a conventional four-implant configuration supporting a ten-tooth design with a one-tooth cantilever on each side (red); the index places these two features in one category, although they are distinct. (**b**) A zero-cantilevered arch: a prosthesis of 12 teeth or more without a distal cantilever, illustrated by a P1A1T1Z0 configuration supporting a 14-tooth design. The box below the panels gives the formula as published, as well as the value reported for 142 arches [1], followed by our recalculation, which shows that the reported value corresponds to a denominator of all arches, not the published formula (see text).

In 2025, the developers applied PATZi to the moderately atrophic maxilla, describing the concept step by step and adding a grading and staging classification, example configurations for moderate and advanced atrophy, and a predictive framework intended to assist triage, referral, and patient management [10]. Like the code, the grading and staging classification is a proposal that has not been validated. The protocol has also been used in

one adult patient with Goldenhar syndrome [11]. A single case shows that the sequence can be followed in a congenitally asymmetric maxilla; it cannot be generalized to congenital or acquired defects, which have not been evaluated.

8. Discussion

8.1. What the Protocol Adds

The anatomical and biomechanical principles on which PATZi rests were not introduced by it. Zonal assessment of the maxilla, anchorage in the buttresses of the facial skeleton, the pursuit of AP spread and the avoidance of distal cantilevers, and each of the implant techniques that the protocol uses were described before PATZi and are shared with other decision schemes [7,8]. PATZi's distinctive features are narrower and consist of three things: an explicit order in which the regions—and the options within them—are considered; a predefined fallback for each region that ends in a zygomatic implant of a specified orientation; and a code that records the final configuration [1]. Frameworks based on the Bedrossian zones choose a configuration before surgery from the bone available in each zone [7,8]. PATZi keeps the zonal logic and adds a stated sequence to follow when a planned implant cannot be placed or stabilized. This may be useful because anatomical variability can force a change of plan mid-procedure, even when a fully guided system is used [1]. However, whether a predefined sequence leads to better decisions or outcomes than the judgment of an experienced surgeon has not been examined.

The protocol makes use of anchorage in the vertical buttresses of the facial skeleton (the lateral nasal walls, the zygomaticomaxillary buttresses, and the pterygomaxillary buttresses), the same structures that carry fixation after a Le Fort I osteotomy (Figure 5) [1]. Placing pterygoid implants first is intended to maximize AP spread and composite torque, shorten or remove the distal cantilever, and reduce the chance that losing one implant will compromise the prosthesis [1]. These are theoretical benefits, derived from mechanical reasoning, and they have to be distinguished from demonstrated ones. A wider distribution of supports and the absence of a cantilever are expected to lower bending moments on the implants and the framework. However, no clinical study has shown that prostheses delivered under PATZi have fewer mechanical or biological complications, or that the patients who receive them have a better quality of life than those treated with other configurations. The argument that full arch length is a patient-centered goal because a shortened dental arch impairs quality of life [1] is likewise unproven for implant-supported prostheses: the evidence from partially dentate patients does not show such an impairment [6], and patient-reported outcomes have not been compared between prostheses of different arch length.

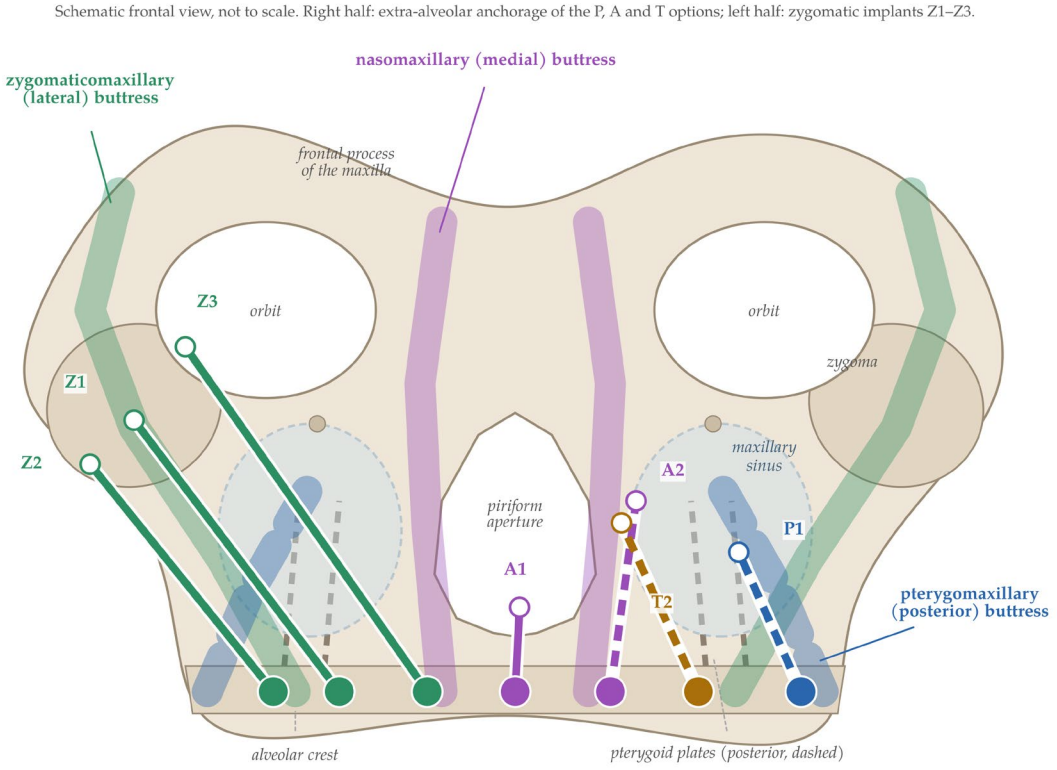


Figure 5. Schematic frontal view of the midface showing the vertical buttresses that provide cortical anchorage for the extra-alveolar implants of the PATZi protocol: the nasomaxillary (medial) buttress along the piriform aperture and the frontal process of the maxilla, engaged by transnasal (A2) and trans-sinus (T2) implants; the zygomaticomaxillary (lateral) buttress, engaged by zygomatic implants (Z1–Z3, left half of the drawing); and the pterygomaxillary (posterior) buttress, engaged by pterygoid implants (P1). A nasopalatine implant (A1) is shown in the midline. Dashed implant bodies indicate anchorage beyond the alveolar process; in this view, they include the pterygoid implant, which is shown without dashes in Figures 1 and 2 because the original algorithm diagram does not label it as extra-alveolar. Drawing by the authors; not to scale.

8.2. Consistency with the Evidence

The agreement between the algorithm and the evidence is partial, and it differs from one decision to the next. None of the decisions has been tested in a study comparing the PATZi sequence with another strategy; each rests on comparative studies of a single technique, indirect evidence from uncontrolled series of that technique, or the developers' reasoning. Table 2 classifies the principal decisions in this way, and Figure 6 shows the outcomes reported for the individual techniques. Three decisions call for particular comment.

Table 2. Basis of the principal decisions of the PATZi algorithm, classified by the type of evidence available. No decision has been tested in a study comparing the PATZi sequence with another strategy.

Decision	Type of Evidence	Sources and Comment
Pterygoid implant considered first	Expert reasoning; indirect evidence	AP spread, cantilever and composite torque argued on mechanical grounds [1]. Cumulative survival 92.5–95.5% in reviews of uncontrolled series [20,21]; lower survival than conventional implants in one meta-analysis [22]. No comparison of sequences.
Intra-alveolar anterior implant (A1), including the nasopalatine canal	Indirect evidence	Small series; success 84.6% for nasopalatine implants in atrophic maxillae [12]; pooled data from studies with mixed indications [28].
Transnasal implant (A2) preferred to anterior zygomatic implant (Z3)	Expert reasoning	Premise of the algorithm [1]. A2 documented by a case report and one short-term series [13,30]. No comparison with Z3.
Conventional tilted implant (T1) as first option in the premolar region	Comparative studies, largely non-randomized	No significant difference from axial implants in most reviews; more failures in the maxilla in the largest meta-analysis [31–37]. The reviews overlap.
Trans-sinus implant (T2) as second option	Comparative studies, few and small	Risk ratio for failure 2.80 (95% confidence interval 0.89–8.77) versus axial or tilted implants: not significant, wide interval [14].
Region declared null and zygomatic implant indicated	Expert reasoning	Anatomical limits and the 35 Ncm criterion not validated for the protocol [1].
Zygomatic implants reserved for null regions	Indirect evidence; expert reasoning	Survival about 95–97% in reviews of case series, with sinusitis and soft-tissue complications [15–17,39]. Not shown that the resulting configurations carry fewer complications.
Apices of Z1 and Z2 kept posteroinferior for salvage	Expert reasoning	Rationale of the developers [1]. No data on salvage.
Immediate loading of the resulting configuration	Indirect evidence	Higher survival with immediate loading in reviews of pterygoid and zygomatic implants, open to confounding by selection [15,17,21]. No threshold validated for PATZi.
Configuration code and Full-Arch Ratio	Not validated	Proposed by the developers [1]. Reproducibility and relation to outcome not studied.

Note. Comparative studies: studies or meta-analyses that compare the technique with another. Indirect evidence: uncontrolled series of the technique, or reviews of such series. Expert reasoning: rationale given by the developers of the protocol without supporting clinical data.

The priority given to the pterygoid implant is a matter of expert reasoning. The developers place it first because of its expected effect on AP spread, cantilever length, and composite torque [1], not because it survives better than the alternatives. The indirect evidence is that pterygoid implants show cumulative survival of 92.5–95.5% in systematic reviews of uncontrolled series [20,21]. The only comparative evidence, a meta-analysis comparing pterygoid implants with conventional implants in complete-arch maxillary rehabilitation, found a higher risk of loss for pterygoid implants [22]. No study has compared a pterygoid-first sequence with any other order, or pterygoid implants with posterior zygomatic implants as posterior support. That most failures of pterygoid implants occur early [20,21,23] is compatible with an algorithm that checks stability at placement. However, as noted in Section 3, a satisfactory check does not prevent early failure.

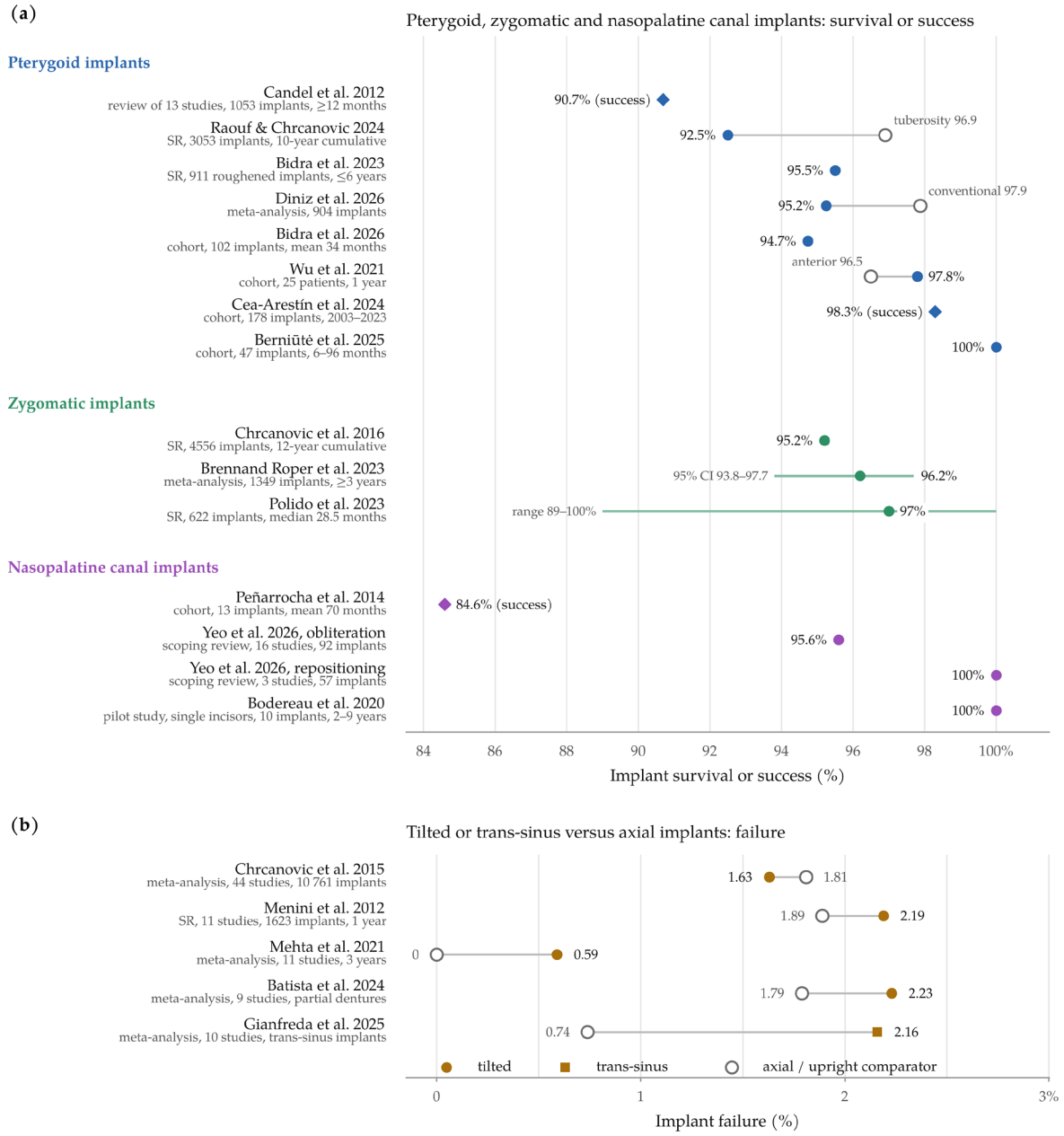
The preference for the transnasal implant (A2) over the anterior zygomatic implant (Z3) is also a matter of expert reasoning, and here the indirect evidence is weaker for the preferred option than for the alternative. Transnasal implants are documented in a case

report and a short-term retrospective series [13,30], without data on nasal complications or long-term survival. In contrast, zygomatic implants, including those placed in quad configurations, are documented in systematic reviews, some with long-term follow-up [15,17,39]. The view that A2 is the less invasive option is reasonable on anatomical grounds, since it avoids an additional implant in the zygoma, but it has not been tested, and it should be acknowledged that a less well-documented technique is being preferred to a better-documented one.

The criteria for moving to zygomatic anchorage are the least well supported. A region is declared null, and a zygomatic implant indicated, when no intra-alveolar or extra-alveolar option is anatomically feasible or when the implant placed does not achieve primary stability or 35 Ncm [1]. The first criterion depends on anatomical limits proposed by individual authors for specific techniques [8,30], not on the protocol; the second depends on a torque threshold that has not been validated for these implants or configurations. Reserving zygomatic implants for null regions is consistent with their complication profile (sinusitis, soft-tissue complications, and the risk of orbital injury) and the required training [8,15–17,39]. However, it has not been shown that configurations with pterygoid, transnasal, or trans-sinus implants in place of zygomatic implants carry fewer complications overall.

The premolar region is the exception. Its first-line option has the largest body of comparative evidence, and the algorithm and the evidence agree best on this decision. Even so, the evidence comes from largely non-randomized studies summarized in overlapping reviews, most of which found no statistically significant difference between tilted and axial implants, while the largest found more failures of tilted implants in the maxilla [31–37]; and the second-line option, the trans-sinus implant, rests on small series whose pooled estimate does not exclude a higher risk of failure [14].

The attention paid to salvage is a design feature of the protocol whose value is, again, untested. Keeping the apices of Z1 and Z2 implants in the posteroinferior zygoma is intended to leave the anterosuperior part of the bone free for a Z3 implant if an anterior or zygomatic implant is later lost [1]. Together with the prosthetically driven positioning of zygomatic platforms advocated by its first author [9], this is directed at the long-term maintainability of the rehabilitation as well as the immediate surgical result. No report has yet described how often salvage was needed after treatment under PATZi, or what the results were.



Filled markers: the implant type named in each panel (circles, survival or failure; diamonds, success); open grey markers: comparator implants in the same study. SR = systematic review; CI = confidence interval. Values are reported as published, not pooled; outcome definitions and follow-up differ between studies.

Figure 6. Outcomes reported for the component techniques of the PATZi protocol in the principal studies reviewed. None of the values refer to implants placed under the protocol. (a) Survival (circles) or success (diamonds) of pterygoid, zygomatic, and nasopalatine canal implants; comparator implants reported in the same studies are shown as open markers, and the range reported by Polido et al. [39] and the 95% confidence interval reported by Brennand Roper et al. [17] are shown as horizontal lines. Survival and success are different outcome measures, and the studies differ in design, follow-up, and definitions; the values are plotted on a common axis for orientation only and are not directly comparable. (b) Implant failure with tilted or trans-sinus implants versus axial (upright) implants in the meta-analyses reviewed; for Gianfreda et al. [14], the percentages were calculated from the reported counts, and the comparator group comprised axial and conventionally tilted implants. Values are shown as published and are not pooled. Data are from the following studies: (a) Candel et al. [19], Raouf and Chrcanovic [21], Bidra et al. [20,23], Diniz et al. [22], Wu et al. [25], Cea-Arestín et al. [24], Berniūtė et al. [26], Chrcanovic et al. [15], Brennand Roper et al. [17], Polido

et al. [39], Peñarrocha et al. [12], Yeo et al. [28], and Bodereau et al. [29]; (b) Chrcanovic et al. [34], Menini et al. [32], Mehta et al. [36], Batista et al. [37], and Gianfreda et al. [14].

8.3. Complications and Outcomes of the Rehabilitation as a Whole

Implant survival does not by itself describe the success of an implant-supported rehabilitation, and for the techniques that PATZi combines, other outcomes are documented unevenly. Sinus-related complications are the best documented. With zygomatic implants, sinusitis is the most frequent biological complication. Its pooled probability was 2.4% in the review of Chrcanovic et al., a figure that the authors regarded as a probable underestimate because many studies did not report complications [15]. In the meta-analysis of Brennand Roper et al., which was restricted to studies with at least 3 years of follow-up, its prevalence was 14.2% (95% confidence interval 8.8–22.0) at about 5 years, and it was the complication most often associated with loss of an implant, although most cases were managed with antibiotics or meatotomy [17]. Sinusitis has been reported less often with anatomy-guided approaches than with the original intrasinus technique, but direct comparisons are lacking [16]. Sinus membrane perforation and sinusitis have been reported occasionally with pterygoid implants [21]. Trans-sinus implants cross the sinus by design; the systematic review available pooled failure rates from 10 small studies, and longer follow-up is needed to establish how well the sinus tolerates them [14]. For transnasal implants, nasal and sinus complications have not been reported systematically [13,30].

Soft-tissue complications are reported less consistently. Around zygomatic implants, the pooled probability of soft-tissue infection was 2.0% in one review [15] and between 4.35% and 7.50%, according to surgical technique, in another [16], and mucositis, bleeding on probing, increased probing depth, and recession are among the reasons for which zygomatic implants fail success criteria [17]. The Zygomatic Success Code was proposed to score sinus status, soft-tissue condition, and prosthetic offset together with implant stability [38]. Peri-implant mucositis has been reported around pterygoid implants [21]; soft-tissue parameters were similar to those of anterior implants at 1 year in one series [25], and plaque accumulation was associated with smoking, age, and thin keratinized tissue in another [26]. The distal position of the pterygoid platform makes oral hygiene access more difficult [26], and palatal emergence of zygomatic implants has been linked to bulky prostheses and difficulties with hygiene and speech [9,16]. Maintenance is therefore a foreseeable difficulty for the configurations that the algorithm generates.

Prosthetic complications and maintenance are documented mainly for prostheses on tilted and on zygomatic implants. With tilted implants, fracture of the interim acrylic prosthesis and screw loosening were the most common complications [35]. With zygomatic implants, mean prosthesis survival was 94% (95% confidence interval 88.6–96.9) at a mean of 76 months. The technical complications reported (loss of retention, chipping or fracture of the veneering material, fracture of the framework, and loosening or fracture of screws and abutments) resembled those of full-arch prostheses on conventional implants [17]; such complications were recorded with both the original and the anatomy-guided technique and are probably under-reported [16]. Although patient-reported outcomes improved after treatment with zygomatic implants, the instruments used were too varied to combine them, and all studies in that meta-analysis were case series [17]. Comparable data for prostheses that combine pterygoid, transnasal, or trans-sinus implants with zygomatic implants were not found, nor were pooled data on the frequency of re-intervention, whether to remove or replace an implant, to treat sinusitis, or to repair or remake a prosthesis.

None of these outcomes have been reported for patients treated under PATZi. For the original series, only immediate loading and the arch length achieved were reported [1], and the case report describes one patient without complications over almost 5 years

[11]. A protocol that aims to reduce the use of zygomatic implants would be expected to reduce their complications; however, this would be achieved by substituting implants whose complications are less well documented. In turn, the net effect for the patient is unknown.

8.4. Limitations of the Evidence and of This Review

The most important limitation is one of inference. The favorable outcomes summarized in this review were obtained with individual implant techniques, by other surgeons, in patients selected for those techniques and in prosthetic configurations that differ from those the algorithm generates. They do not amount to clinical validation of the protocol. An algorithm that combines the techniques, uses some as fallbacks in the least favorable anatomy, and loads the result immediately may perform better or worse than its components in isolation, and the rehabilitation outcome depends on the weakest anchor and the prosthesis that connects them. No survival or complication rate quoted in this review should therefore be read as a result of PATZi, and only studies of patients treated under the protocol can provide evidence for it.

Such studies are scarce. In the literature searched, data specific to PATZi consist of a technical description with five illustrative cases and a series of 142 rehabilitations performed over the course of one year and reported only in terms of immediate loading and the FAR [1], a descriptive extension to the moderately atrophic maxilla [10] and a single case report [11]. No implant or prosthesis survival, complication, or patient-reported outcome data have been published for PATZi cohorts; no follow-up was reported for the 142 rehabilitations, and no comparison with other strategies has been made. The FAR and the configuration code have the ambiguities set out in Section 7: the published formula and the published value of the FAR do not coincide, its two categories are not described consistently, the index combines the number of teeth with the distal cantilever, and the coding of asymmetric arches and of adjunctive implants and the number of implants are not specified. The protocol was developed and reported by experienced high-volume surgeons, and one of its originators has declared a consultancy with an implant manufacturer [11]; its reproducibility in other hands is unknown.

The evidence for the individual components has its own limitations. Much of it comes from retrospective, uncontrolled studies with heterogeneous definitions of survival and success; the systematic reviews of zygomatic implants are reviews of case series [17]; the meta-analyses of tilted implants overlap in their primary studies and rest largely on non-randomized comparisons; and for transnasal implants the evidence is confined to a case report and one short-term series [13,30]. Some evidence concerns populations other than the atrophic edentulous maxilla, such as partially edentulous patients or patients treated after maxillary resection, and cannot be transferred to it without qualification.

This review has limitations as well. It is a narrative review: it was not registered, the flow of records is not reported, the search was extended beyond MEDLINE only at the revision stage, the two independent screening passes were applied to the PubMed records, the sources added during revision were chosen without that screening, data were not extracted with a standardized form, no formal assessment of the risk of bias was made, and no data were pooled. Relevant publications may therefore have been missed, and the weight given to each source reflects our judgment. In particular, descriptions and case series of the protocol published in journals that are not indexed in MEDLINE or Web of Science, in continuing-education periodicals or in textbooks may have been missed, and would have to be sought in any systematic assessment of the protocol. Where the original description is not explicit, notably on which decisions are taken before and which during surgery, on asymmetric arches, and on the criteria for immediate loading, our reading of the algorithm is an interpretation, and it is identified as such in the text.

8.5. Future Directions

Prospective multicenter cohorts reporting implant and prosthesis survival, complications (including sinus, nasal, and soft-tissue complications), marginal bone levels, peri-implant health, prosthetic maintenance, re-interventions, and patient-reported outcomes by PATZi configuration are the obvious next step. Such reports should give the code for each side of the arch together with the number of implants, distinguish configurations that were planned from those adopted during surgery, state the individual and composite insertion torque for each configuration, and record the number of teeth and the presence and length of a distal cantilever separately. The classification itself should be validated, including inter-observer agreement and its relationship to operating time, morbidity, and cost, if it is to serve as a triage and communication tool, and the FAR should be defined unambiguously before it is used as an endpoint. Comparative studies against conventional four- or six-implant concepts, grafting, and quad zygoma would show where each pathway offers a real advantage; comparisons of transnasal with anterior zygomatic implants, and of pterygoid with posterior zygomatic implants, would test the two preferences on which the order of the algorithm depends; and long-term data on pterygoid implants under full-arch prostheses are particularly needed given their distal position and the hygiene problems reported around them [26].

9. Conclusions

PATZi is a prosthetically driven, anatomically based algorithm proposed for planning immediate-loaded full-arch rehabilitation of the atrophic maxilla. It considers pterygoid, anterior, tilted, and zygomatic implants in a fixed order of preference and reserves zygomatic implants for regions in which no other anchorage is feasible. This order is the organizing principle of the protocol and reflects its developers' view of invasiveness; it is not a demonstrated progression from less invasive to more invasive interventions. The algorithm aims at full arch length without distal cantilevers, gives the surgeon a structured response when a planned implant cannot be placed or stabilized, and provides a code that is proposed for describing complexity and that may facilitate communication and the planning of salvage; none of these functions has been validated. Its components are supported by evidence of varying strength, from several overlapping meta-analyses of largely non-randomized studies for tilted implants to a case report and a short-term series for transnasal implants, and the favorable outcomes of the individual techniques cannot be extrapolated to the algorithm. Evidence for the protocol as a whole remains preliminary and lacks implant survival, complication, or patient-reported outcome data. Prospective, comparative, and long-term studies are needed before its outcomes can be regarded as established.

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Abbreviations

The following abbreviations are used in this manuscript:

AP	Anteroposterior
FAR	Full-Arch Ratio
ITI	International Team for Implantology
PATZi	Pterygoid, anterior, tilted, zygomatic implants
PFAST	Pterygoid fixated arch stabilization technique
ZAGA	Zygoma anatomy-guided approach

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