UNIVERSIDAD CATÓLICA DE CUENCA

Comunidad Educativa al Servicio del Pueblo

DIRECCIÓN DE POSGRADOS

Especialidad en Imagenología oral y maxilofacial

"PRECISIÓN DIAGNÓSTICA Y APLICACIONES CLÍNICAS DE LA ECOGRAFÍA EN ODONTOLOGÍA ESTÉTICA Y CARACTERIZACIÓN DE TEJIDOS BLANDOS FACIALES: UNA REVISIÓN SISTEMÁTICA"

ARTICULO CIENTIFICO PREVIO A LA OBTENCIÓN DEL TÍTULO DE IMAGENOLOGIA ORAL Y MAXILOFACIAL

AUTOR: MARIA JOSÉ FERNÁNDEZ SIGUENCIA

DIRECTOR: VERÓNICA IVANNOVA VERDUGO TINITANA

CUENCA – ECUADOR

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DIOS, PATRIA, CULTURA Y DESARROLLO

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El informe de investigación "Precisión diagnóstica y aplicaciones clínicas de la ecografía en odontología estética y caracterización de tejidos blandos faciales: Una Revisión Sistemática", de autoría del Sr./a Maria José Fernández Siguencia" con número de identidad 030254920-9, con nacionalidad Ecuatoriana, previo a la obtención del Título de Cuarto Nivel o Posgrado correspondiente a Especialidad de Imagenología oral y maxilofacial, cumple con la caracterización y estructura (parte protocolaria y parte expositiva) y se sujeta a la normativa pertinente exigida por el Consejo de Educación Superior, CES y la Universidad Católica de Cuenca, en consecuencia se autoriza su presentación para los tramites pertinentes.

Santa Ana de los Ríos de Cuenca

Fecha 10 septiembre 2026

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Od. Esp. Verónica Ivannova Verdugo Tinitana

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F: ……………………………………………..

Maria José Fernández Siguencia

C.I. **0302549209**

Agradecimiento

Agradezco a la Universidad Católica de Cuenca y a quienes formaron parte de la Especialización en Imagenología Oral y Maxilofacial, por los conocimientos, experiencias y oportunidades que contribuyeron a mi crecimiento académico y profesional durante esta etapa de formación.

A mis docentes, por compartir sus conocimientos y experiencias, y por contribuir a fortalecer mi preparación en el campo de la Imagenología Oral y Maxilofacial.

De manera especial, agradezco a mi familia, por acompañarme siempre, por su apoyo incondicional y por estar presente en cada uno de los proyectos y metas que he decidido emprender. Gracias por ser mi respaldo durante estos años y por celebrar conmigo cada logro alcanzado.

Finalmente, agradezco a todas aquellas personas que, de una u otra manera, contribuyeron a que este proceso llegara a su culminación.

A todos, mi más sincero agradecimiento.

Dedicatoria

Esto me lo dedico a mí.

A la mujer que decidió comenzar, que tuvo la determinación de continuar y la fortaleza para no rendirse. A mí, por cada día de esfuerzo, por las horas dedicadas, por los retos superados y por seguir adelante incluso cuando el camino se volvió difícil.

Me lo dedico por haber confiado en mis capacidades, por exigirme siempre un poco más y por demostrarme que, con constancia, disciplina y determinación, soy capaz de alcanzar aquello que me propongo.

Porque fui yo quien estuvo presente en cada etapa, quien asumió cada desafío y quien hizo todo lo necesario para llegar hasta aquí.

Este logro me lo dedico a mí, porque me lo gané

ANALYSIS | ISSN: 2386-3994 | Vol. 41, (Ene. 2026), pp. 1–40

Maria José Fernández Siguencia, Verónica Ivannova Verdugo Tinitana

Diagnostic accuracy and clinical applications of ultrasound in aesthetic dentistry and facial soft-tissue characterization: a systematic review

ABSTRACT: To evaluate the agreement, reproducibility, diagnostic performance, and clinical applications of high-frequency ultrasound (HFUS) in orofacial soft tissues. Materials and Methods: A systematic review following PRISMA 2020 guidelines, registered in PROSPERO (CRD420251207172), was conducted using PubMed and Scopus (2010–2025). Results: Nineteen original studies and two narrative reviews were included. HFUS demonstrated good agreement with CBCT, transgingival probing, histology, and clinical examination, and proved useful for vascular mapping, dermal filler assessment, and complication management. Conclusions: HFUS is a non-invasive, radiation-free imaging modality with promising clinical applications, although standardized protocols and prospective multicenter studies are still needed.

KEYWORDS: High-frequency ultrasound; Doppler ultrasonography; Gingival thickness; Dermal fillers; Facial soft tissues; Esthetic dentistry.

Precisión diagnóstica y aplicaciones clínicas de la ecografía en odontología estética y caracterización de tejidos blandos faciales: una revisión sistemática

RESUMEN: Evaluar la concordancia, reproducibilidad, rendimiento diagnóstico y aplicaciones clínicas de la ecografía de alta frecuencia (HFUS) en tejidos blandos orofaciales. Materiales y métodos: revisión sistemática según prisma 2020, registrada en PROSPERO (CRD420251207172), con búsqueda en Pubmed y Scopus (2010–2025). resultados: se incluyeron 19 estudios originales y 2 revisiones narrativas. La HFUS mostró buena concordancia con CBCT, sondaje transgingival, histología y examen clínico, además de utilidad en mapeo vascular, evaluación de rellenos dérmicos y sus complicaciones.

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ARTÍCULO [SP]: Recibido: 1–DIC–2025 | Aceptado: 28–ENE–20226 | © Autor(es) 202x. Publicado por Studia Humanitatis.

Conclusiones: la HFUS es una modalidad no invasiva y libre de radiación con prometedoras aplicaciones clínicas, aunque se requieren protocolos estandarizados y estudios prospectivos multicéntricos.

PALABRAS CLAVE: Ecografía de alta frecuencia; Ecografía doppler; Espesor gingival; Rellenos dérmicos; Tejidos blandos faciales; Odontología estética.

Introduction

Ultrasound has emerged as an increasingly relevant diagnostic tool for the evaluation of orofacial soft tissues and facial aesthetic procedures, owing to its non-invasive nature, absence of radiation, broad accessibility, and ability to provide real-time dynamic imaging. Recent literature recognizes that ultrasound enables precise characterization of structures such as mucosa, facial muscles, salivary glands, peri-implant tissues, and vascular pathways, thereby significantly expanding its usefulness in contemporary dental practice (1,4,5,6,10).

Over the past 15 years, research in this field has progressed from basic applications—such as the assessment of salivary glands and soft-tissue lesions to highly specialized uses, including the planning of minimally invasive aesthetic procedures, localization of filler material, identification of complications, and evaluation of the peri-implant biotype (4,6). This methodological advancement reflects the availability of high-frequency transducers (≥15 MHz), improvements in image resolution, and the growing integration of ultrasound into clinical and educational settings.

Current trends in the literature show particular interest in: (a) the quantitative characterization of peri-implant mucosal thickness, (b) facial vascular mapping prior to aesthetic procedures, (c) ultrasound-guided facial filler placement and complication management, and (d) the dynamic assessment of muscular function in aesthetic and orofacial rehabilitation contexts (5,6). However, important gaps persist, including the lack of protocol standardization, heterogeneity in probe frequencies, and considerable inter-operator variability factors that help explain the inconsistency observed across studies (5,6,10).

Methodologically, diagnostic-accuracy studies predominate, comparing ultrasound with reference methods such as magnetic resonance imaging and computed tomography. These studies have yielded encouraging results in the detection of disc displacements, peri-implant assessment, and the diagnosis of superficial facial fractures (8). In parallel, observational studies and case series have demonstrated that ultrasound-guided procedures enhance the safety and predictability of aesthetic interventions by enabling prior anatomical mapping and precise identification of filler material (9).

Current scientific output is led by research groups in Europe, Asia, and Latin America, composed of multidisciplinary teams that include dentistry, maxillofacial surgery, radiology, and aesthetic medicine, underscoring the cross-disciplinary character of ultrasound in this field. Current literature generally supports the concept that ultrasound does not fully replace CBCT or MRI; however, it represents a valuable complementary tool for diagnosis and aesthetic planning, minimizing risks and supporting a safer, evidence-based practice (10).

In this context, and considering the accelerated expansion of ultrasound as both a diagnostic and therapeutic tool in aesthetic dentistry and facial medicine, a critical appraisal of the available evidence is essential. Therefore, the aim of this systematic review is to analyse the diagnostic accuracy of high-frequency ultrasound in the evaluation of orofacial soft tissues and to synthesise its clinical applications in aesthetic dentistry, peri-implantology, and facial aesthetic medicine. Additionally, it seeks to identify strengths, limitations, knowledge gaps, and future research opportunities. This analysis will allow for an assessment of the reliability of ultrasound compared with established reference methods, as well as its actual contribution to the safety and effectiveness of contemporary clinical procedures.

Materials and Methods

Study design:

A systematic review was conducted following the PRISMA 2020 guidelines and was prospectively registered in PROSPERO under the title "Diagnostic Accuracy and Clinical Applications of Ultrasound in Aesthetic Dentistry and Facial Soft-Tissue Characterization" (registration number: CRD420251207172). No amendments were made to the registered protocol. The primary aim of the review was to evaluate the diagnostic accuracy of high-frequency ultrasound (HFUS) compared with established reference standards and to synthesise its clinical applications in aesthetic dentistry, periodontology, peri-implantology, and facial aesthetic medicine.

A comprehensive search strategy was developed and implemented in PubMed and Scopus to identify relevant studies published between 2010 and 2025. The final electronic search was conducted on September 30, 2025. No language restrictions were applied. The search strategy combined controlled vocabulary (Medical Subject Headings [MeSH], when applicable) with free-text terms related to high-frequency ultrasound, orofacial soft tissues, periodontal and peri-implant assessment, and facial aesthetic procedures. Boolean operators (AND/OR) were used to maximize search sensitivity and ensure comprehensive retrieval of the available literature.

For PubMed, the search included MeSH terms such as Ultrasound, Ultrasound, Doppler, Mouth Mucosa, Gingiva, and Periodontium, complemented by keywords including "high-frequency ultrasound," "high-resolution ultrasound," "intraoral ultrasound," "gingival thickness," "peri-implant mucosa," and "facial soft tissues." In Scopus, the search was adapted to platform-specific syntax using TITLE-ABS-KEY.

The final PubMed search string was:

("Ultrasound"[MeSH] OR "Ultrasound, Doppler"[MeSH] OR "high-frequency ultrasound" OR "high resolution ultrasound" OR "B-mode ultrasound" OR "intraoral ultrasound" OR "Doppler ultrasound") AND ("Mouth Mucosa"[MeSH] OR "Gingiva"[MeSH] OR "Periodontium"[MeSH] OR "oral soft tissues" OR "gingival thickness" OR "peri-implant mucosa" OR "orofacial soft tissues" OR "facial soft tissues" OR "dermal fillers") AND ("Diagnostic Accuracy"[MeSH] OR "Sensitivity and Specificity"[MeSH] OR "Reproducibility of Results"[MeSH] OR "reference standard" OR CBCT OR "cone-beam computed tomography" OR MRI OR "magnetic resonance imaging" OR "transgingival probing").

The corresponding Scopus search strategy was:

(TITLE-ABS-KEY ("high frequency ultrasound" OR ultrasonography OR ultrasound OR ecograf* OR HFUS) AND TITLE-ABS-KEY ("aesthetic dentistry" OR "esthetic dentistry" OR "facial esthetics" OR "cosmetic dentistry" OR "dental esthetics" OR "dermal filler" OR "smile esthetics" OR "tissue thickness" OR "gingival phenotype" OR "gingival biotype") AND TITLE-ABS-KEY (dentistry OR odontolog* OR "oral soft tissue" OR gingiva OR periodontal OR "peri-implant" OR perioral OR lip OR lips OR "facial soft tissue")) AND (LIMIT-TO (SUBJAREA, "DENT") OR LIMIT-TO (SUBJAREA, "MEDI") OR LIMIT-TO (SUBJAREA, "HEAL")) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO (LANGUAGE, "English") OR LIMIT-TO (LANGUAGE, "Spanish")).

This multi-database approach ensured comprehensive coverage of the relevant literature on diagnostic accuracy and clinical applications of high-frequency ultrasound in aesthetic dentistry, peri-implantology, and facial soft-tissue assessment.

Methodology for Study Identification, Selection, and Evidence Synthesis

The PICOS (Population, Intervention, Comparator, Outcomes, and Study Design) framework was used to define eligibility criteria and guide study selection. The target population included adult and paediatric patients undergoing assessment of orofacial soft tissues in clinical settings, including periodontal, peri-implant, dental, and facial aesthetic applications. Anatomical regions of interest comprised the gingiva, oral mucosa, lips, perioral tissues, and other facial soft-tissue structures evaluated using ultrasonography.

The intervention of interest was high-frequency ultrasound (HFUS), including both intraoral and extraoral applications. HFUS was used for gingival thickness measurement, localization of dermal fillers, detection of treatment-related complications, Doppler-based vascular assessment, and characterization of orofacial soft tissues. Comparator methods included cone-beam computed tomography (CBCT), transgingival probing, direct surgical inspection, histological assessment, and clinical examination. In addition, technical and observational studies without a formal comparator were eligible when they reported clinically relevant applications of ultrasound aligned with the objectives of the review.

Outcomes of interest included both diagnostic and clinically relevant parameters. Diagnostic outcomes comprised measures such as sensitivity, specificity, agreement indices, and intraclass correlation coefficients (ICC), whereas clinical outcomes included gingival thickness assessment, detection of filler migration and treatment-related complications, vascular findings identified through Doppler imaging, and the diagnostic or procedural utility of ultrasound in dental and facial aesthetic applications. Eligible study designs included cross-sectional, prospective, retrospective, observational, case-series, and selected preclinical investigations. Studies with incomplete data, purely in vitro research, animal studies lacking translational or clinical relevance, grey literature, conference abstracts, letters, and editorials were excluded.

To ensure the inclusion of relevant and methodologically sound evidence, eligible studies were required to be original investigations, employ ultrasound as the primary imaging modality, and be available in full text. When applicable, studies were expected to include a reference standard or comparator method. Technical, observational, and application-focused studies were also considered eligible if they provided clinically relevant data regarding the use of ultrasound in dental, periodontal, peri-implant, or facial aesthetic settings. Publications lacking verifiable primary data were excluded.

The study selection process was conducted using Rayyan, a web-based platform that enabled independent and blinded screening by two reviewers. The software facilitated duplicate detection, comparison of screening decisions, and efficient workflow management. Study selection was performed in two stages: an initial screening of titles and abstracts followed by full-text assessment of potentially eligible articles. Any disagreements were resolved through discussion and consensus; when necessary, a third reviewer was consulted. The study selection process is summarised in a PRISMA 2020 flow diagram to ensure transparency and reproducibility.

Data extraction was performed using a standardized matrix designed to capture key study characteristics, including author and year of publication, country of origin, study design, sample size, anatomical region assessed, ultrasound characteristics (including transducer frequency), comparator or reference method (when applicable), and principal clinical findings. Two reviewers independently extracted the data and subsequently consolidated the information into a standardized Microsoft Excel extraction sheet to ensure consistency and minimize potential errors.

Methodological quality was assessed using the QUADAS-2 tool for studies evaluating diagnostic performance, measurement agreement, or reproducibility. The instrument examines four domains: patient selection, index test, reference standard, and flow and timing. Studies focused exclusively on technical descriptions, clinical applications, narrative reviews, or case-based evidence were not formally assessed using QUADAS-2. The results of the quality assessment were summarised in comparative tables and a traffic-light plot to facilitate interpretation. Any disagreements were resolved through discussion and consensus, with consultation of an external reviewer when necessary.

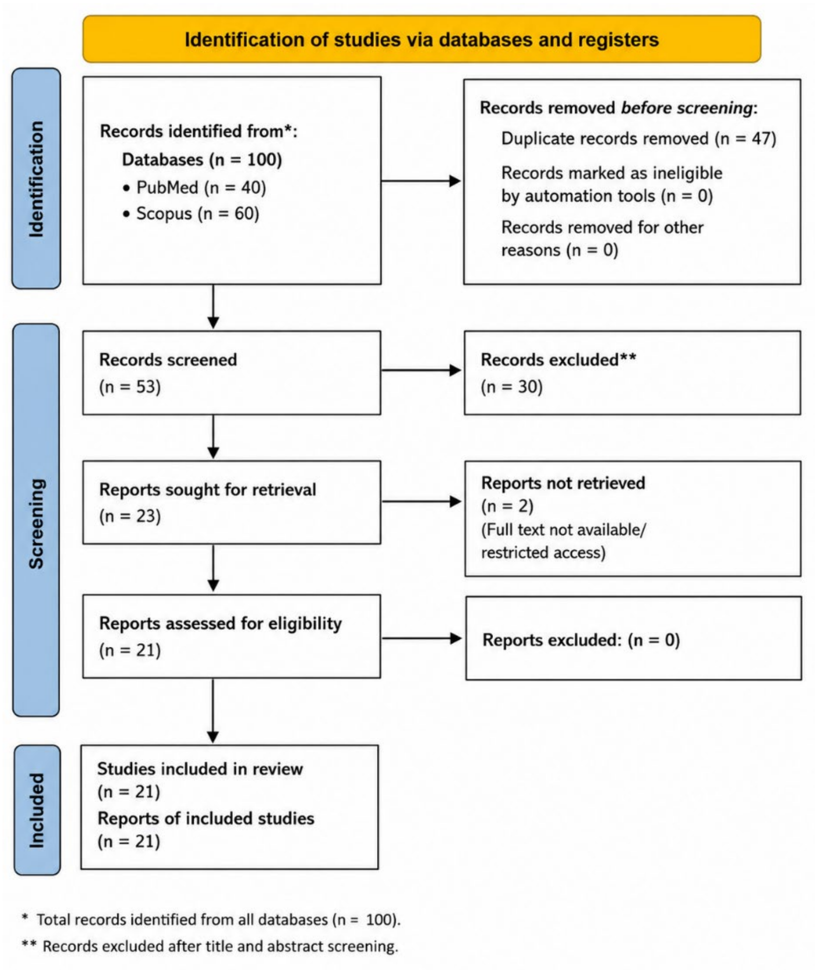
Given the substantial heterogeneity among studies in terms of ultrasound applications, comparator methods, outcome measures, and study designs, a quantitative meta-analysis was not considered appropriate. Consequently, a narrative synthesis was performed. The findings were organised into thematic domains reflecting the main areas of evidence identified during the review process, including diagnostic accuracy for gingival and periodontal assessment, clinical applications in facial aesthetics, Doppler-based vascular evaluation, measurement reproducibility, and methodological quality assessment.

Results

Study Selection

After applying the inclusion and exclusion criteria established in the protocol, a total of 21 studies were included in this systematic review. Most of the selected articles were comparative clinical studies or diagnostic validation studies assessing the use of ultrasound (US) as a non-invasive tool for the evaluation of soft tissues in dental and aesthetic contexts. Figure 1.

Figure 1. PRISMA 2020 flow diagram for the selection of studies included in the systematic review



The PRISMA diagram illustrates the complete flow of study identification, screening, eligibility assessment, and final inclusion. Of the total records initially retrieved, duplicates were removed, and a considerable number were excluded after title and abstract screening. Full-text assessment resulted in further exclusions due to lack of diagnostic accuracy data, non-relevance to ultrasound, absence of a reference standard, or incomplete data. Ultimately, 21 studies met all criteria and were included in the review.

3.2 General characteristics and methodological classification of included studies

Nineteen original studies were included in the formal qualitative synthesis. Two narrative reviews were retained as contextual evidence to support discussion of clinical implementation and emerging applications. The included publications were published between 2018 and 2025 and originated from a broad geographical distribution encompassing Europe, Asia, the Middle East, and North America (11–31).

To facilitate interpretation of the available evidence, the included publications were categorized into four evidence domains: diagnostic accuracy studies (n = 7), reliability studies (n = 2), clinical application studies (n = 10), and narrative contextual evidence studies (n = 2). Diagnostic accuracy studies primarily evaluated gingival thickness, periodontal phenotype, peri-implant soft tissues, and periodontal inflammation using histology, cone-beam computed tomography (CBCT), and transgingival probing as reference standards (14–16,18,21,22,27). Reliability studies assessed measurement reproducibility and interobserver agreement for ultrasound-derived periodontal and facial soft-tissue parameters (26,31). Clinical application studies explored the use of high-frequency ultrasound in facial aesthetic medicine, vascular mapping, filler-related complications, anatomical soft-tissue assessment, and ultrasound-guided treatment monitoring (11,12,13,17,19,20,23,28–30). Narrative contextual evidence studies provided expert perspectives and clinical recommendations regarding the implementation of ultrasound in dentistry and facial aesthetic practice (9,10).

Sample sizes varied considerably across investigations, ranging from six miniature pigs in a preclinical validation study (24) to 240 cases in a multicenter investigation of filler-related granulomas (19). Methodological approaches were heterogeneous and included cross-sectional studies, comparative clinical studies, prospective investigations, retrospective cohorts, observational studies, preclinical validation models, and narrative reviews. Periodontal and peri-implant applications were predominantly represented by diagnostic accuracy studies (14–16,18,21,22,27,31), whereas facial aesthetic applications were largely explored through observational and retrospective clinical designs (11–13,17,19,20,23,28–30). Collectively, these findings illustrate the expanding scope of HFUS applications while highlighting the methodological diversity that currently characterizes the evidence base. Table 1.

Table 1. General characteristics and methodological classification of included studies.

Author, year	Country	Study design	Sample size	Clinical field	Main outcome / contribution	Evidence domain
Kloukos et al. (2018)	Switzerland	Cross-sectional clinical study	20 patients	Periodontal soft tissues	Gingival thickness measurement compared with CBCT	Diagnostic accuracy
Bednarz-Tumidajewicz et al. (2022)	Poland	Comparative cross-sectional study	30 patients	Periodontology / Implantology	Gingival phenotype and peri-implant soft-tissue assessment	Diagnostic accuracy
Alizad-Rahvar et al. (2024)	Iran	Comparative clinical study	30 patients	Gingival thickness assessment	Intraoral ultrasound compared with transgingival probing	Diagnostic accuracy
Koca-Ünsal et al. (2022)	Turkey	Cross-sectional clinical study	25 patients	Periodontology	Palatal/gingival tissue thickness compared with clinical measurement	Diagnostic accuracy

Author, year	Country	Study design	Sample size	Clinical field	Main outcome / contribution	Evidence domain
Sabri et al. (2025)	Lebanon	Cadaveric diagnostic accuracy study	115 teeth / 16 cadaver heads	Gingival thickness assessment	HFUS compared with histology, CBCT and transgingival probing	Diagnostic accuracy
Samal et al. (2025)	United States	Preclinical diagnostic accuracy study	6 miniature pigs	Periodontal imaging	HFUS compared with histological soft-tissue dimensions	Diagnostic accuracy / preclinical validation
Sönmez et al. (2021)	Turkey	Prospective clinical study	40 patients	Implantology	Soft-tissue thickness before implant placement	Diagnostic accuracy / reliability
Majzoub et al. (2022)	Germany	Inter-rater agreement study	12 patients	Periodontal ultrasound	Agreement among raters for ultrasound-derived parameters	Reliability
Bravo et al. (2024)	Brazil	Experimental monitoring study	11 HA fillers	Aesthetic medicine	Ultrasound monitoring of filler degradation after hyaluronidase	Clinical application / treatment monitoring

Author, year	**Country**	**Study design**	**Sample size**	**Clinical field**	**Main outcome / contribution**	**Evidence domain**
Kim JS (2024)	South Korea	Doppler observational study	50 patients	Vascular mapping / lip augmentation	Labial artery mapping before filler injection	Clinical application
Kozáková et al. (2025)	Slovakia	Observational ultrasound study	121 adults	Facial soft tissues	Effect of head position on facial soft-tissue thickness	Clinical application / anatomical assessment
Schelke et al. (2023a)	Netherlands	Retrospective cohort study	28 patients	Dermal fillers	Localization of filler material in overfilled syndrome	Clinical application
Lambrou et al. (2024)	Greece	Cross-sectional study	6 patients	Paediatric gingival ultrasound	Gingival thickness and width in children	Clinical application
Mlosek et al. (2020)	Poland	Cross-sectional observational study	15 patients	Dermal fillers	Diagnosis of palpable nodules after HA filler injection	Clinical application
Schelke et al. (2023b)	Netherlands	Retrospective cohort study	21 patients	Ultrasound-guided filler management	Diagnosis and management of filler-related vascular adverse events	Clinical application

Author, year	Country	Study design	Sample size	Clinical field	Main outcome / contribution	Evidence domain
Schelke et al. (2024)	Multinational	Multicenter retrospective study	200 patients / 382 zygomatic regions	Filler migration	Ultrasound characterization of filler redistribution patterns	Clinical application
Wortsman et al. (2025)	Multinational	Multicenter retrospective study	240 cases	Granulomas and filler complications	Ultrasound features and anatomical distribution of filler granulomas	Clinical application
Švábová et al. (2024)	Slovakia	Cross-sectional observational study	127 individuals	Facial soft tissues	Biological predictors of facial soft-tissue thickness	Clinical application / anatomical assessment
Shen Wei et al. (2023)	China	Cross-sectional Doppler study	33 patients / 66 hemifaces	Facial artery mapping	Facial artery course, diameter and depth by Doppler ultrasound	Clinical application
Kroumpouzos et al. (2023)	United States	Narrative review	N/A	Aesthetic ultrasound	Prevention, assessment and management of filler complications	Narrative contextual evidence

Author, year	Country	Study design	Sample size	Clinical field	Main outcome / contribution	Evidence domain
Meikle & Stephan (2020)	United Kingdom	Narrative review	N/A	Facial soft-tissue ultrasonography	Standardized B-mode ultrasound approach for FSTT measurement	Narrative contextual evidence

Note. N/A, not applicable; HA, hyaluronic acid; HFUS, high-frequency ultrasound; CBCT, cone-beam computed tomography; FSTT, facial soft-tissue thickness.

Evidence synthesis of diagnostic performance of high-frequency ultrasound for gingival and periodontal assessment

Seven studies evaluated the diagnostic performance of high-frequency ultrasound (HFUS) for the assessment of gingival, periodontal, and peri-implant soft tissues using cone-beam computed tomography (CBCT), transgingival probing, histological examination, and clinical or implant-planning reference methods as comparators (14–16,18,21,22,27). Two studies compared HFUS with CBCT (14,15), two with transgingival probing (16,27), two incorporated histological validation (18,21), and one evaluated peri-implant soft-tissue thickness in the context of implant planning (22). Across the included investigations, HFUS demonstrated favorable agreement with the corresponding reference methods. Studies comparing HFUS with CBCT reported minimal measurement discrepancies, generally below 0.3 mm, whereas comparisons with transgingival probing revealed no significant differences and strong measurement concordance (14–16,27). Histology-based studies reported intraclass correlation coefficients ranging from 0.73 to 0.96 and correlation coefficients between 0.88 and 0.98, indicating close agreement between ultrasound-derived measurements and reference tissue dimensions (18,21). Additionally, Sönmez et al. (2021)(22) reported excellent measurement reliability (ICC = 0.944) for peri-implant soft-tissue thickness assessment, supporting the consistency of HFUS in implant-related applications. Overall, the available evidence suggests that HFUS provides consistent and reproducible measurements of gingival, periodontal, and peri-implant soft tissues across different validation approaches. Table 2.

Table 2. Evidence synthesis of diagnostic performance of high-frequency ultrasound for gingival and periodontal assessment

Study	Population / sample	Index test	Reference standard	Main diagnostic metric	Direction of findings
Kloukos et al. (2018)	20 patients	HFUS / ultrasound-based measurement	CBCT	Moderate-to-high agreement; minimal bias reported in repeated measurements	HFUS yielded gingival thickness measurements comparable to CBCT, supporting non-invasive periodontal phenotype assessment.
Bednarz-Tumidajewicz et al. (2022)	30 patients	Ultrasonic method	CBCT + intraoral scanning / prosthetic-driven planning	Mean discrepancy generally <0.3 mm; Bland-Altman agreement 93.3-95.6%	Minimal discrepancy between ultrasound and radiographic/digital workflow measurements.
Alizad-Rahvar et al. (2024)	30 patients	Intraoral ultrasonography	Transgingival probing	No significant differences reported ($p > 0.05$)	Ultrasound and transgingival probing produced comparable gingival thickness

Study	Population / sample	Index test	Reference standard	Main diagnostic metric	Direction of findings
					measurements without tissue penetration.
Koca-Ünsal et al. (2022)	25 patients	Ultrasonography	Transgingival probing / clinical measurement	Mean difference approximately 0.15 mm; strong correlation in repeated/bilateral measures	High agreement between ultrasound and direct clinical measurement.
Sabri et al. (2025)	115 teeth / 16 cadaver heads	Ultrasonography	Histology, CBCT and TGP	ICC 0.73-0.95; r = 0.88-0.98	HFUS showed strong agreement with histology and performed well against multiple comparators.
Samal et al. (2025)	6 miniature pigs	HFUS	Histology	ICC 0.77-0.96	HFUS closely reproduced histological dimensions and may outperform CBCT for thin superficial tissues.

Study	Population / sample	Index test	Reference standard	Main diagnostic metric	Direction of findings
Sönmez et al. (2021)	40 patients	High-resolution ultrasound	Clinical/radiographic comparator for implant planning	ICC 0.944 reported for measurement reliability	HFUS showed high consistency for soft-tissue thickness assessment before implant placement.

Note. HFUS, high-frequency ultrasound; CBCT, cone-beam computed tomography; TGP, transgingival probing; ICC, intraclass correlation coefficient; r, correlation coefficient.

Clinical applications of high-frequency ultrasound in facial soft-tissue assessment

Seven studies evaluated the application of high-frequency ultrasound (HFUS) in facial soft-tissue assessment, including anatomical characterization, filler localization and migration, identification of filler-related complications, and treatment monitoring (12,13,17,19,20,29,30).

Two studies investigated anatomical variability in facial soft tissues. Švábová et al. (2024)(13) reported that body mass index was the principal determinant of facial soft-tissue thickness, whereas Kozáková et al. (2025)(12) demonstrated that head position influenced measurements in more than half of the evaluated landmarks, with maximum differences reaching 1.31 mm.

Several investigations focused on filler localization and redistribution. Schelke et al. (2024)(17) identified four redistribution patterns following zygomatic filler placement in 200 patients, while Schelke et al. (2023)(30) localized filler deposits in specific anatomical layers among patients presenting with overfilled syndrome. Ultrasound-guided assessment was also used to characterize filler-related complications. Mlosek et al. (2020)(29) reported hyaluronic acid deposits in 60.0% of palpable nodules, granulomas in 20.0%, fibrosis in 13.3%, and inflammatory deposits in 6.7% of cases. Similarly, Wortsman et al. (2025)(19) analyzed 240 cases of filler-related granulomas and found that the infraorbital, lower eyelid, and medial cheek regions were the most frequently affected anatomical sites (41.7%).

Treatment monitoring was evaluated by Bravo et al. (2024)(20), who used serial ultrasound examinations to monitor hyaluronidase-induced filler degradation, reporting volume reductions of 64.1% after one hour and 81.7% after 24 hours.

Overall, the included studies indicate that HFUS can be applied to anatomical assessment, characterization of filler distribution, evaluation of filler-related complications, and monitoring of treatment response in facial aesthetic practice. Table 3.

Table 3. Clinical applications of high-frequency ultrasound in facial soft-tissue assessment

Clinical application	Studies	Sample size / evidence base	Ultrasound role	Main findings	Clinical implication
Facial soft-tissue thickness and anatomical variability	Švábová et al. (2024); Kozáková et al. (2025)	248 participants total	B-mode / high-frequency ultrasound for anatomical measurement	BMI was a major determinant of FSTT; head position affected more than half of evaluated landmarks; maximum reported difference 1.31 mm.	Supports standardized acquisition conditions and individualized anatomical assessment before aesthetic planning.
Filler redistribution and migration	Schelke et al. (2024)	200 patients / 382 zygomatic regions	Ultrasound localization of filler distribution across facial layers	Four redistribution patterns were identified after zygomatic filler injections.	Allows visualization of migration patterns and may guide corrective treatment.
Filler localization and overfilled syndrome	Schelke et al. (2023a)	28 patients	Ultrasound-guided localization of filler deposits	Filler localized in subdermal fat 35.7%, supra-periosteal fat 28.6%, fibrous layer 10.7%, and non-localized in 25.0%; significant oral commissure improvement after targeted treatment.	Supports targeted hyaluronidase treatment and objective follow-up.
Post-filler nodules	Mlosek et al. (2020)	15 patients	Ultrasound differential diagnosis of palpable nodules	HA deposits 60.0%, granulomas 20.0%, fibrosis 13.3%, inflammatory deposits 6.7%.	Provides non-invasive differentiation of filler-related complications.
Granulomatous filler reactions	Wortsman et al. (2025)	240 cases	Ultrasound characterization by anatomical	HA represented 50.4%; lower eyelid/infraorbital/medial cheek region 41.7%;	Improves anatomical and layer-based characterization

Clinical application	Studies	Sample size / evidence base	Ultrasound role	Main findings	Clinical implication
			region and tissue layer	hypodermis involved 37.1%.	of delayed filler reactions.
Filler degradation monitoring	Bravo et al. (2024)	11 HA fillers	Serial ultrasound monitoring after hyaluronidase	Volume reduction 64.1% at 1 hour and 81.7% at 24 hours.	Enables objective treatment-response monitoring after enzymatic degradation.

Note. BMI, body mass index; FSTT, facial soft-tissue thickness; HA, hyaluronic acid.

Ultrasound and Doppler applications for vascular mapping and filler-related complication assessment

Four studies evaluated the application of ultrasound and Doppler imaging for vascular mapping and the assessment of soft-tissue complications associated with facial aesthetic procedures (11,28–30). Two studies focused primarily on vascular anatomy. Kim JS (2024)(11) evaluated 50 patients undergoing lip augmentation and used Doppler ultrasound to visualize the superior and inferior labial arteries before filler injection. No vascular complications were reported during the three-month follow-up period. Objective measurements showed a reduction in lip corner angle of 8.80%, a mean lip corner elevation of 1.02 mm, and a 6.5% elongation of the upper-lip contour.

Similarly, Shen Wei et al. (2023) (28) examined 66 hemifaces and reported that the most frequent facial artery pattern corresponded to a Type 1 course (59.1%), whereas the artery was located inferior to the nasolabial fold in 50.0% of cases. Mean arterial diameters ranged from 1.32 to 1.56 mm depending on the anatomical location, with significantly larger diameters observed on the right side ($p < 0.05$).

Two additional studies investigated filler-related soft-tissue complications. Mlosek et al. (2020) (29) evaluated 15 patients with palpable nodules following hyaluronic acid injections and identified hyaluronic acid deposits in 60.0% of cases, granulomas in 20.0%, fibrosis in 13.3%, and inflammatory deposits in 6.7%. Schelke et al. (2023) (30) assessed 28 patients with facial overfilled syndrome or vascular adverse events and localized filler material within different anatomical layers, including the subdermal fat layer (35.7%) and supra-periosteal fat layer (28.6%). Ultrasound-guided hyaluronidase administration was associated with significant improvements in oral commissure position ($p < 0.001$).

Overall, the included studies indicate that ultrasound and Doppler imaging can be applied to vascular mapping, characterization of anatomical variability, localization of filler material, evaluation of filler-related complications, and treatment guidance in facial aesthetic procedures. Table 4.

Table 4. Ultrasound and Doppler applications for vascular mapping and filler-related complication assessment

Study	Diagnostic / clinical focus	Sample size	Ultrasound contribution	Quantitative findings	Clinical significance
Kim JS (2024)	Labial artery mapping before lip augmentation	50 patients	Doppler ultrasound visualization of superior and inferior labial arteries	Lip corner elevation 1.02 mm; lip corner angle reduction 8.80%; upper-lip elongation 6.5%; no vascular complications during 3-month follow-up.	Improved procedural planning and vascular safety in high-risk injection areas.
Shen Wei et al. (2023)	Facial artery anatomy around the nasolabial fold	33 patients / 66 hemifaces	Doppler characterization of artery trajectory, depth and diameter	Type 1 course 59.1%; artery inferior to nasolabial fold 50.0%; diameter 1.32-1.56 mm; right-sided vessels significantly larger ($p < 0.05$).	Supports individualized vascular assessment rather than relying only on textbook anatomy.
Mlosek et al. (2020)	Palpable nodules after HA fillers	15 patients	High-frequency ultrasound pattern recognition	HA deposits 60.0%, granulomas 20.0%, fibrosis 13.3%,	Enables non-invasive differential

Study	Diagnostic / clinical focus	Sample size	Ultrasound contribution	Quantitative findings	Clinical significance
				inflammatory deposits 6.7%.	diagnosis of post-filler nodules.
Schelke et al. (2023b)	Facial overfilled syndrome / vascular adverse event management	28 patients	Ultrasound-guided localization and targeted hyaluronidase administration	Filler localization: 35.7% subdermal fat, 28.6% supra-periosteal fat, 10.7% fibrous layer; oral commissure improvement +0.60 cm vertical and +0.30 cm horizontal ($p < 0.001$).	Supports objective diagnosis and targeted management of filler-related complications.

Note. HA, hyaluronic acid.

Reproducibility and reliability outcomes of high-frequency ultrasound measurements

Seven studies reported reproducibility, reliability, or measurement agreement outcomes associated with high-frequency ultrasound assessment of oral and facial soft tissues (14,15,18,21,22,27,31). Different methodological approaches were used to evaluate measurement consistency, including intraclass correlation coefficients (ICC), Pearson correlation analyses, Bland–Altman agreement analyses, and repeated-measurement assessments. Overall, the reported metrics indicated high levels of measurement consistency across a variety of clinical applications.

Kloukos et al. (2018)(14) assessed gingival thickness measurements and reported minimal measurement bias ranging from 0.05 to 0.06 mm, with narrow confidence intervals, indicating high reproducibility between repeated assessments. Similarly, Bednarz-Tumidajewicz et al. (2022)(15) evaluated free, supracrestal, and crestal gingival thickness and reported agreement levels ranging from 93.3% to 95.6% using Bland–Altman analyses, despite small measurement biases between methods.

Koca-Ünsal et al. (2022)(27) reported a strong positive correlation between ultrasound-derived and comparative tissue thickness measurements ($r = 0.902$; $p < 0.001$). Studies reporting ICC values consistently showed high reliability. Majzoub et al. (2022)(31) and Sönmez et al. (2021)(22) reported ICC values of 0.925 and 0.944, respectively, indicating excellent measurement consistency. Sabri et al. (2025)(18) documented ICC values ranging from 0.73 to 0.95 together with correlation coefficients ranging from 0.88 to 0.98, whereas Samal et al. (2025)(21) reported ICC values between 0.77 and 0.96 when comparing ultrasound measurements with histological references.

Overall, the available evidence suggests that HFUS measurements exhibit moderate-to-excellent reproducibility and consistent measurement performance across different anatomical regions, clinical settings, and methodological approaches. Table 5.

Table 5. Reproducibility and reliability outcomes of high-frequency ultrasound measurements

Study	Variable evaluated	Reliability method	Quantitative findings	Reliability level
Kloukos et al. (2018)	Gingival thickness	Repeated-measurement agreement	Bias 0.05-0.06 mm; narrow 95% CI	High reproducibility
Bednarz-Tumidajewicz et al. (2022)	Free, supracrestal and crestal gingival thickness	Bland-Altman agreement analysis	Agreement 93.3-95.6%; bias 0.45 to -0.17 mm	High agreement
Koca-Ünsal et al. (2022)	Palatal tissue thickness	Pearson correlation analysis	$r = 0.902$; $p < 0.001$	Very strong correlation
Majzoub et al. (2022)	Facial / periodontal soft-tissue measurements	Intraclass correlation coefficient	ICC = 0.925	Excellent reliability
Sönmez et al. (2021)	Peri-implant soft-tissue measurements	Intraclass correlation coefficient	ICC = 0.944	Excellent reliability

Study	Variable evaluated	Reliability method	Quantitative findings	Reliability level
Sabri et al. (2025)	Gingival thickness	ICC and correlation analysis	ICC 0.73-0.95; r = 0.88-0.98	Moderate-to-excellent reliability
Samal et al. (2025)	Periodontal soft tissues	Intraclass correlation coefficient	ICC 0.77-0.96	Good-to-excellent reliability

Note. HFUS, high-frequency ultrasound; ICC, intraclass correlation coefficient; r, Pearson correlation coefficient. ICC values were interpreted as follows: <0.50 poor, 0.50–0.75 moderate, 0.75–0.90 good, and >0.90 excellent reliability.

Risk of bias and applicability assessment according to QUADAS-2

Seven studies were assessed using the QUADAS-2 tool to evaluate risk of bias and applicability concerns across the domains of patient selection, index test, reference standard, and flow and timing (14–16,18,21,22,27).

Most studies demonstrated a low risk of bias in the index test and flow-and-timing domains, indicating that ultrasound assessments were generally performed and interpreted consistently across investigations. However, uncertainty was identified in several studies regarding patient selection and reference standard domains, primarily due to incomplete reporting of recruitment methods, blinding procedures, or comparator implementation (14–16,22,27).

Sabri et al. (2025)(18) showed one of the strongest methodological profiles among the included diagnostic studies because it incorporated multiple reference standards, including histology. However, its cadaveric design introduced some applicability concerns when extrapolating the findings to routine clinical settings. Similarly, Samal et al. (2025)(21) demonstrated low risk of bias in all assessed domains; however, applicability concerns were identified because the study was conducted in a preclinical animal model rather than in human participants.

Overall, the QUADAS-2 assessment suggests that the included studies were generally of acceptable methodological quality, although limitations related to participant selection, reporting transparency, and applicability were identified in several investigations. Table 6.

Table 6. Risk of bias and applicability assessment according to QUADAS-2

Study	Patient selection	Index test	Reference standard	Flow and timin g	Applicabili ty concerns	Overall judgment
Kloukos et al. (2018)	Unclear	Low	Unclear	Low	Low	Unclear
Bednarz-Tumidajewic z et al. (2022)	Unclear	Low	Unclear	Low	Low	Unclear
Alizad-Rahvar et al. (2024)	Unclear	Low	Unclear	Low	Low	Unclear
Koca-Ünsal et al. (2022)	Unclear	Low	Unclear	Low	Low	Unclear
Sabri et al. (2025)	Low	Low	Low	Low	Unclear	Low-to-unclear
Samal et al. (2025)	Low	Low	Low	Low	High	Low ROB / high applicability concern
Sönmez et al. (2021)	Unclear	Low	Unclear	Low	Low	Unclear

Note. ROB, risk of bias; QUADAS-2, Quality Assessment of Diagnostic Accuracy Studies-2.

Discussion

Diagnostic Accuracy of High-Frequency Ultrasound for Gingival and Periodontal Assessment

The studies included in this review consistently demonstrated that high-frequency ultrasound (HFUS) provides measurements of gingival and periodontal soft tissues that are comparable to established reference methods. Kloukos et al., Bednarz-Tumidajewicz et al., Alizad-Rahvar et al., and Koca-Ünsal et al. reported close agreement between ultrasound, CBCT, and transgingival probing, with minimal measurement differences and no significant discrepancies between techniques [14–16,27]. These findings suggest that HFUS may provide a reliable approach for assessing gingival thickness and periodontal phenotype, both of which are relevant for periodontal, implant, and esthetic treatment planning.

Among the included studies, Sabri et al. provided one of the most comprehensive comparisons against multiple reference standards, including histology, CBCT, transgingival probing, periodontal probe transparency, and color-coded assessment [18]. The study reported intraclass correlation coefficients ranging from 0.73 to 0.95 and correlation coefficients between 0.88 and 0.98, indicating a high degree of agreement between HFUS and histological measurements. Given that histology remains the reference standard for soft-tissue evaluation, these findings further support the potential of ultrasound to assess periodontal tissue dimensions with substantial agreement relative to histological references. The lower agreement observed between CBCT and histology in thin tissues further highlights the challenges of radiographic assessment when evaluating superficial soft-tissue structures [18].

Measurement reproducibility was another consistent finding. Sönmez et al. reported excellent agreement for gingival thickness measurements (ICC > 0.92), while Majzoub et al. demonstrated high inter-rater reliability among evaluators [22,31]. Together, these findings indicate that HFUS can provide reliable and reproducible measurements when standardized acquisition protocols are applied.

From a clinical perspective, HFUS offers several advantages over conventional methods. Unlike transgingival probing, it is non-invasive and does not require tissue penetration. Unlike CBCT, it does not expose patients to ionizing radiation and can be repeated during follow-up examinations without additional biological risk [10]. These characteristics make ultrasound particularly suitable for longitudinal monitoring of gingival phenotype, peri-implant tissues, and soft-tissue healing.

Despite these favorable results, the available evidence remains heterogeneous. Differences in ultrasound frequencies, transducer characteristics, acquisition protocols, and reference standards limit direct comparison among studies. Furthermore, most investigations involved relatively small sample sizes and single-center designs. Additional multicenter studies using standardized imaging protocols are therefore needed to establish reference values and support the broader integration of HFUS into routine periodontal practice.

Clinical Applications of High-Frequency Ultrasound in Facial Aesthetic Procedures

The studies included in this review demonstrate the growing role of high-frequency ultrasound (HFUS) in facial aesthetic medicine. Beyond its diagnostic function, ultrasound has become an important tool for treatment planning, procedural guidance, monitoring, and the evaluation of filler-related complications [9,25].

One of the most frequently reported applications was the localization of dermal fillers. Schelke et al. reported that ultrasound enables identification of filler location, depth, and distribution before corrective interventions, providing objective anatomical information that may support clinical decision-making [30]. Similarly, Bravo et al. reported that ultrasound can be used to monitor filler degradation after hyaluronidase administration, documenting substantial reductions in filler volume within the first 24 hours after treatment [20]. Together, these findings highlight the value of ultrasound both before and after therapeutic intervention.

Another important application involves the identification of filler migration and soft-tissue alterations. Schelke et al. described distinct migration patterns involving displacement of filler material across facial compartments [17]. Similar observations were reported by Mlosek et al., who identified filler deposits, granulomas, fibrosis, and inflammatory changes during ultrasound examinations of patients presenting with post-treatment complications [29].

These findings suggest that ultrasound can detect structural alterations that may remain unnoticed during routine clinical assessment.

HFUS also demonstrated potential utility in the evaluation of delayed inflammatory complications. Wortsman et al. reported that ultrasound allows detailed characterization of granulomas, including their anatomical distribution and tissue-layer involvement [19]. Likewise, Kroumpouzos et al. highlighted the usefulness of ultrasound for identifying granulomas, nodules, migration patterns, and other filler-related complications within a single diagnostic examination [25]. The ability to directly visualize affected tissues may facilitate differential diagnosis and contribute to more targeted management strategies.

Beyond complication assessment, several studies explored the role of ultrasound in facial soft-tissue characterization. Kozáková et al. documented variations in facial soft-tissue thickness across different anatomical regions, while Meikle and Stephan proposed standardized ultrasound protocols for soft-tissue evaluation [12,26]. These findings emphasize the considerable anatomical variability among individuals and support the use of ultrasound for personalized treatment planning.

Collectively, the available evidence suggests that HFUS provides objective anatomical information that complements clinical examination and may expand the diagnostic capabilities available in facial aesthetic practice. However, differences in study design, imaging protocols, ultrasound equipment, and outcome reporting contribute to substantial heterogeneity across studies. Further prospective multicenter investigations are needed to establish standardized protocols and strengthen the evidence supporting routine ultrasound-guided aesthetic procedures.

Doppler Ultrasound and Vascular Safety

The increasing use of injectable facial procedures has highlighted the importance of imaging techniques capable of identifying vascular structures before treatment. Among the studies included in this review, Doppler ultrasound was investigated as a tool for vascular mapping and the evaluation of complications associated with facial aesthetic procedures [11,28,29,30].

Kim reported a high concordance between Doppler ultrasound findings and the anatomical course of the labial artery, suggesting its potential utility for pre-procedural vascular mapping in high-risk injection areas [11]. Similarly, Shen et al. reported substantial variations in the trajectory, depth, and diameter of the facial artery among individuals, emphasizing that vascular anatomy cannot always be predicted based on standard anatomical descriptions alone [28]. Together, these findings highlight the relevance of patient-specific vascular assessment and reinforce the role of Doppler ultrasound in identifying anatomical variations that may influence procedural safety.

Beyond anatomical mapping, Doppler ultrasound has also shown utility in the recognition of vascular-related complications. Schelke et al. reported the use of ultrasound for the early identification of vascular compromise following hyaluronic acid filler injections, facilitating prompt diagnosis and treatment of adverse events [30]. Early recognition is particularly important because vascular occlusion may rapidly progress to ischemia and tissue damage if not managed appropriately.

Although primarily focused on filler-related complications, Mlosek et al. also documented vascular-associated findings during ultrasound evaluation and reported migration of filler material in some patients [29]. These observations suggest that ultrasound can provide valuable information regarding both vascular integrity and structural tissue alterations following aesthetic procedures.

The available evidence suggests that Doppler ultrasound may extend beyond anatomical visualization by providing clinically relevant information for both the prevention and management of complications. The ability to identify vascular pathways, estimate vessel depth, and evaluate suspected vascular compromise offers advantages over approaches based solely on anatomical landmarks [11,28,30].

Despite these promising findings, the available evidence remains limited by the predominance of observational studies and the lack of standardized imaging protocols. Differences in operator experience, ultrasound equipment, and reporting methodologies may influence diagnostic performance and limit comparisons across studies. Future prospective multicenter investigations are required to determine the impact of Doppler-guided procedures on complication prevention and patient outcomes in facial aesthetic practice.

Reproducibility and Reliability of Ultrasound Measurements

Beyond diagnostic accuracy, measurement reproducibility is essential for the clinical implementation of any imaging modality. In the context of periodontal and soft-tissue assessment, reliable measurements are particularly important because treatment decisions and longitudinal follow-up often depend on small dimensional changes over time.

The studies included in this review consistently reported favorable reproducibility outcomes for high-frequency ultrasound (HFUS). Majzoub et al. documented excellent intraclass correlation coefficients (ICC = 0.925), whereas Sönmez et al. reported an ICC of 0.944 for peri-implant soft-tissue measurements [22,31]. Similarly, Samal et al. reported ICC values ranging from 0.77 to 0.96 when comparing ultrasound measurements with histological evaluation, supporting the consistency of HFUS under experimental conditions [21].

Interobserver agreement was also favorable across studies. Majzoub et al. demonstrated high agreement among multiple evaluators when assessing ultrasound-derived periodontal parameters, suggesting that measurement variability may be reduced when standardized acquisition protocols are followed [31].

Additional evidence of reliability was provided by studies comparing HFUS with established reference methods. Kloukos et al., Bednarz-Tumidajewicz et al., Alizad-Rahvar et al., and Koca-Ünsal et al. consistently reported close agreement between ultrasound and CBCT or transgingival probing, with minimal differences between techniques [14–16,27]. Although these investigations primarily focused on diagnostic performance, their findings indirectly support the stability and reliability of ultrasound-derived measurements.

The collective evidence suggests that HFUS is capable of producing consistent measurements across different operators, anatomical sites, and clinical settings. Nevertheless, several factors may influence reproducibility, including probe frequency, transducer design, image acquisition protocols, tissue compression, and operator experience. These factors highlight the importance of methodological standardization as ultrasound becomes increasingly integrated into dental practice.

Overall, the available literature suggests that HFUS demonstrates a level of reproducibility and reliability that may support periodontal phenotype assessment, peri-implant evaluation, treatment monitoring, and longitudinal follow-up. However, further multicenter studies using standardized imaging protocols are needed to confirm these findings and improve comparability across investigations [14–16,21,22,27,28,31].

Strengths, Limitations, and Future Perspectives

One of the main strengths of the available evidence is the consistent performance of high-frequency ultrasound (HFUS) across a wide range of clinical applications. Although the included studies evaluated different outcomes, including periodontal assessment, facial soft-tissue characterization, vascular mapping, and filler-related complications, most reported favorable results regarding diagnostic performance, anatomical visualization, and measurement reliability [11–31]. The use of multiple reference standards, including CBCT, transgingival probing, histological analysis, anatomical assessment, and clinical examination, further strengthens confidence in the findings reported across studies [14–16,18,21,22,27,28].

Another important strength is the versatility of HFUS. The evidence suggests that its applications extend beyond periodontal diagnostics to include facial aesthetic procedures, evaluation of filler-related complications, treatment monitoring, vascular mapping, and individualized treatment planning [11,12,17,19,20,25,28–30]. This broad range of applications highlights the potential of ultrasound as a versatile soft-tissue imaging modality in both dentistry and facial aesthetic medicine.

Despite these encouraging findings, several limitations should be considered. The most important limitation is the substantial heterogeneity among studies. Differences in ultrasound frequency, transducer characteristics, acquisition protocols, anatomical regions evaluated, reference standards, and outcome measures limited direct comparisons across investigations [14–31]. Additionally, many studies were observational, retrospective, or based on case series, while large prospective multicenter trials remain scarce [17,19,25,29,30].

In addition, the QUADAS-2 assessment identified areas of uncertainty related to patient selection, reference standards, and reporting transparency in several studies, highlighting the need for improved methodological standardization and reporting practices.

Sample size also represents a limitation. Several investigations included relatively small populations, particularly those evaluating specific clinical conditions or uncommon complications [12,13,18,21,23]. Furthermore, most studies were conducted in specialized centers with operators experienced in ultrasound acquisition and interpretation, which may limit the generalizability of the reported findings to routine clinical settings.

Some limitations are inherent to the technology itself. HFUS remains an operator-dependent imaging modality, and image quality may be influenced by probe positioning, acquisition technique, tissue compression, and examiner experience [10]. In addition, although higher frequencies improve spatial resolution, they also reduce tissue penetration depth, requiring the selection of appropriate ultrasound settings according to the clinical objective [5,10].

Future research should focus on multicenter prospective studies using standardized imaging protocols and reporting criteria. Establishing consensus regarding optimal frequencies, acquisition parameters, and measurement procedures would improve comparability among studies and facilitate broader clinical adoption. Further investigations should also evaluate the impact of HFUS on clinical decision-making, treatment outcomes, and patient-centered measures.

Emerging technologies may further expand the role of ultrasound in dentistry and facial aesthetics. Integration with digital workflows, three-dimensional imaging systems, and artificial intelligence-assisted image analysis may improve diagnostic standardization and facilitate automated assessment of soft-tissue structures [9,10]. In addition, advances in ultra-high-frequency ultrasound technology may enhance visualization of superficial anatomical structures and support more detailed tissue characterization.

Overall, the evidence synthesized in this review suggests a growing clinical role for HFUS as a non-invasive, radiation-free, and reproducible imaging modality for soft-tissue assessment. Although methodological heterogeneity and limited standardization remain important challenges, the available literature indicates that HFUS has considerable potential for integration into contemporary periodontal diagnostics, peri-implant evaluation, vascular mapping, complication management, and facial aesthetic practice [11–31].

Conclusion

High-frequency ultrasound (HFUS) appears to be a promising imaging modality for the assessment of orofacial soft tissues in periodontal, peri-implant, and facial aesthetic applications. The available evidence indicates that HFUS provides measurements that are comparable to established reference standards for gingival and periodontal evaluation while offering the advantages of real-time imaging, absence of ionizing radiation, and non-invasive assessment.

Beyond periodontal applications, ultrasound showed potential clinical utility in facial aesthetic procedures, particularly for the detection of filler-related complications, characterization of soft-tissue alterations, vascular mapping, and image-guided treatment planning. Doppler ultrasound may contribute to procedural safety by enabling visualization of individual vascular anatomy and early identification of vascular adverse events.

Although the overall findings suggest potential clinical applicability of HFUS, the current evidence is limited by methodological heterogeneity, variability in imaging protocols, and the predominance of observational designs. Future prospective multicenter studies using standardized acquisition and reporting protocols are needed to strengthen the evidence base and facilitate broader integration of ultrasound into routine dental and facial aesthetic practice.

Conflict of Interest Statement: The authors declare that they have no financial, personal, institutional, or other conflicts of interest that could have influenced the development, analysis, interpretation, or presentation of the results of this study. This review was conducted independently and without the involvement of commercial entities or external sponsors. **Ethical Statement:** Since this study is a systematic review of the literature and did not involve direct interventions with human subjects or access to identifiable personal data, approval from an institutional research ethics committee was not required. All included studies had previously obtained their own ethical approval as reported by their original authors. This review was conducted in accordance with the ethical principles of the Declaration of Helsinki, the recommendations of the International Committee of Medical Journal Editors (ICMJE), and the good practice guidelines of the Committee on Publication Ethics (COPE), ensuring methodological rigor, transparency in study selection, and the absence of manipulation or biased reinterpretation of original results. No primary data were collected, no contact with human participants was made, and no sensitive information that could identify individuals was accessed. Furthermore, all included works were accurately cited and acknowledged, maintaining academic integrity and respect for intellectual property. **Authors Contributions:** M.J.F.S contributed to the conception and design of the study, literature search, study selection, data extraction and analysis, methodological quality assessment, manuscript drafting, and final approval of the submitted version. V.I.V.T contributed to the supervision of the study, critical revision of the manuscript for important intellectual content, interpretation of findings, and final approval of the submitted version. All authors have read and approved the final manuscript. All authors have read and approved the final manuscript. Correspondence: (✉) maria.fernandezs@ucacue.edu.ec

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How to Cite This Article
Fernández Siguencia, María José, and Verónica Ivannova Verdugo Tinitana. (2026). “Diagnostic Accuracy and Clinical Applications of Ultrasound in Aesthetic Dentistry and Facial Soft-Tissue Characterization: A Systematic Review.” *Analysis* 41: pp. 1–40.