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ORIGINAL RESEARCH

Development and design of implant success prediction tool: AI risk assessment for peri-implant disease prevention

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Abstract

Peri-implant diseases remain a major cause of late implant failure, and current risk assessment tools show limited capacity to integrate prosthetic factors, salivary biomarkers and artificial intelligence-based prediction. This study aimed to develop the Implant Success Prediction Tool (ISPT), a multifactorial peri-implant risk stratification system structurally designed for modular integration with artificial neural networks and salivary omics data. ISPT development followed three main pillars: (1) incorporation of Implant Disease Risk Assessment (IDRA)-validated clinical vectors, including bleeding on probing percentage, number of sites with probing depth ≥ 5 mm, bone loss in relation to age, periodontitis susceptibility, supportive periodontal therapy and hygiene/compliance parameters; (2) qualitative usability testing of IDRA by implantologists, who identified elements to maintain, clarify or expand; and (3) alignment with a precision medicine framework, establishing collaboration with a salivary diagnostics laboratory SalivaTec (https://ciis.ucp.pt/salivatec) to enable systematic saliva collection and future deep phenotyping. The final ISPT structure comprises ten standardized risk vectors displayed in a colour-coded radial traffic-light diagram, integrating six adapted IDRA-derived vectors and four novel vectors: abutment height/angulation; saliva collection/deep phenotyping vector ("*salivaomics*"); foreign bodies, titanium particles and tribocorrosion; and other for occlusal loading and functional risk. The tool is conceptually prepared to function as a structured input matrix for artificial neural networks, supporting longitudinal training with combined clinical and salivary data to predict implant outcomes (peri-implant health, mucositis, peri-implantitis) over a minimum 5-year monitoring period. ISPT represents the first peri-implant risk assessment tool explicitly designed for modular integration of artificial intelligence and salivary omics data within a precision dentistry framework. Its standardised vectors, traffic-light visualisation and longitudinal validation methodology provide a scalable structure for future externally validated predictive models of implant success and failure.

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Keywords Dental implants · Peri-implantitis · Artificial intelligence · Risk assessment · Precision dentistry · Salivary biomarkers

Introduction

Dental implants have become a first-line option for the rehabilitation of edentulous areas, allowing restoration of function and aesthetics with high long-term survival rates. However, peri-implant diseases, particularly peri-implant mucositis and peri-implantitis, are now among the main causes of late implant failure, compromising the longevity of implant-supported rehabilitations and significantly increasing the biological and economic burden of treatment. Despite advances in the understanding of their etiopathogenesis, diagnosis is still frequently late and relies on clinical and radiographic parameters that reflect already established tissue destruction [1–6].

To minimise the risk of peri-implantitis, several risk analysis models have been proposed over the years, inspired by approaches previously used in periodontology [7–9]. Among these, the Implant Disease Risk Assessment (IDRA) currently represents one of the most structured tools for risk stratification of peri-implant diseases, integrating multiple clinical vectors, namely the percentage of sites with bleeding on probing (BOP%), the prevalence of sites with probing depth (PD) ≥ 5 mm, periodontal bone loss in relation to age, periodontitis susceptibility according to the 2017 classification, supportive periodontal therapy (SPT) and parameters related to hygiene/prosthetics [7–14]. Nevertheless, the IDRA diagram itself acknowledges that, as additional risk factors emerge from the literature, modifications and updates of the model may be required [15]. In addition to biological and patient-related factors, biomechanical determinants such as occlusal loading have been suggested as potential modulators of peri-implant bone stability. Excessive or traumatic occlusal forces, particularly when non-axial or concentrated on a limited number of implants, may contribute to marginal bone loss and implant complications, especially in susceptible patients in whom biofilm-induced inflammation is already present. Although the causal role of occlusal overload in peri-implantitis remains a matter of debate, contemporary evidence indicates that functional loading patterns should be considered as part of a comprehensive risk framework rather than being neglected in favour of purely biological variables [16–18].

More recently, attention has also turned to implant- and material-related factors, including foreign bodies and tribocorrosion phenomena involving the implant–abutment complex. Titanium particles and corrosion products have been detected at higher levels in peri-implantitis sites and have been linked to pro-inflammatory tissue responses and altered bone metabolism, in both dental and orthopaedic implant literature. These findings support the concept that metal wear, metallosis and exogenous particles may act as co-factors that amplify peri-implant inflammation and bone loss in predisposed individuals [19–24].

In parallel, the concept of precision medicine has gained prominence in dentistry, proposing that diagnosis, prognosis and treatment decisions should result from the integration of clinical, behavioural and biological data at different levels of complexity, including biomarkers and *omics* data. In the context of peri-implant diseases,

inflammatory biomarkers present in oral fluids have been investigated as adjunctive tools for early diagnosis and monitoring of treatment response, with a particular emphasis on active MMP-8 (aMMP-8) in peri-implant sulcular fluid. Elevated aMMP-8 levels have been associated with an increased risk of periodontitis and peri-implantitis progression, and specific cut-off values have been proposed to distinguish health, reversible inflammation and progressive tissue destruction [25–30].

Furthermore, systematic saliva collection from the peri-implant sulcus represents a versatile approach for biomarker analysis, encompassing both point-of-care (PoC) tests such as ImplantSafe®/PerioSafe® kits with ORALyzer® reader for immediate aMMP-8 quantification, and comprehensive laboratory analyses including proteomics, genomics, and microbiome profiling through SalivaTec collaboration. This dual strategy provides clinicians with both rapid inflammatory activity assessment and high-dimensionality biological data for advanced risk stratification. When integrated into multifactorial models like ISPT, salivary biomarkers enhance early risk identification prior to evident clinical/radiographic changes, while artificial neural networks enable predictive modelling leveraging these diverse clinical and biological datasets to optimise implant prognosis accuracy [25, 31, 32].

Based on these premises, the Implant Success Prediction Tool (ISPT) was conceived as a multifactorial risk assessment system representing a conceptual evolution of the IDRA. The ISPT retains six key vectors derived from the IDRA, including BOP%, sites with PD ≥ 5 mm, bone loss in relation to age, periodontitis susceptibility (staging and grading), supportive periodontal therapy and a hygiene/prosthetic vector more focused on patient compliance, and adds four further vectors: "*salivaomics*" vector; another oriented towards the future incorporation of advanced deep phenotyping data [7, 8, 10–12, 33–36]; other for foreign bodies, titanium particles and tribocorrosion; and other for occlusal loading and functional risk. The tool was designed to generate a traffic-light–type risk diagram, facilitating clinician–patient communication, and to be subsequently integrated into artificial intelligence algorithms capable of predicting implant success on an individual, longitudinal basis.

In this context, there is a need for clinically applicable risk assessment tools that integrate conventional peri-implant risk factors with emerging biological markers, while remaining feasible for chairside use. The aim of the present work was to develop the conceptual framework of the ISPT, a streamlined, multifactorial system intended to support personalised risk stratification and clinical decision-making in implant dentistry.

Methodology

This work describes the conceptual development of the ISPT, a multifactorial risk assessment system aimed at preventing peri-implant diseases and optimising dental implant prognosis. The ISPT was constructed by integrating three main pillars: (1) evidence available in the literature on risk factors for peri-implantitis and risk assessment models, with particular focus on the functional diagram of IDRA [15]; (2) the results of a usability test of the IDRA conducted with implantologist clinicians, who evaluated the tool in a simulated clinical context and identified aspects to

maintain, simplify or modify [37]; and (3) contemporary precision medicine frameworks, including the potential of inflammatory biomarkers and deep phenotyping strategies [29, 38, 39].

In developing the ISPT, the overarching design principle was to create a clinically applicable tool that can be completed rapidly and consistently in routine practice, rather than a comprehensive checklist of all potential risk indicators. Extensive tools may be theoretically informative, but if they are time-consuming or complex, clinicians are unlikely to adopt them at the chairside. Accordingly, and based on the three pillars described above, the ISPT was deliberately restricted to a set of ten risk vectors that emerged as both biologically relevant and pragmatically feasible.

For the clinician, the practical value lies in the ability to rapidly stratify biological risk prior to implant placement (for example, avoiding angulated prosthetic configurations in patients with an unfavourable salivary profile) and to generate specific personalised maintenance recommendations. For the patient, the tool provides clear communication about their individual risk level and concrete guidance (such as reinforced hygiene programmes or more intensive monitoring frequency), promoting adherence and autonomy in managing their implant rehabilitation.

The present version of the ISPT should therefore be regarded as an initial framework for clinical applicability, that is explicitly designed to balance biological depth with real-world usability. None of the ten included vectors is expected to predict peri-implantitis in isolation; rather, the tool is conceived as a platform for integrating heterogeneous sources of risk information and for future longitudinal validation.

A clinical applicability study is currently underway to test the model in real patients, assessing its implementation in daily clinical workflows, acceptance by clinicians and patients, and ability to generate clinically actionable decisions.

The working hypothesis underpinning the ISPT is that the combined behaviour of these vectors over time, analysed through prospective datasets and advanced artificial intelligence methods (including machine learning and deep learning approaches), will enable the derivation of individually tailored risk scores for each patient. Within this perspective, particular emphasis is placed on the saliva-based vector, as molecular diagnostics and omics-based profiling (proteomics, genomics and microbiology) are likely to become pivotal for identifying high-risk patients and refining risk stratification beyond traditional clinical parameters [40].

Results

The IDRA served as the initial structural model, organising the assessment of peri-implant disease risk across different clinical vectors [7–11, 41]. The usability test with implantologists enabled the identification of practical limitations related to the clarity of some vectors, the need to better specify the impact of prosthetic factors (such as abutment height and angulation) and the interest in incorporating additional biological data [37]. In parallel, the literature review on biomarkers, saliva and precision medicine, together with the possibility of collecting and processing saliva samples in collaboration with the SalivaTec laboratory (ciis.ucp.pt/salivatec), guided the inclusion of a vector dedicated to systematic saliva collection for future integration

of omics data and artificial intelligence-based models. The logo was already created by the communication department of FMDUCP (Fig. 1).

Selection and operationalisation of risk vectors

The final ISPT structure integrates ten risk vectors for dental implant success. Six vectors are common to the IDRA, with conceptual adaptations, and four additional vectors were introduced to reflect specific prosthetic factors and advanced biological data collection:

1. Percentage of sites with bleeding on probing (BOP%).
2. Bleeding on probing was included as an objective inflammatory indicator, consistent with its use in periodontal and peri-implant indices and is applicable to both screw-retained and cement-retained prostheses. The ISPT scale follows the IDRA rationale, using ascending BOP% categories (9, 16, 25, 36 and > 49%) as critical thresholds, considering BOP% <10% as low risk and BOP% >25% as an indicator of higher risk for disease progression [7, 9, 14].

Green	BOP≤9% of sites.
Yellow	BOP>9% and ≤25% of sites
Red	BOP>25% of sites

3. Prevalence of probing depths ≥ 5 mm (PD ≥ 5 mm).
4. The number of sites (teeth and implants) with PD ≥ 5 mm was retained as an independent vector, given its role in periodontal disease progression and the colonisation of peri-implant sites by periodontal pathogens, rather than representing a deterministic predictor of future bone loss around implants. The scale is linear (2, 4, 6, 8, ≥ 10 sites), classifying 1–2 deep pockets as low risk and more than six sites as high risk for biological complications [14, 42]. It should be emphasised that the presence of PD ≥ 5 mm does not inevitably lead to additional peri-implant bone loss, as long-term cohort studies have shown that even residual pockets ≥ 5–6 mm mainly act as risk indicators for future tooth loss and disease

Fig. 1 Implant success prediction tool–ISPT Logo

progression, particularly when combined with other unfavourable factors such as high bleeding scores or smoking. In the context of implant therapy, residual periodontal pockets and deep peri-implant pockets with bleeding on probing have been associated with increased peri-implant bone loss compared with periodontally healthy patients, supporting their use as risk markers rather than stand-alone diagnostic thresholds. Within this framework, our model uses the number of sites with PD ≥ 5 mm as a relative risk indicator that identifies patients with higher biological susceptibility and a greater need for intensive supportive care, rather than as a direct predictor of future bone loss around individual implants [43].

Green	1–2 sites with PD≥5 mm
Yellow	3–6 sites with PD≥5 mm
Red	>6 sites with PD≥5 mm

5. Periodontal bone loss in relation to age (BL/age).
6. Alveolar bone loss in relation to age was operationalised following the IDRA, estimating the percentage of bone loss at the most affected site and dividing it by the patient's age. The ISPT scale uses increments of 0.25, with 0.5 as the critical value between low and moderate risk and 1.0 as the threshold between moderate and high risk. [11, 44].

Green	BL/AGE ratio≤0.5
Yellow	BL/AGE ratio>0.5 and ≤1.0
Red	BL/AGE ratio>1.0

7. Periodontitis susceptibility (staging and grading).
8. The 2017 classification for periodontal diseases is used to assess susceptibility, integrating staging, grading and tooth loss due to periodontitis. Consistent with the IDRA, only patients in Stage I Grade A are considered low risk, while Stages 2–4 and Grades B/C represent increasing risk categories [14, 44, 45].

Green	History compatible with low periodontal susceptibility (e.g. Stage I, non-smoker, good response to therapy)
Yellow	Moderate susceptibility (e.g. Stage II–III, former smoker or controlled systemic conditions
Red	High susceptibility (e.g. Stage III–IV with tooth loss due to periodontitis, current smoker, or poorly controlled systemic risk)

9. Supportive periodontal therapy (SPT).
10. Adherence to a regular maintenance programme is recorded as an independent vector, considering evidence that recall intervals ≤ 5 months are associated with better peri-implant health maintenance. In the ISPT, absence of SPT or irregular adherence is classified as high risk, while consistent adherence to recommended intervals is considered low risk [45, 46].

Green	Regular SPT attendance according to recommended intervals (fully compliant)
Yellow	Irregular SPT attendance (partially compliant)
Red	No SPT or clear discontinuation of maintenance (non-compliant)

11. Hygiene/prosthetic factors and patient compliance.
12. This vector was adapted to emphasise patient compliance. Assessment is based on plaque indices obtained with disclosing agents, enabling objective quantification of oral hygiene and using the record as a communication and motivation tool [47, 48].

Green	Totally compliant with self-performed and professional hygiene; good plaque control around all implants
Yellow	Partially compliant; plaque present occasionally or in localised areas, but without persistent inflammation.
Red	Poor or absent compliance; generalised plaque accumulation and/or persistent peri-implant inflammation.

13. Abutment height and angulation (abutment height 30°).
14. A specific vector was introduced to characterise abutment height and prosthetic design (including the presence of 30° abutments), considering evidence that certain abutment designs and prosthetic emergences may influence hygiene accessibility, plaque accumulation and the distribution of occlusal forces. In the ISPT, this vector classifies configurations from more favourable prosthetic setups (smooth emergence profiles, good accessibility for self-performed and professional plaque control, abutment heights facilitating hygiene and stable peri-implant soft tissues) to higher-risk situations, such as 30° angled abutments in hard-to-access areas or emergence profiles that hinder plaque control and predispose to non-axial and concentrated load transfer to the crestal bone [49]. Beyond impairing biofilm removal, markedly angulated abutments are therefore assumed to increase the likelihood of inadequate occlusal loading, which is recognised as an additional risk factor for peri-implant bone loss and both technical and biological complications in susceptible patients [48, 50].

Green	Favourable abutment height and emergence profile, with angulation ≤ 30° and good access for hygiene
Yellow	Intermediate situations with minor deviations from ideal height/angulation or slightly restricted access
Red	Markedly unfavourable configurations, such as 30° abutments in hard-to-access areas or emergence profiles that severely hinder plaque control and soft-tissue stability

15. Saliva collection and advanced deep phenotyping vectors.
16. Instead of directly integrating a point-of-care test, the ISPT, in this pilot phase, includes a vector dedicated to systematic patient saliva collection, with the aim of enabling, in a subsequent phase, the integration of advanced biological data. Thanks to the integration at the university of the SalivaTec laboratory, collected saliva samples can be processed and analysed for future omics approaches (e.g. proteomics, genomics or other biomarkers relevant to peri-implant health). This vector thus serves as a "bridge" between the immediate clinical use of the ISPT and a precision medicine model, where salivary data will be incorporated into artificial intelligence algorithms to refine risk stratification and the tool's predictive capacity.
17. Foreign bodies, titanium particles and tribocorrosion.
18. A ninth vector was introduced to capture the potential impact of foreign bodies, titanium particle release and tribocorrosion phenomena on peri-implant health. Given the current lack of chairside methods to directly quantify titanium particles or corrosion products at the individual level, this vector was operationalised using simple clinical and radiographic indicators that can be assessed during routine visits. A low-risk category (green) is assigned in the absence of peri-implant soft-tissue discoloration, without radiographic or clinical evidence of foreign bodies (e.g. residual cement, metallic fragments) and when a homogeneous implant–abutment–prosthesis material combination is present. A moderate-risk category (yellow) is assigned in cases with a history of repeated abutment manipulation, aggressive debridement with metal instruments or the use of potentially dissimilar metallic components, but without clear signs of metallosis or progressive bone loss. A high-risk category (red) is attributed when clinical signs suggestive of metallosis (dark peri-implant tissue discoloration) are present, and/or when persistent foreign bodies (such as cement remnants or metallic fragments) are detected radiographically or clinically in association with peri-implant inflammation and marginal bone loss. In line with current evidence, this vector is conceptualised as a co-factor that may amplify inflammatory responses and bone resorption in susceptible patients, rather than as an isolated causal determinant.

Green	No clinical or radiographic evidence of foreign bodies; homogeneous implant–abutment–prosthesis materials; no peri-implant soft-tissue discoloration
Yellow	History of repeated abutment manipulation, metal instrumentation on implant surfaces, or use of dissimilar metallic components, but without clear signs of metallosis or progressive bone loss

Red	Clinical signs suggestive of metallosis (dark/grey tissue discoloration) and/or persistent foreign bodies (residual cement, metallic fragments) detected in association with peri-implant inflammation and marginal bone loss

19. Occlusal loading and functional risk.
20. An additional vector was introduced to capture functional risk related to occlusal loading, acknowledging emerging evidence that excessive or traumatic occlusal forces may contribute to marginal bone loss and peri-implantitis, particularly in synergy with bacterial biofilm. This vector was designed to rely on simple chair-side criteria that can be assessed within a standard clinical examination, without specialised instrumentation. A low-risk category (green) is assigned to patients with no reported or observed parafunctional habits, no history of technical complications (e.g. ceramic chipping, screw loosening or framework fractures) and a clinically acceptable occlusal scheme with well-distributed contacts and no obvious premature contacts. A moderate-risk category (yellow) is assigned when parafunctional habits are suspected or controlled (e.g. reported bruxism with protective splint use), or when occasional minor technical events or slightly eccentric load distributions are present without associated symptoms or radiographic changes. A high-risk category (red) is assigned in the presence of clear, uncontrolled parafunctional activity (e.g. severe wear facets, repeated fractures or screw loosening) and/or markedly non-axial and concentrated occlusal loading patterns on a limited number of implants, especially when accompanied by pain, discomfort or peri-implant bone loss compatible with overload.

Green	No reported or observed parafunctional habits; no history of technical complications; occlusal contacts well distributed and predominantly axial
Yellow	Suspected or controlled parafunction (e.g. bruxism with splint); occasional minor technical issues or slightly eccentric loading without symptoms or bone changes
Red	Uncontrolled parafunction with severe wear facets and/or repeated fractures or screw loosening; clearly non-axial, concentrated loading patterns associated with discomfort or peri-implant bone loss compatible with overload.

Risk representation and longitudinal artificial intelligence model

Based on the eight vectors, the ISPT generates a radial diagram in which each vector is represented by a risk scale, colour-coded (green, yellow, red). The result is presented to the clinician and patient in the form of a traffic-light diagram, where a greater predominance of green indicates a higher likelihood of implant success, while the presence of multiple yellow or red vectors alerts to the need for intervention and more rigorous monitoring (Fig. 2).

The ISPT was also designed to serve as a data collection platform in longitudinal studies (Fig. 3) aimed at developing artificial intelligence-based predictive models. The proposed methodological design consists of the systematic recording of ISPT vectors (inputs) at multiple assessment time points, associated with the observation of clinical outcomes (peri-implant health, mucositis, peri-implantitis) over time (outputs). As the number of cases and assessment cycles increases, the data will be processed by artificial neural networks, enabling identification of the most relevant

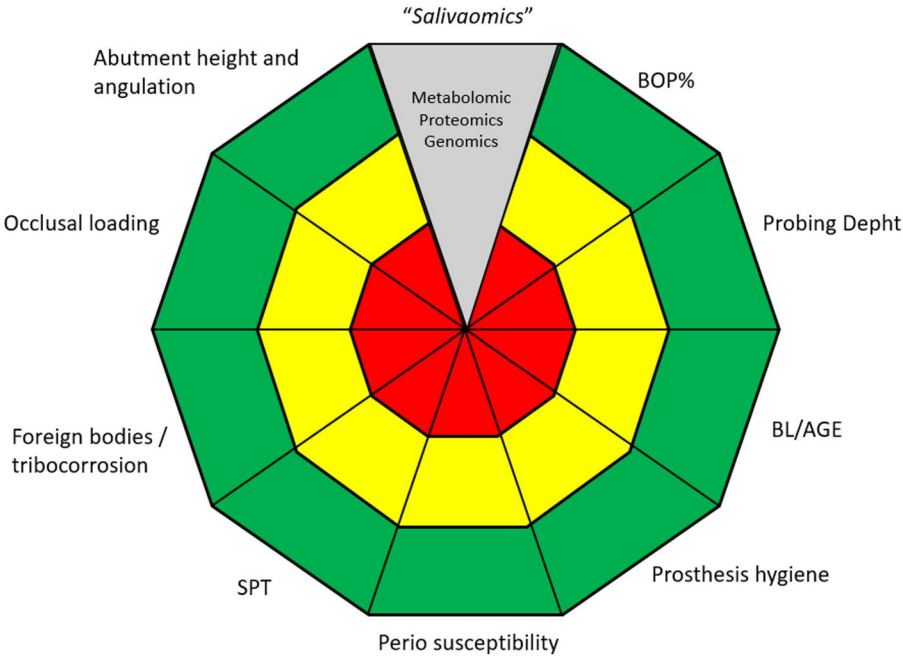

Fig. 2 ISPT tool—each vector represents one risk parameter categorized

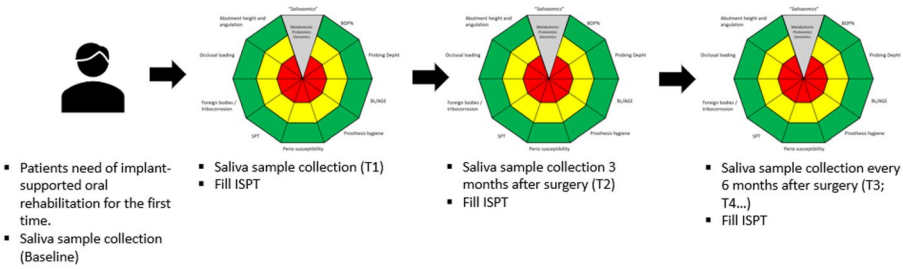

Fig. 3 Longitudinal application of the implant success prediction tool (ISPT)

predictors and estimation of the relative weight of each variable in the probability of implant failure. Final risk categorisation (low, moderate, high) will be determined algorithmically based on these longitudinal outcomes, following repeated cycles of data collection, modelling and progressive refinement of risk stratification consistent with precision medicine frameworks.

Discussion

The ISPT was specifically structured for future integration into artificial intelligence algorithms, namely artificial neural networks. Each of the eight vectors constitutes a quantifiable variable (input) with standardised scales, enabling systematic processing of large volumes of clinical and biological data.

The saliva collection vector, in collaboration with the SalivaTec laboratory, provides high-dimensionality data (proteomics, genomics, microbiome) amenable to machine learning analysis. The planned longitudinal methodology follows the stratified medicine paradigm: systematic collection of ISPT inputs associated with clinical outputs (peri-implant health, mucositis, peri-implantitis), iteratively processed for identification of relevant predictors and determination of algorithmic weights.

Characterisation of risk vectors and clinical operationalisation

The six vectors adapted from IDRA (BOP%, PD≥5 mm, BL/age, periodontal susceptibility, SPT, hygiene/compliance) maintain consolidated scientific validation for peri-implant risk stratification.

From a biomechanical standpoint, the inclusion of an occlusal loading and functional risk vector aims to acknowledge the potential contribution of excessive or traumatic forces to peri-implant bone loss, while maintaining a pragmatic assessment approach. Rather than requiring sophisticated instrumentation, the ISPT relies on easily observable indicators, such as uncontrolled parafunctional activity, recurrent technical complications and clearly concentrated non-axial contacts, to flag patients in whom functional loading patterns may exacerbate biologically driven inflammation. This is consistent with recent literature suggesting that occlusal overload likely acts as a co-factor that modulates disease expression in susceptible individuals, rather than as a stand-alone cause of peri-implantitis, and supports its integration into a multifactorial risk framework. Likewise, the foreign bodies, titanium particles and tribocorrosion vector represents a first attempt to operationalise implant- and material-related risk within a chairside tool. Studies have demonstrated increased levels of titanium particles and corrosion products in peri-implantitis lesions and have linked these findings to pro-inflammatory responses and altered peri-implant bone metabolism. In the present ISPT, such phenomena cannot be quantified directly; instead, they are captured through clinical signs suggestive of metallosis, evidence of persistent foreign bodies and a history of repeated mechanical manipulation or potentially susceptible material combinations. This approach is deliberately conservative, recognising metal wear and tribocorrosion as biologically plausible co-factors that may amplify inflammatory breakdown, while awaiting more standardised and feasible diagnostic protocols for future refinement of the model.

Longitudinal validation methodology and algorithmic development

ISPT validation will follow prospective longitudinal design with minimum 5-year monitoring, systematically recording the eight vectors at multiple time points. Clinical outcomes will be used for:

1. Initial training of artificial neural networks with clinical and salivary data.
2. Statistical identification of independent predictors and synergistic interactions.
3. Cross-validation of developed predictive models.
4. Iterative refinement of algorithmic weights based on new cases.

This methodological approach ensures rigorous development of externally validated predictive models, consistent with machine learning standards applied to clinical practice.

Immediate clinical applications during validation phase

During the longitudinal validation period, ISPT offers preliminary risk stratification based on established thresholds for each individual vector. Configurations with predominance of low-risk indicators (green) suggest standard monitoring; presence of multiple moderate/high-risk indicators (yellow/red) indicate need for intensified preventive intervention, including prosthetic optimisation and reinforcement of therapeutic adherence.

Systematic saliva collection during this phase constitutes a biological repository for future validation of developed predictive models.

Positioning within current evidence-based implantology

The ISPT contributes to the development of quantitative risk stratification tools in implantology, integrating validated clinical parameters with systematic salivary biomarker collection and structural preparation for predictive analysis by artificial intelligence. The outlined methodology ensures orderly transition from current clinical assessment to validated predictive models, aligned with precision medicine principles.

Conclusions

The present work describes the conceptual development of the ISPT, a structured, clinically oriented framework for peri-implant risk assessment based on ten standardised vectors that can be quantified chairside. The tool was explicitly designed to be compatible with subsequent artificial intelligence analyses, by organising conventional clinical parameters and emerging biological markers into a modular architecture suitable for machine-learning workflows. At this stage, the ISPT should be regarded as an initial, hypothesis-generating framework rather than a validated predictive model. Its primary immediate utility lies in providing clinicians with a simple, traffic-light–based multifactorial stratification of peri-implant risk, while systematically collecting longitudinal clinical and salivary data in a format that is ready for future training and external validation of predictive algorithms. Ongoing and future cohort studies will be essential to determine the actual prognostic performance of the ISPT, to refine the relative weighting of the included vectors, and to clarify the added value of salivary omics for precision risk stratification in implant dentistry.

Limitations and future directions

This study presents the conceptual development of the ISPT, but no predictive performance metrics can yet be inferred, as the tool has not been tested on large, independent patient cohorts. The traffic-light categorisation of each vector is based on current evidence and expert consensus, and therefore requires empirical refinement through prospective longitudinal data. The salivary and omics-based components are still exploratory and will need robust standardisation and validation before they can be routinely implemented. Future research should focus on applying the ISPT in real-world clinical cohorts, assessing inter-examiner reproducibility, calibrating the weight of each vector within machine-learning models, and evaluating whether the resulting individual risk scores translate into improved clinical decision-making and long-term implant outcomes.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

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