*Int. J. Odontostomat.,*
*19(3)*:224-233, 2025.

# Biomechanics in Dental Implants: Analysis Using Artificial Intelligence Systems

## Biomecánica en Implantes Dentales: Análisis Mediante la Aplicación de Sistemas de Inteligencia Artificial

**Aritza Brizuela-Velasco[1]; Saray Fernández-Hernández[2]; José Gaviria-de la Puerta[3]; Francisco T Barbosa[4]; Igone Porto-Gómez[5]; Iker Bellanco-de la Pinta[6]; Esteban Pérez-Pevida[4] & Daniel Robles-Cantero[4]**

**BRIZUELA-VELASCO, A.; FERNÁNDEZ-HERNÁNDEZ, S.; GAVIRIA-DE LA PUERTA, J.; BARBOSA, T. F; PORTO-GÓMEZ, I.; BELLANCO-DE LA PINTA, I.; PÉREZ-PEVIDA, E. & ROBLES-CANTERO, D.** Biomechanics in dental implants: Analysis using artificial intelligence systems. *Int. J. Odontostomat., 19(3)*:224-233, 2025.

**ABSTRACT:** This study aims to analyze the field of dental implant biomechanics using a novel AI-powered bibliometric approach. By leveraging machine learning and natural language processing, we mapped key research trends, identified dependent and independent variables, and highlighted commonly used testing procedures. This analysis seeks to pinpoint underexplored areas in biomechanics research and offer a roadmap for future studies. We conducted a systematic review of 1,512 full-text articles from the PubMed database. Using the Rapid Automatic Keyword Extraction (RAKE) algorithm, key concepts were identified and classified into three categories: dependent variables, independent variables, and procedures. Advanced co-occurrence analysis was then applied to visualize the interrelations between these terms and their prevalence across the body of literature. Our analysis revealed that the most frequently studied independent variable is loading type, while the most prominent dependent variable is loading transfer, and the most employed procedure is insertion torque measurement. The study also uncovered a reliance on in vitro methodologies, indicating the need for more in vivo research to bridge the gap between laboratory findings and clinical practice. Several important biomechanical factors, such as bone quality and implant connection type, remain underexplored despite their potential clinical impact. Our findings reveal critical knowledge gaps in the field of dental implant biomechanics and underscore the importance of in vivo research to improve clinical outcomes. By combining bibliometric analysis with AI-driven keyword extraction, this study introduces a reproducible, scalable approach to mapping research landscapes in dental science.

**KEY WORDS: biomechanics, dental implants, analysis, artificial intelligence.**

## INTRODUCTION

Traditional bibliometric analysis relies on manual or semi-automated techniques to identify keywords and categorize relationships among them. These methods are limited in scope and prone to human subjectivity. In this study, we address these limitations by leveraging AI-based approaches to automate keyword extraction and categorization. Specifically, the RAKE algorithm allows for the unbiased identification of frequently co-occurring terms, offering a more objective and scalable alternative to manual classification. This approach enables us to analyze relationships between independent and dependent variables at a larger scale than previous bibliometric reviews (Thompson & Clark, 2015) This analysis is crucial for the identification of highly researched topics and the assessment of their impact factors, thereby informing the scientific community about potential future research directions by highlighting specific areas of interest or novel research ideas (Godin, 2006). Despite its proven utility in the medical sciences, particularly within the field of

[1] Director of Dens-iA Research Group, Faculty of Health Sciences, European University Miguel de Cervantes, Valladolid, Spain.
[2] Predoctoral researcher of Dens-iA Research Group, Faculty of Health Sciences, European University Miguel de Cervantes, Valladolid, Spain.
[3] Lecturer in Computer Science, Faculty of Engineering, University of Deusto, Bilbao, Spain.
[4] Researcher of Dens-AI Research Group, Faculty of Health of Sciences, European University Miguel de Cervantes, Valladolid, Spain.
[5] Engineer at University Deusto, Graphic Expression and Engineering Projects Department, Bilbao, Spain.
[6] Assistant Professor Faculty of Health Sciences, European University Miguel de Cervantes, Valladolid, Spain.

Received: 2025-03-18 Accepted: 2025-07-08

dentistry, its application has predominantly been confined to select areas such as implantology, orthodontics, pediatrics, and general dentistry (Daryakenari & Batooli, 2022). To date, there is a noticeable absence of bibliometric studies focusing on biomechanics, especially concerning dental implants and implant-supported prostheses biomechanics.

Biomechanics examines the forces acting on cells, elucidates the interplay between the biological behavior of living structures and the physical effects they encounter, and explores the physics underpinning life processes (Brunsky *et al*., 2000). In the domain of implantology, implant-supported restorations endure occlusal forces or loads during functional and parafunctional activities, which are conveyed through the implant-abutment-prosthesis complex, eliciting a biomechanical response (Bidez & Misch, 1992). This understanding enables the identification of variables influencing the biomechanical behavior of implant-supported restorations.

Among these factors, the peri-implant bone is a crucial biomechanical factor due to its ability to remodel in response to applied loads, significantly impacting the osseointegration of the dental implant (Frost, 1987). Depending on its macro- and microgeometry, including the implant material and surface characteristics, the dental implant plays a key role in the biomechanical behavior of the system (Pérez-Pevida *et al*., 2016). Moreover, the implant-supported prosthesis is the first component to bear the masticatory load; thus, depending on its characteristics, the prosthesis transfers this load to the other restoration components (Maminskas *et al*., 2016). Moreover, the patient's characteristics, including the magnitude, direction, and duration of masticatory loads, act as critical factors that influence the force distribution through the prosthesis to the implant-bone complex (Van Eijden, 1991).

In the literature concerning dental implant biomechanics, numerous studies have correlated the previously mentioned factors with clinical outcomes. These outcomes predominantly evaluate success, survival rates, and the impact of various factors on the most common complications in implant-supported restorations. These complications are categorized into mechanical, technical, and biological types. Mechanical complications arise in the factory-manufactured components of the implant and prosthesis, often involving the loosening of screws and prosthetic attachments (Hämmerle *et al*., 2018). Technical complications, occurring less frequently, manifest in custom-made components prepared in dental laboratories and typically involve fractures of prosthetic superstructures or chipping of the covering ceramic (Sailer *et al*., 2018). Biological complications, the most extensively studied category, affect the supporting tissues. They include mucositis (inflammation of the peri-implant mucosa) and lead to marginal bone loss around the dental implant. It is essential to delineate two clinical phenomena associated with the absence of bone support in contact with the implant: peri-implantitis and physiological peri-implant marginal bone loss. Peri-implantitis, a bacterial infection, triggers inflammation, bleeding, or suppuration upon probing and progressive, radiographic, peri-implant marginal bone loss (Schwarz *et al*., 2021). Conversely, physiological peri-implant marginal bone loss stems from non-infectious bone remodeling of variable magnitude around a dental implant (Galindo-Moreno *et al*., 2022)

Due to the challenges associated with analyzing biomechanical variables *in vivo*, few clinical trials have been conducted; consequently, most of the research on dental implant biomechanics has utilized *in vitro* methodologies. In this context, numerous studies have adopted finite element models (FEMs) for implant-supported restorations to mathematically analyze displacement vectors and determine stress distribution within mechanical systems (Reddy *et al*., 2019).

Additionally, strain gauge analysis (SGA) methods are widely used in dental implant biomechanical evaluations. These methods, utilizing electrical resistance strain gauges, allow for the recording of strains present in prosthetic components (Matos *et al*., 2022). While less prevalent, other biomechanical evaluation methods, including photoelastic stress analysis (PSA), histomorphometric analysis (HMA) (Marín-Miranda *et al*., 2022), and cyclic loading tests (Spitznagel *et al*., 2021), are also applied in dental implant studies.

Considering the aforementioned discussion, this study was designed to perform a thorough bibliometric analysis of the scientific literature on applied biomechanics in oral implantology. This was achieved by utilizing various artificial intelligence (AI) systems to pinpoint the dependent and independent variables that are most frequently analyzed within this domain. Additionally, the study aimed to catalog the procedures employed for analysis and to elucidate the frequency and relationships of these variables. The utility and proficiency of AI technology in facilitating bibliometric analysis also constitute a significant focus of this study.

## MATERIAL AND METHOD

A systematic literature review was conducted using the PubMed database. The search strategy employed MeSH Keywords "Dental Implant" and "Biomechanics," combined with the Boolean connector AND. This strategy formulated the search equation.

The exclusion criteria were defined by two principal reasons: articles irrelevant to the field of dentistry (EX1) and dentistry articles not pertinent to the domain of dental implant biomechanics (EX2). Within these parameters, specific exclusion criteria included studies focusing on surface modifications or treatments that chemically—rather than mechanically—affect osseointegration, investigations into tooth-implant splinting, research on orthodontic or zygomatic implants, and studies detailing methods for measuring implant stability.

After article search and selection, the bibliometric analysis was performed according to the following steps: In the first step, text was extracted from each selected article, excluding sections that were not accessible, such as plots. In the next, the Rapid Automatic Keyword Extraction (RAKE) algorithm was utilized to identify keywords within each article. These keywords were determined by the algorithm as significant for comprehending the article, rather than being chosen by the article's author (Berry & Kogan 2010). In the third stage, each keyword was classified into three categories, namely dependent variables, independent variables, and procedures. These three categories were related to each other through AI. Finally, a graph was plotted to help understand relationships among categories related to dental implant biomechanics.

Unlike conventional co-word analysis, which relies on human pre-selection of terms, the RAKE algorithm automates the process of identifying high-impact keywords directly from the text, ensuring objectivity and scalability. This approach allows for the identification of emerging trends and previously unexamined relationships among research variables. Unlike previous bibliometric reviews, which analyze titles and abstracts, our study analyzed 1,512 full-text articles in their entirety. This comprehensive approach significantly increases the breadth and depth of the analysis, providing a more holistic view of the research landscape.

This algorithm is capable of assigning scores to extracted keywords. In our study, we identified each candidate keyword, constructed a co-occurrence graph, and calculated the scores based on their frequency (freq(w)), degree (deg(w)), and ratio of the degree to frequency (deg(w)/freq(w)). Association rules were utilized to find relationship patterns among extracted keywords, which is useful in drawing conclusions (Buneman & Jajodia, 1993). The algorithm quantifies the strength of relationships between two meta-keywords on a scale from 0 to 1, where 1 indicates the strongest possible association. This is expressed as follows:

The present study can be considered a review of the current state of the topic, in which artificial intelligence tools have been applied, which is ultimately not subject to ethical approval.

## RESULTS

The implementation of AI-driven keyword extraction and categorization allowed for the identification of unique patterns that would have been difficult to detect manually. For instance, relationships between "load transfer" and "implant micromotion" were revealed as significant despite these concepts being sparsely mentioned in prior reviews. This analysis was facilitated by the co-occurrence mapping of 3,669 extracted terms, of which 584 were classified as independent variables and 279 as dependent variables. The use of the RAKE algorithm ensured that the process was objective, repeatable, and scalable across a dataset of over 1,500 full-text articles, as opposed to relying solely on titles and abstracts as in previous studies.

From these 1,512 articles, a total of 3,669 words were extracted using the RAKE algorithm. These words were classified into four broad categories: (1) independent variables (584), (2) dependent variables (279), (3) recording or measurement procedures (73), and words without a relevant meaning (2,733).

Subsequently, we identified coincidences among different words with the same meaning within each category, with the corresponding results presented in Table I.

System employed in this study combined the resulting categories, indicating their correlation. Based on these relationships, graphs were plotted to help understand how words in articles on dental implant biomechanics were related to each other. The manual and automated method of analysis and the respective sequence of steps are shown in Figure 1.

Table I. Relationship of independent variables, dependent variables, and recorded procedures.

| **Independent variables** | **Dependent variables** | **Procedures** |
|---|---|---|
| Abutment | Fracture strength | Fatigue Failure |
| Bone quality | GAP | Finite Element A |
| Cantilever | Implant Micromotion | Insertion torque |
| Implant connection type | Implant stability | Removal torque |
| Implant design | Load Transfer | RFA |
| Implant diameter | Marginal bone loss | Strain gauges |
| Implant Length | Mechanical/technical complications | |
| Implant Type | Osseointegration | |
| Implant manufacturing materials | Survival | |
| Loading protocols | | |
| Loading types | | |
| Mechanical properties | | |
| Platform switching | | |
| Prosthesis manufacturing materials | | |
| Prosthesis type | | |
| Retention type | | |
| Surface treatment | | |

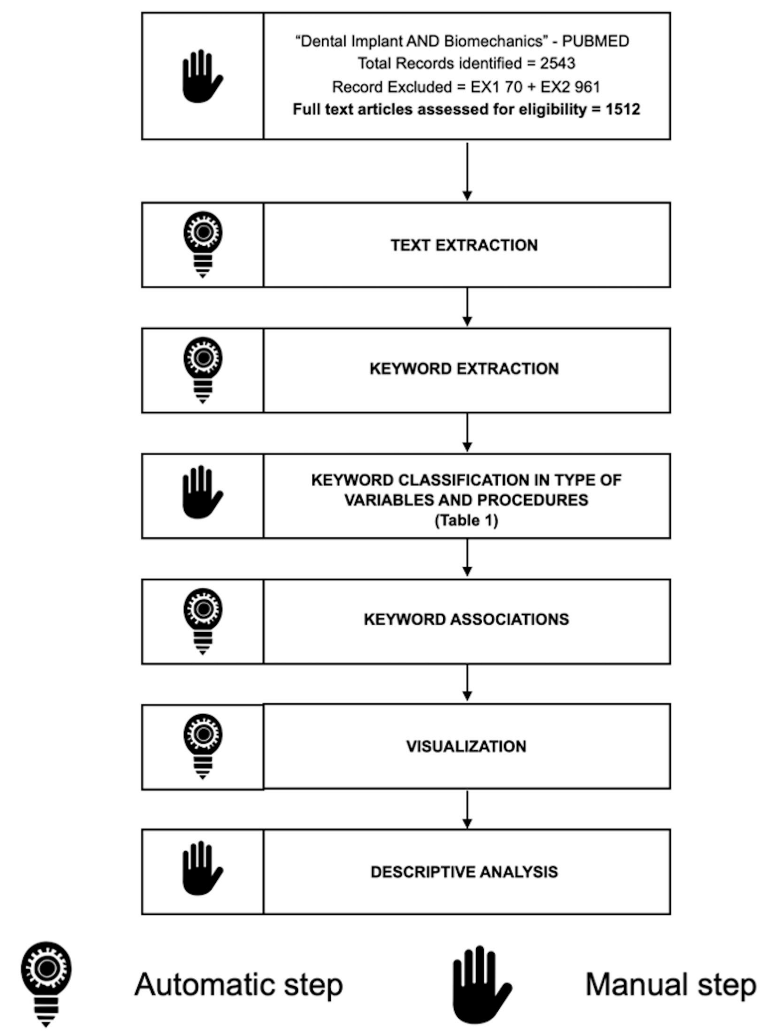


Fig. 1. Description of the methodology used in this study.

Figure 2 shows the frequency and relationships of independent variables, represented on a radar chart. Here, each keyword is assigned a distinct color and plotted along the circle's perimeter based on its occurrence rate. Among the seventeen independent variables identified, 'loading type' emerged as the most frequently studied, while 'bone quality' and 'platform switching' were among the least mentioned variables in the articles scrutinized for this SLR. Moreover, the chart employs colored arrows to illustrate the variables' correlations and the directionality of these relationships, with primary connections emanating from the keyword in question depicted in the same color, and secondary connections originating from alternative keywords shown in corresponding hues. This analytical and graphical presentation method enables the determination of a keyword's prominence by summing the primary and secondary relationships associated with that term.

Similar to Figure 2, the following graphs follow the same analytical and visualizing approach, Figure 3 illustrated the dependent variables and their correlations, while Figure 4 shows the relationship between the variables and the methods used.

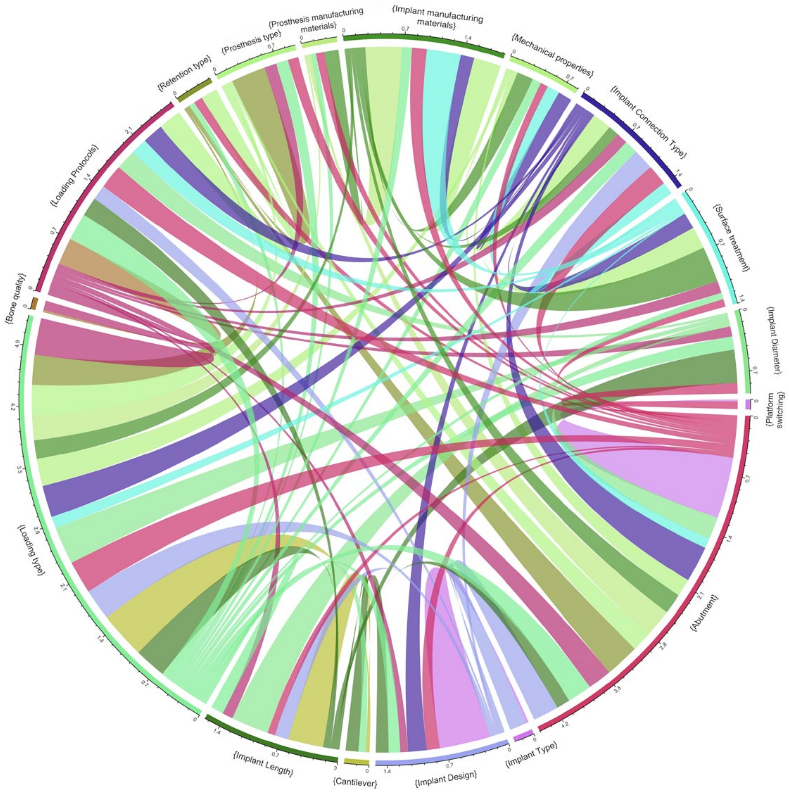


Fig. 2. Graphical representation of extracted independent variables and their correlation.

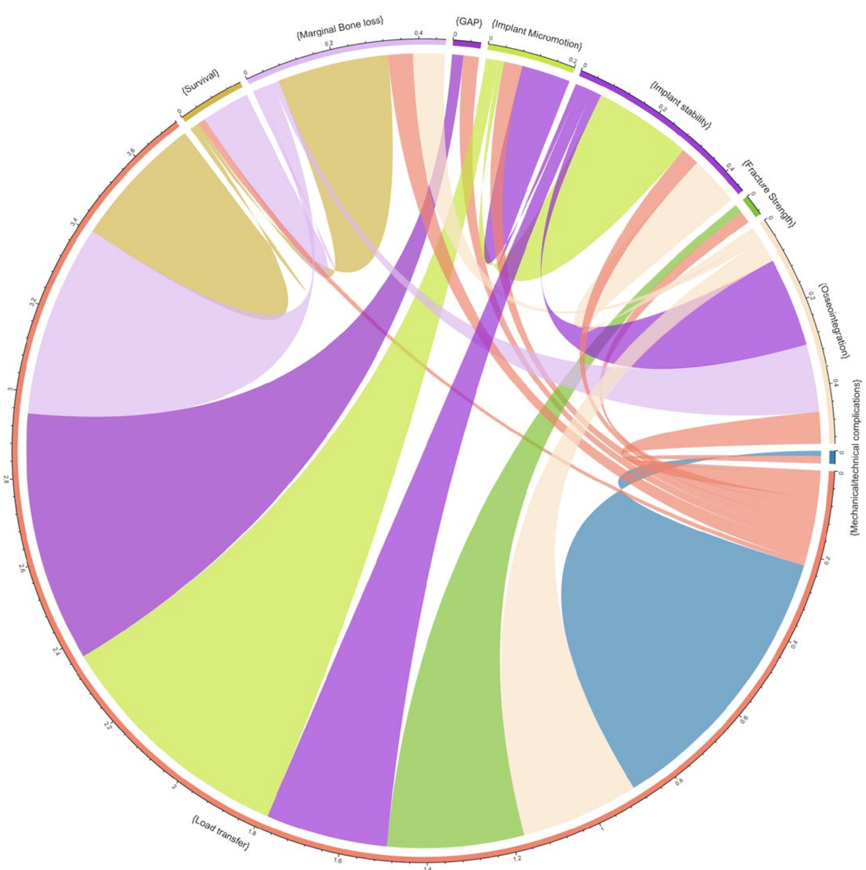


Fig. 3. Graphical representation of extracted dependent variables and their correlation.

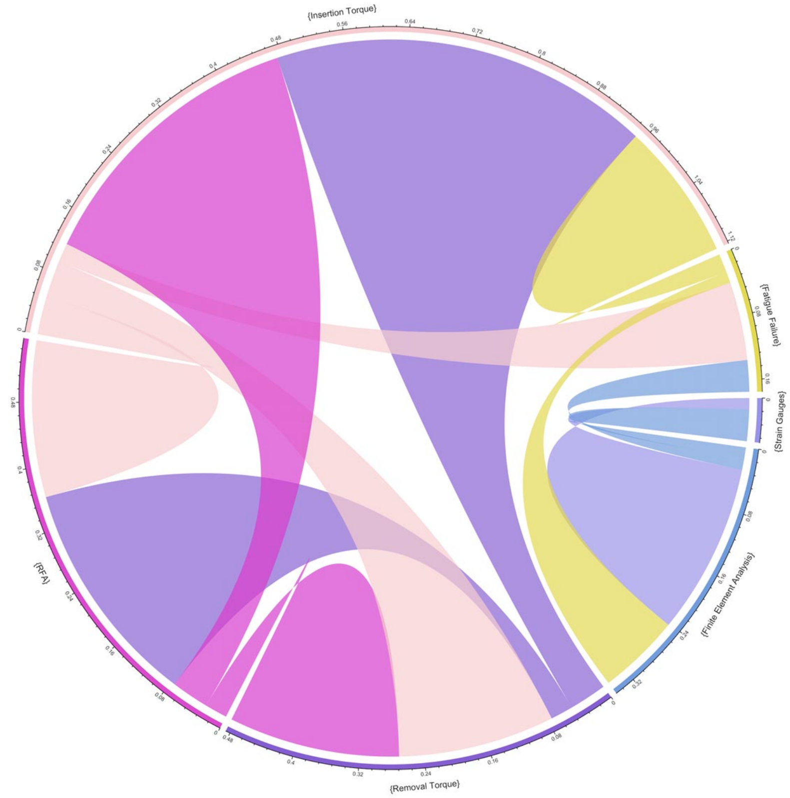


Fig. 4. Graphical representation of extracted variables and analysis procedures and their correlation.

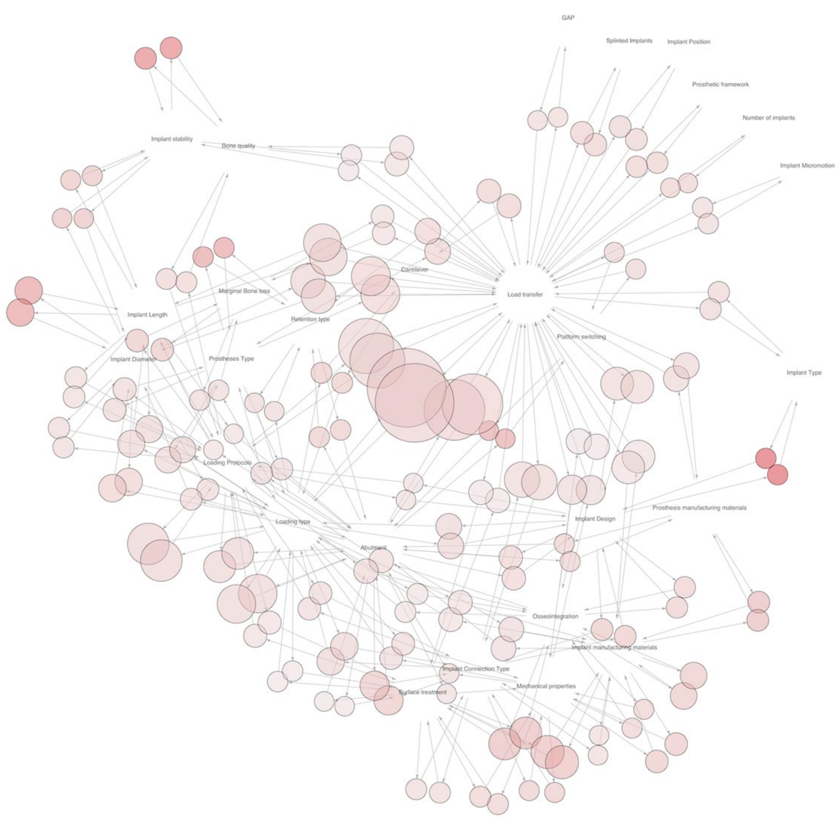


Fig. 5. Network map graph of the correlation between dependent and independent variables.

We utilized AI to assess the relationship between dependent and independent variables and between procedures and dependent variables. These results were analyzed by plotting a co-occurrence network diagram of keywords (Figs. 5 and 6). In this map, the circle size indicates keyword frequency, circle proximity indicates the frequency at which two keywords are found in the same article, the size of the keyword label is proportional to its total link strength, and a darker shade of color means that while the relationship may not be repeated in the papers, its frequency is important.

Figure 5 shows that the dependent variable load transfer prevails, with numerous correlations with multiple independent variables. Furthermore, two independent variables stand out due to the importance of their correlations, such as the implant type (which refers to a bone-level or smooth-neck implant) and implant design (which refers to implant body macro-design or thread type).

Finally, Figure 6 illustrates a scheme of the relationship between dependent variables and procedures. This analysis facilitates an understanding of the current research landscape by examining not just the variables potentially related to the success of dental restorations using implants, based on biomechanical criteria, but also the methods available to assess these effects and their evidential value. Notably, the associations between insertion torque, RFA, and implant stability are highlighted for their significance. These first two independent variables are particularly pertinent since they are applicable in clinical settings, explaining their frequent mention in clinical, observational, and experimental studies. Load transfer is identified as a principal variable; however, its mention often pertains to the context of procedures employed in *in vitro* or animal model studies.

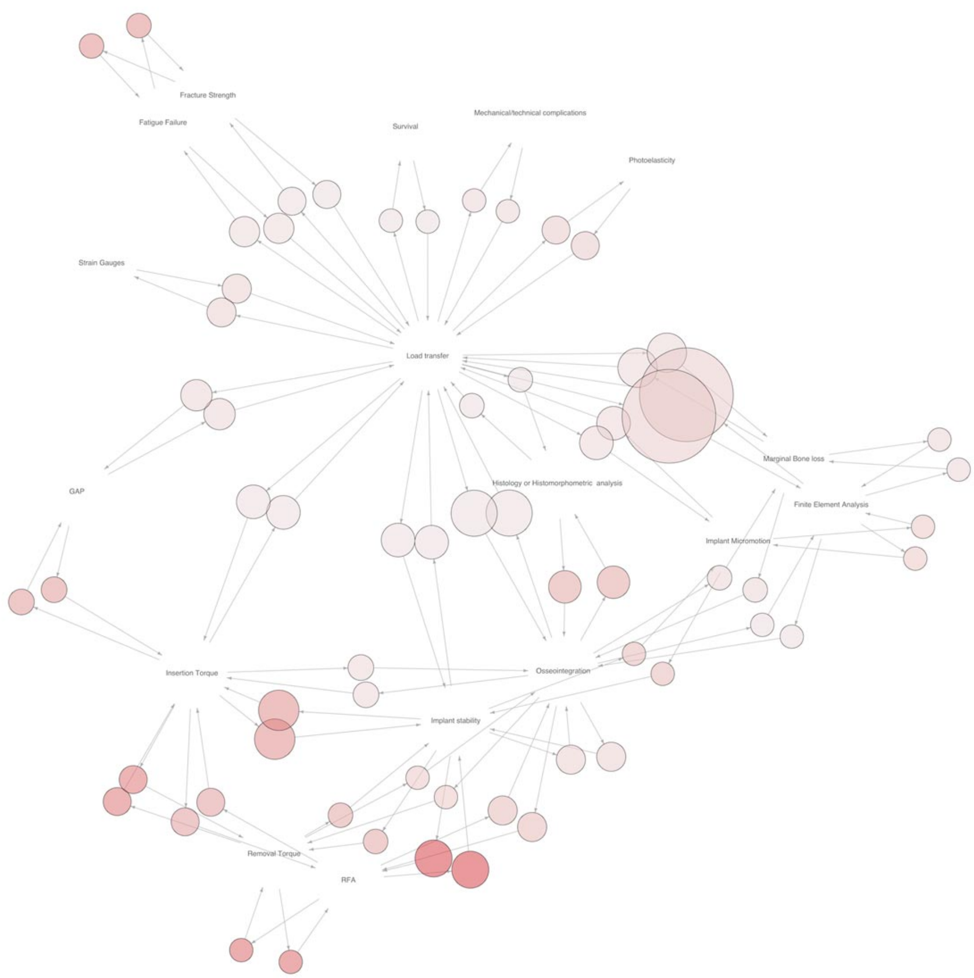


Fig. 6. Network map graph of the correlation between dependent variables and analysis procedures used in this study.

## DISCUSSION

This study aimed to identify the dependent and independent variables, along with the most utilized analysis and study procedures in dental implant biomechanics, and their interrelations. To achieve this, we utilized an AI system that integrates machine learning and natural language processing for the selective extraction of keywords and the graphical representation of these correlations.

However, this approach incorporates manual processes, as detailed in the Material and Methods section. The necessity of these manual processes calls for further investigation to mitigate their potential bias and the subjective classification of the results. Despite this limitation, the methodology deployed in this study enables the processing and analysis of a vast volume of data, which would have been challenging to manage manually.

The use of AI-driven analysis and the RAKE algorithm revealed several previously underexplored relationships in the field of dental implant biomechanics. For example, the association between “implant micromotion” and “peri-implant bone loss” emerged as a recurrent theme, even though it was not a focus in previous reviews. The ability to extract and visualize keyword relationships from entire full-text articles—not just titles and abstracts—allowed for a more complete view of the research landscape. This level of granularity would have been impractical to achieve using manual or traditional bibliometric methods, which typically require prior selection of keywords. By highlighting these connections, this study provides actionable insights for researchers and clinicians aiming to address underexplored areas in implant design and patient outcomes.

Our network map graph demonstrates that the keywords "loading type" and "load transfer" are consistently encountered in the literature, indicating a bidirectional relationship. Previous studies have also frequently explored two other relationships: the relationship between the abutment and load transfer, and the relationship between loading protocols and load transfer, both of which exhibit bidirectionality. While the relationship between implant type and implant design is less commonly cited, it is deemed highly significant when mentioned, similar to the relationship between implant stability and bone quality.

The most prevalent association identified between procedures and dependent variables involved load transfer with FEA. In contrast, a significant yet underemphasized relationship exists in assessing implant stability through RFA. Other important associations, though less frequently mentioned, include the relationship between insertion torque and removal torque, as well as between RFA and implant stability. Describing relationships among independent variables presents a greater challenge than elucidating those among dependent variables. Understanding the impact of a specific factor on various outcomes is straightforward; however, this clarity diminishes with the addition of more factors, especially when these additional factors serve as covariates or confounders.

Furthermore, bibliometric analysis definitively illustrates that research on dental implant biomechanics predominantly relies on *in vitro* assays. This reliance is attributed to the challenges in developing *in vivo* tests for both animal and clinical models, which are compounded by the costs and ethical considerations associated with such procedures.

*In vitro* findings often present challenges in clinical application, as the development of such laboratory tests necessitates the implementation of simplifications based on assumptions that influence the outcomes. This gap in clinical translation aligns with findings from other published reviews, which critique the *in vitro* methods used in studies on dental implant biomechanics. These critiques particularly focus on the evaluation of various independent variables, including the type of loading, mechanical properties of implant and prosthesis manufacturing materials, and fatigue, all of which were examined in this study (Bonfante & Coelho, 2014).

Among *in vitro* procedures, FEMs are the most extensively utilized technique in biomechanics studies. However, these studies exhibit a high degree of heterogeneity, making their results challenging to interpret, as highlighted in a recent SLR [8]. Despite these challenges, FEMs play an essential role in elucidating the biomechanical behavior of implant restorations and their impact on various dependent variables. These variables include the type of loading, bone-implant contact, and implant connection or peri-implant bone loss, aligning with the variables investigated in this study.

Furthermore, numerous studies have, to a lesser extent, utilized various types of *in vitro* assays, such as PSA and SGA. PSA is employed to demonstrate stress in more complex structures or stress patterns within a complete model, aiming to quantify stress magnitude and identify its location. Conversely, SGA can also be applied in *in vivo* tests and may be combined with PSA or FEA, offering significant advantages (Pesqueira *et al*., 2014).

Nevertheless, some studies have conducted *in vivo* animal tests and clinical trials to assess biomechanical variables. The most researched independent variables in this area pertain to implant-supported prostheses, such as manufacturing material, connection type, and prosthetic attachments and overhangs, which are also examined in the current review (Alzahrani *et al*., 2020). Accordingly, certain studies have utilized technology for assessing functional overload on prostheses (Tscan; Tekscan Inc.) and correlated their findings with dependent variables, such as levels of inflammatory markers in the peri-implant sulcus, indicative of bone remodeling (Viña-Almunia *et al*., 2020). Among the *in vivo* trials reviewed in this study, the most frequently investigated dependent variables include implant stability, RFA—an implant stability assessment procedure, and insertion torque. These studies illustrate that clinical trials focusing on biomechanics can correlate key variables, such as overload, load transfer, and bone loss, potentially enhancing the level of evidence in this field of dental science in the future (Natiella, 1988).

Science has advanced in this domain primarily through pairwise comparison methods and the accumulation of new evidence, enabling the incorrect validation of false hypotheses. In this context, SLRs and meta-analyses, which consolidate evidence on a specific topic at a particular time, play a pivotal role in advancing research. Furthermore, bibliometric methods that incorporate AI systems, such as the approach employed in this study—merging machine learning and natural language processing for automatic keyword extraction—are immensely beneficial. They allow for the assessment of the current state of any research area by processing large volumes of data that would be unmanageable manually and by generating reports on correlations between variables. Once accessible at the user level, this technology will soon efficiently furnish researchers with vital information regarding the state of their field of knowledge.

## CONCLUSION

Bibliometric analysis indicates that load transfer is among the most frequently investigated variables, with RFA being the most commonly utilized procedure. Moreover, the outcomes of variable extraction and their correlation underscore the advanced development of dental implant biomechanics, as well as the necessity for *in vivo* research in this domain, which currently depends heavily on *in vitro* experimentation. The primary conclusion derived from this bibliometric analysis is the significant potential of AI-based procedures for delineating the developmental status of any research area.

**BRIZUELA-VELASCO, A.; FERNÁNDEZ-HERNÁNDEZ, S.; GAVIRIA-DE LA PUERTA, J.; BARBOSA, F.T.; PORTO-GÓMEZ, I.; BELLANCO-DE LA PINTA, I.; PÉREZ-PEVIDA, E. & ROBLES-CANTERO, D.** Biomecánica en implantes dentales: Análisis mediante la aplicación de sistemas de inteligencia artificial. *Int. J. Odontostomat., 19(3)*:224-233, 2025.

**RESUMEN:** El objetivo de este estudio es analizar el campo de la biomecánica de implantes dentales mediante un novedoso enfoque de bibliometría basada en Inteligencia Artificial (IA). Aprovechando el aprendizaje automático y el procesamiento del lenguaje natural, hemos trazado las principales tendencias de investigación, identificado las variables dependientes e independientes y destacado los procedimientos de prueba más utilizados. Este análisis pretende identificar áreas poco exploradas en la investigación biomecánica y ofrecer una hoja de ruta para futuros estudios. Se realizó una revisión sistemática de 1.512 artículos a texto completo de la base de datos PubMed. Utilizando el algoritmo Rapid Automatic Keyword Extraction (RAKE), se identificaron los conceptos clave y se clasificaron en tres categorías: variables dependientes, variables independientes y procedimientos. Se aplicó un análisis avanzado de concordancia para visualizar las interrelaciones entre estos términos y su prevalencia en el conjunto de la literatura. Nuestro análisis reveló que la variable independiente estudiada con más frecuencia es el tipo de carga, mientras que la variable dependiente más destacada es la transferencia de carga, y el procedimiento más empleado es la medición del torque de inserción. El estudio reveló una dependencia de las metodologías *in vitro*, lo que indica la necesidad de más investigación *in vivo* para salvar la distancia entre los hallazgos de laboratorio y lapráctica clínica. Factores biomecánicos importantes, como la calidad ósea y el tipo de conexión del implante, siguen sin explorarse a pesar de su posible repercusión clínica. Nuestros hallazgos revelan lagunas de conocimiento críticas en el campo de la biomecánica de implantes dentales y subrayan la importancia de la investigación *in vivo* para mejorar los resultados clínicos. Al combinar el análisis bibliométrico con la extracción de palabras clave basada en IA, este estudio introduce un enfoque reproducible y escalable para mapear los campos de investigación odontológica.

**PALABRAS CLAVE: biomecánica, implantes dentales, análisis, inteligencia artificial.**

## REFERENCES


Alzahrani, K. M. Implant bio-mechanics for successful implant therapy: A systematic review. *J. Int. Soc. Prev. Community Dent., 10(6)*:700-14, 2020.

Berry, M. W. & Kogan, J. T*ext mining: Applications and theory.* 1st ed. Chichester, United Kingdom, Wiley & Sons, 2010. pp. 1-20.

Bidez, M. W. & Misch, C. E. Issues in bone mechanics related to oral implants. *Implant. Dent., 1(4)*:289-94, 1992.

Bonfante, E. A. & Coelho, P. G. A critical perspective on mechanical testing of implants and prostheses. *Adv. Dent. Res., 28(1):18-27*, 2016.

Brunski, J. B.; Puleo, D. A. & Nanci, A. Biomaterials and biomechanics of oral and maxillofacial implants: Current status and future developments. *Int. J. Oral Maxillofac. Implants., 15(1)*:15-46, 2000.

Buneman, P. & Jajodia, S. *Proceedings of the ACM SIGMOD International Conference on Management of Data (SIGMOD'93)*. 1st ed. New York, United States: ACM, 1993. pp. 207-216.

Daryakenari, G. & Batooli, Z. A bibliometric and subject analysis of 3300 most-cited articles in dentistry. *Clin. Exp. Dent. Res., 8(5)*:1302-10, 2022.

Frost, H. M. Bone ¨mass¨and the ¨mechanostat": A proposal. *Anat. Rec, 219(1)*:1-9, 1987.

Galindo-Moreno, P.; Catena, A.; Pérez-Sayáns, M.; Fernández-Barbero, J. E.; O'Valle, F. & Padial-Molina, M. Early marginal bone loss around dental implants to define success in implant dentistry: A retrospective study. *Clin. Implant. Dent. Relat. Res., 24(5)*:630-42.

Godin, B. On the origins of bibliometrics. *Scientometrics, 68*:109-33, 2006.

Hämmerle, C. H. F.; Cordaro, L.; Alccayhuaman, K. A. A.; Botticelli, D.; Esposito, M. & Colomina, L. E. Biomechanical aspects: Summary and consensus statements of group 4. The 5th EAO Consensus Conference 2018. *Clin. Oral Implants. Res., 29*:326-31, 2018.

Maminskas, J.; Puisys, A.; Kuoppala, R.; Raustia, A. & Juodzbalys, G. The prosthetic influence and biomechanics on peri-implant strain: A systematic literature review of finite element studies. *J. Oral Maxillofac. Res., 7(3)*:e4, 2016.

Marín-Miranda, M.; Wintergerst, A. M.; Moreno-Vargas, Y. A.; Juárez-López, M. L. A. & Tavera-Ruiz, C. Photoelasticity for stress concentration analysis in dentistry and medicine. *Materials (Basel), 15(19)*:6819-42, 2022.

Matos, J. D. M.; Queiroz, D. A.; Nakano, L. J. N.; Andrade, V. C.; de Ribeiro, N. C. R. & Borges, A. L. S. Bioengineering tools applied to dentistry: Validation methods for *in vitro* and in silico analysis. *Dent. J. (Basel), 10(8)*:145-67, 2022.

Natiella, J. R. The use of animal models in research on dental implants. *J. Dent. Educ., 52*:792-7, 1988.

Pérez-Pevida, E.; Brizuela-Velasco, A.; Chávarri-Pardo, A.; Jiménez-Garrudo, A.; Sánchez-Lasheras, F. & Solaberrieta-Méndez, E. Biomechanical consequences of the elastic propierties of dental implant alloys on the supporting bone: Finite Element analysis. *BioMed. Res. Int., 2016*:1850401-9, 2016.

Pesqueira, A. A.; Goiato, M. C.; Filho, H. G.; Monteiro, D. R.; Santos, D. M. & Haddad, M. F. Use of stress analysis methods to evaluate the biomechanics of oral rehabilitation with implants. *J. Oral Implantol., 40(2)*:217-28, 2014.

Reddy, M. S.; Sundram, R.; Eid Abdemagyd, H. A. E. Application of finite element model in implant dentistry: A systematic review. *J. Pharm. Bioallied. Sci., 11(Suppl 2)*:S85-S91, 2019.

Sailer, I.; Strasding, M.; Valente, N. A.; Zwahlen, M.; Liu, S. & Pjetursson, B. E. A systematic review of the survival and complication rates of zirconia-ceramic and metal-ceramic multiple-unit fixed dental prostheses. *Clin. Oral Implants Res., 29 Suppl 16*:184-98, 2018.

Schwarz, F.; Alcoforado, G.; Guerrero, A.; Jönsson, D.; Klinge, B. & Lang, N. Peri-implantitis: Summary and consensus statements of group 3. The 6th EAO Consensus Conference 2021. *Clin. Oral Implants Res., 32 Suppl 21*:245-53, 2021.

Spitznagel, F. A.; Bonfante, E. A.; Campos, T. M. B.; Vollmer, M. A.; Boldt, J. & Doerken, S. Mechanical stability of screw-retained monolithic and bi-layer posterior hybrid abutment crowns after thermomechanical loading: An *in vitro* study. *Materials (Basel), 14(24)*:7539-52, 2021.

Thompson, D. R.; Clark, A. M. Measuring research success via bibliometrics: Where they fit and how they help and hinder. *J. Adv. Nurs., 71(12)*:2699-701, 2015.

Van Eijden, T. M.; Three-dimensional analyses of human bite-force magnitude and moment. *Arch. Oral Bio.l, 36(7)*:535-9, 1991.

Viña-Almunia, J.; Pellicer-Chover, H.; García-Mira, B.; Romero-Millán, J.; Peñarrocha-Oltra, D. & Peñarrocha-Diago, M. Influence of occlusal loading on peri-implant inflammatory cytokines in crevicular fluid: A prospective longitudinal study. *Int. J. Implant. Dent., 6(1)*:71-8, 2020.



Corresponding author:
Saray Fernández-Hernández
Predoctoral researcher of of Dens-AI Research Group
Faculty of Health Sciences
European University Miguel de Cervantes
C/ Padre Julio Chevalier, 2
47012 Valladolid
SPAIN

E-mail: sfernandezh@uemc.es