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INPLASY

Color and Whiteness Metrics in Tooth Bleaching: Protocol for a Systematic Review of CIELAB, CIEDE2000, and Whiteness Index for Dentistry

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ADMINISTRATIVE INFORMATION

Support - This study is supported by a CAPES/DS doctoral scholarship (Grant No. 23106.028232/2026-97) awarded to Daniella Birnbaum Pessoa de Mello.

Review Stage at time of this submission - Formal screening of search results against eligibility criteria.

Conflicts of interest - None declared.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 6 October 2026 and was last updated on 13 October 2026.

INTRODUCTION

Review question / Objective In permanent natural human teeth evaluated clinically and in extracted human or bovine teeth evaluated in vitro, all submitted to dental bleaching, how are color changes measured by ΔE*ab, ΔE00, and ΔWID rela-ted, and to what extent do these metrics provide concordant classifications according to their respective perceptibility and acceptability thresholds?

Rationale Color and whiteness changes after bleaching are commonly reported using ΔE*ab (CIELAB), ΔE00 (CIEDE2000), and the change in the Whiteness Index for Dentistry (ΔWID). These metrics are not numerically interchangeable and differ conceptually: ΔE*ab and ΔE00 quantify color differences between measurements, whereas WID was developed as an index of perceived tooth whiteness at a given time (Pérez et al., 2016). Each metric also has its own perceptibility and acceptability thresholds (Paravina et al., 2015; Pérez et al., 2019), so the same bleaching outcome may be classified differently depending on the metric chosen. Although narrative reviews have described color and whiteness metrics in dentistry, no systematic review has specifically compared ΔE*ab, ΔE00, and ΔWID in the context of tooth bleaching. This review will address that gap.

Condition being studied Tooth bleaching is a conservative esthetic procedure performed to improve tooth color using agents such as hydrogen peroxide or carbamide peroxide. Color and whiteness changes are commonly quantified from instrumental measurements using ΔE*ab in the CIELAB color space, ΔE00 from the CIEDE2000 equation, and the change in the Whiteness Index for Dentistry (ΔWID). These metrics are not numerically interchan-geable and do not operate on a common scale. In addition, they differ conceptually: ΔE*ab and ΔE00 quantify color differences between measurements, whereas WID was developed as an index of perceived tooth whiteness at a given time. Therefore, the

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longitudinal interpretation of ΔWID as a bleaching-efficacy outcome warrants specific investigation, and agreement among these metrics cannot be assumed. The relative weighting of L*, a*, and b* in the WID equation may also influence the direction and magnitude of ΔWID. Moreover, WID was derived from spectroradiometric measurements of standardized reference spe-cimens under controlled laboratory conditions (Pérez et al., 2016), whereas clinical bleaching studies predominantly use contact spectrophotometers; the transferability of WID-based thresholds across measure-ment devices and intraoral conditions has not been established. This methodological systematic review will compare pairwise relationships among ΔE*ab, ΔE00, and ΔWID and the concordance of classifications produced by their respective perceptibility and acceptability thresholds. The primary analysis will use metrics calculated for the same specimens or participants at the same evaluation time. Independent vi-sual/perceptual assessment, including numerical shade-guide change (ΔSGU) when available, will be exa-mined as a secondary external-validation outcome. Studies evaluating restorative materials alone will not be included.

METHODS

Search strategy Searches were originally executed on 16 September 2026 and re-executed on 13 October 2026 without date, language, or publication-type limits; the re-executed searches constitute the review dataset. The strategy combines a dental bleaching block with a color/whiteness metric block. Full strategies and yields:

1. PubMed/MEDLINE (n=491). Search date: October 13, 2026 (refined by advisor with MeSH terms)
(("Tooth Bleaching"[mh] OR "Tooth Bleaching"[tiab]) OR (("Tooth"[mh] OR "tooth"[tiab] OR "teeth"[tiab] OR "dental"[tiab] OR "enamel"[tiab] OR "dentin"[tiab] OR "premolar*"[tiab] OR "molar*"[tiab] OR "incisor*"[tiab] OR "canine*"[tiab]) AND ("bleaching"[tiab] OR "whitening"[tiab]))) AND ("CIEDE 2000"[tiab] OR "CIEDE2000"[tiab] OR "deltaE00"[tiab] OR "delta E00"[tiab] OR "deltaEab"[tiab] OR "delta Eab"[tiab] OR "whiteness index"[tiab] OR "WID"[tiab] OR "WI_D"[tiab] OR "CIELAB"[tiab])
2. Embase (Elsevier) (n=625). Search date: October 13, 2026
('tooth bleaching'/exp OR 'tooth bleaching':ti,ab,kw OR (((tooth OR teeth OR dental OR enamel OR dentin OR premolar* OR molar* OR incisor* OR canine*):ti,ab,kw) AND ((bleaching OR whitening):ti,ab,kw))) AND ('CIEDE 2000':ti,ab,kw OR CIEDE2000:ti,ab,kw OR deltaE00:ti,ab,kw OR 'delta E00':ti,ab,kw OR deltaEab:ti,ab,kw OR 'delta Eab':ti,ab,kw OR 'whiteness index':ti,ab,kw OR WID:ti,ab,kw OR WI_D:ti,ab,kw OR CIELAB:ti,ab,kw)
3. Scopus (n=1,325). Search date: October 13, 2026
(("Tooth Bleaching") OR ((tooth OR teeth OR dental OR enamel OR dentin OR premolar* OR molar* OR incisor* OR canine*) AND (bleaching OR whitening))) AND ("CIEDE 2000" OR CIEDE2000 OR deltaE00 OR "delta E00" OR deltaEab OR "delta Eab" OR "whiteness index" OR WID OR WI_D OR CIELAB)
4. Web of Science Core Collection (n=429). Search date: October 13, 2026
TS=(("Tooth Bleaching" OR ((tooth OR teeth OR dental OR enamel OR dentin OR premolar* OR molar* OR incisor* OR canine*) AND (bleaching OR whitening))) AND ("CIEDE 2000" OR CIEDE2000 OR deltaE00 OR "delta E00" OR deltaEab OR "delta Eab" OR "whiteness index" OR WID OR WI_D OR CIELAB))
5. LILACS Plus/BVS (n=316 in LILACS Plus; n=583 in the complete BVS collection). Search date: October 13, 2026
(("Clareamento Dental" OR "Branqueamento Dental" OR "Tooth Bleaching") OR ((dente OR tooth OR teeth OR dental OR esmalte OR dentina OR premolar* OR molar* OR incisivo* OR canino*) AND (bleaching OR whitening OR clareamento OR branqueamento))) AND ("CIEDE 2000" OR CIEDE2000 OR deltaE00 OR "delta E00" OR deltaEab OR "delta Eab" OR "whiteness index" OR WID OR WI_D OR CIELAB)
6. Livivo (n=1,188). Search date: October 13, 2026
(("Tooth Bleaching") OR ((tooth OR teeth OR dental OR enamel OR dentin OR premolar* OR molar* OR incisor* OR canine*) AND (bleaching OR whitening))) AND ("CIEDE 2000" OR CIEDE2000 OR deltaE00 OR "delta E00" OR deltaEab OR "delta Eab" OR "whiteness index" OR WID OR WI_D OR CIELAB)
7. Google Scholar (first 200 results to be screened by relevance; approximately 6,470 total results). Search date: October 13, 2026
("CIEDE 2000" OR CIEDE2000 OR deltaE00 OR "delta E00" OR deltaEab OR "delta Eab" OR "whiteness index" OR WID OR WI_D OR CIELAB) AND (("Tooth Bleaching") OR ((tooth OR teeth OR dental OR enamel OR dentin OR premolar* OR molar* OR incisor* OR canine*) AND (bleaching OR whitening)))
8. ProQuest, limited to source type Dissertations & Theses (n=142). Search date: October 13, 2026
((((("Tooth Bleaching") OR ((tooth OR teeth OR dental OR enamel OR dentin OR premolar* OR

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molar* OR incisor* OR canine*) AND (bleaching OR whitening))) AND ("CIEDE 2000" OR CIEDE2000 OR deltaE00 OR "delta E00" OR deltaEab OR "delta Eab" OR "whiteness index" OR WID OR WI_D OR CIELAB)))
Execution notes: The Embase search was executed in the Advanced Search interface without date, language, or publication-type limits and returned 625 records (595 articles and 30 clinical-trial records). The Scopus strategy was executed in the Advanced query interface as displayed, without an additional field limiter. The Web of Science strategy was executed in the Advanced Search query builder. In BVS, the LILACS Plus collection was selected for the review dataset (n=316); the complete BVS collection displayed 583 records but was not designated as a second dataset. Google Scholar was ordered by relevance, with citations included and patents excluded; the first 200 records will be screened. The ProQuest search was run on the ProQuest platform using the databases available through the University of Brasília subscription (ProQuest Dissertations & Theses Global is not included in this subscription), with results limited to the source type Dissertations & Theses. Compared with the originally registered strategies, hyphenation errors in the Web of Science and LILACS strings were corrected; test searches run on 13 October 2026 with both versions returned identical yields in the designated datasets.
Search sensitivity: Formula-specific title/abstract terminology may miss eligible studies that report ΔE nota-tion only in the full text. Therefore, reference-list checking and citation searching of included studies and known sentinel records will be mandatory. Exploratory supplementary searches using broader color-change and instrumental-measurement terms will be logged with their dates and results. A further limitation is that the executed strategy does not include the bare "ΔE" notation (without suffix), "WIDENT", or the unabbre-viated term "whiteness index dentistry"; it also relies on "WID", which is used as an acronym in unrelated fields in some databases (e.g., Scopus), potentially adding noise or missing records. Given that searches have already been executed and their yields reported, these terms will not be added to the primary strategy retrospec-tively; this is acknowledged as a search-sensitivity limitation, partly mitigated by the mandatory reference-list and citation-searching steps described above.
Management: Records retrieved from the designated databases will be exported to EndNote 2025 for deduplication and then uploaded to Rayyan. Two reviewers (1R and 2R) will independently screen ti-tles/abstracts and full texts while blinded to each other's decisions. Reasons for full-text exclusion will be recorded. Disagreements will be resolved by discussion and, when necessary, arbitration by the third re-viewer (3R). The same independent process will be used for data extraction and risk-of-bias assessment.

Participant or population Permanent natural human teeth in clinical studies and extracted human or bo-vine teeth in in vitro studies, all submitted to dental bleaching. The WID formula was developed and validated in human teeth; its applicability to bovine sub-strate has not been systematically established. Comparisons involving ΔWID in bovine specimens will therefore be interpreted with caution and reported sepa-rately by substrate.

Intervention Dental bleaching followed by instrumental assessment of color and/or white-ness change. The measurement metrics are the objects of comparison rather than therapeutic interventions.

Comparator Pairwise comparisons among ΔE*ab, ΔE00, and ΔWID calculated from the same sample and evaluation time; no single metric is designated as a fixed reference standard.

Study designs to be included In vitro experimental studies, randomized clinical trials, and non-randomized clinical intervention studies reporting at least two eligible metrics for the same teeth/participants and evaluation time.

Eligibility criteria Inclusion: (1) clinical or in vitro studies evaluating bleaching-induced color and/or whiteness changes in permanent natural human teeth or extracted human or bovine teeth; (2) studies reporting at least two of ΔE*ab, ΔE00, and ΔWID; (3) metrics calculated for the same specimens or participants and the same evaluation time; (4) studies reporting paired individual data, a pairwise association or agreement statistic, or sufficiently detailed paired summary data, defined as at minimum mean, standard deviation (or equivalent dispersion measure), and sample size for each paired metric; studies reporting only p-values or qualitative comparisons will not meet this criterion; (5) randomized clinical trials, non-randomized clinical intervention studies, and in vitro experimental studies; (6) any language and no restriction on publication date.Exclusion: studies evaluating only restorative or prosthetic materials, deciduous teeth, or non-dental substrates; studies reporting only one eligible metric or reporting metrics for different samples or non-matching evaluation times; studies not reporting quantitative

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color or whiteness change data or an eligible pairwise result; case reports, case series, purely cross-sectional observational studies, cohort studies without a bleaching intervention, case-control studies, in vivo animal studies, conference abstracts without sufficient data, editorials, letters, narrative reviews, systematic reviews, and meta-analyses.Corresponding authors of otherwise eligible studies (including conference abstracts) with missing or insufficiently detailed paired data will be contacted by e-mail, with a reminder after 2 weeks. If no response is received within 4 weeks of first contact, the study will be excluded or, when partial data are usable, synthesized narratively with this limitation noted.

Information sources Databases: PubMed/MEDLINE, Embase, Scopus, Web of Science Core Collection, LILACS Plus (via BVS), and Livivo. Grey literature: Google Scholar and ProQuest (databases available through the University of Brasília subscription, limited to Dissertations & Theses). Additional sources: hand searching of reference lists of included studies and citation searching of included studies and known sentinel records.

Main outcome(s) (1) Pairwise association between metrics (ΔE*ab vs ΔE00, ΔE*ab vs ΔWID, ΔE00 vs ΔWID), expressed as reported Pearson or Spearman correlation or another pairwise statistic. (2) Pairwise agreement in perceptibility/acceptability classification using metric-specific 50:50% thresholds: ΔE*ab 1.2/2.7 and ΔE00 0.8/1.8 (Paravina et al., 2015); ΔWID 0.72/2.60 applied to |ΔWID| (Pérez et al., 2019; values for all observers as reported in the Results, whereas the abstract reports WAT = 2.62). Agreement will be expressed as Cohen's kappa and percentage agreement.

Additional outcome(s) Magnitude and direction of change by each metric; agreement with an independent visual or perceptual assessment, including numerical shade-guide change (ΔSGU) when available, treated as a secondary external clinical comparator; time at which thresholds are first crossed; and color stability during follow-up. ΔSGU is not a primary metric because the executed search targeted instrumental metrics and does not systematically capture studies reporting ΔSGU alone, and because ΔSGU depends on the shade-guide system and on the value-oriented ordering used for its numerical conversion.

Data management A standardized Excel form will be piloted independently by 1R and 2R on five included studies. After re-finement, both reviewers will independently extract all data and compare their entries. Disagreements will be resolved by discussion or by 3R. Risk-of-bias assessment will be performed separately from data extrac-tion, using the design-appropriate tool and the measurement-process items described below. Multiple groups, concentrations, and follow-up times from one study will retain a common Study ID so that non-independent observations are not treated as separate studies.

Quality assessment / Risk of bias analysis Risk of bias will be assessed independently by two reviewers, with disagreements resolved by a third reviewer, using design-specific tools: ROBUST-RCT for randomized clinical trials, the JBI Critical Appraisal Checklist for Quasi-Experimental Studies for non-randomized clinical intervention studies, and the QUIN tool for in vitro studies. Judgments will be applied to the results relevant to this review rather than to the parent trial as a whole. Across all designs, reviewers will also record measurement-process safeguards: paired calculation on the same sample and time, instrument calibration, repeated readings, examiner blinding where feasible, standardized measurement geometry, and specimen hydration control. These items will be reported separately and will not be converted into an unvalidated composite score. GRADE will not be applied as if this were a review of an intervention effect; certainty in the conclusions will be discussed according to study limitations, consistency, precision, directness, and potential reporting bias.

Strategy of data synthesis Because ΔE*ab, ΔE00, and ΔWID operate on different numerical scales, raw values will not be pooled together, and Lin's concordance correlation coefficient or Bland-Altman limits of agreement will not be calculated across these metrics. Analyses will use only metrics calculated from the same specimens or participants at the same evaluation time. Clinical and in vitro studies will be synthesized separately, with human and bovine substrates as prespecified subgroups. Results will be organized by metric pair. Reported Pearson or Spearman correlations will be summarized by pair; when at least three sufficiently comparable independent studies report the same coefficient, correlations may be pooled after Fisher's z transformation using a random-effects model, and Pearson and Spearman coefficients will not be pooled together. Each metric will be classified using its prespecified thresholds, and Cohen's kappa and percentage agreement will be reported for each pair when calculable; Fleiss' kappa will be restricted to studies reporting all three metrics for the same

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observations. In studies with an independent visual or perceptual assessment, including ΔSGU, associations or classification performance will be summarized separately for each metric. The original sign of ΔWID will be examined descriptively to identify results in which ΔWID indicates decreased whiteness despite bleaching-related change according to ΔE*ab, ΔE00, and/or ΔSGU, exploring the contribution of L*, a*, and b* when available; this analysis is hypothesis-generating. Multiple follow-up times or groups from one study will not be entered as independent studies; one prespecified time point will be selected, or dependence will be handled with a multilevel or robust-variance model. Meta-analysis will be performed only when at least three studies are clinically and methodologically comparable; otherwise, structured narrative synthesis will be used. Heterogeneity will be described using τ^2, I^2, confidence intervals, and prediction intervals when estimable. Analyses will be conducted in R; RevMan may be used for compatible conventional analyses.

Subgroup analysis When supported by sufficient studies: clinical versus in vitro design; human versus bovine substrate; in-office versus at-home bleaching; bleaching agent and concentration; evaluation time; measurement device and geometry; measurement standardization procedures (positioning guides, measured surface and window area, angulation, background, number of readings, hydration control); and metric pair. Device- and standardization-related factors will be analyzed descriptively when subgroup counts are small. Subgroup analyses will not be performed when fewer than two studies contribute to a subgroup, and differences will not be inferred solely from statistical significance within separate subgroups.

Sensitivity analysis Sensitivity analyses will exclude studies at high risk of bias or with major measurement-process concerns.

Language restriction No language restrictions will be applied to searches or study inclusion.

Country(ies) involved Brazil.

Other relevant information The protocol follows PRISMA-P 2015. Prespecified thresholds and key references: Pérez MM, et al. Development of a customized whiteness index for dentistry based on CIELAB color space. Dent Mater. 2016;32(3):461-467. Paravina RD, et al. Color difference thresholds in dentistry. J Esthet Restor Dent. 2015;27 Suppl 1:S1-S9. Pérez MM, et al. Whiteness difference thresholds in dentistry. Dent Mater. 2019;35(2):292-297.

Keywords CIEDE2000; CIELAB; WID; Tooth bleaching; Color change; Systematic review.

Dissemination plans Findings will be submitted for publication in a peer-reviewed dental journal and presented at scientific meetings. The final publication will cite this registration and report any deviations from the protocol.

Contributions of each author

Author 1 - Daniella Mello - First reviewer: conceptualization and design, search and selection, data collection, data analysis, manuscript preparation.
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