Journal of Oral Rehabilitation

WILEY

JOURNAL OF ORAL REHABILITATION

ORIGINAL ARTICLE OPEN ACCESS

Tooth Wear Severity and Temporomandibular Joint Degenerative Findings on Cone-Beam Computed Tomography: A Cross-Sectional Study in Adults

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Received: 5 June 2026 | **Revised:** 6 August 2026 | **Accepted:** 18 August 2026

Keywords: bruxism | cone-beam computed tomography | cross-sectional studies | occlusal loading | temporomandibular joint | tooth wear

ABSTRACT

Background: Tooth wear is commonly assumed to be a marker of parafunctional load and, by extension, of mechanical stress on the temporomandibular joint (TMJ); whether greater wear accompanies greater degeneration in the same joint has rarely been tested.

Objective: To determine whether tooth wear severity is associated with ipsilateral CBCT-detected TMJ degeneration in adults with TMD symptoms.

Methods: In this cross-sectional study, 80 adults (160 joints; mean age 27 years; 80% female) underwent standardised tooth-wear scoring (Smith and Knight index, 0–4) and blinded CBCT assessment of osteophyte, erosion, subchondral cyst, flattening and sclerosis, categorised as no, indeterminate or definite osteoarthritis by established imaging criteria. Side-wear was modelled against same-side findings with generalised estimating equations for paired-joint clustering, and patient-level wear by logistic regression, adjusted for age, sex and Angle class with Bonferroni correction across the prespecified primary outcomes.

Results: Osseous findings were prevalent (flattening 86.9%, osteophyte 50.0%, erosion ≥ Grade 1 66.2%) and 75.6% of joints met criteria for definite osteoarthritis. Tooth wear showed no association with any joint outcome: adjusted odds ratios per +5 side-wear clustered around unity for osteophyte (1.01, 95% CI 0.79–1.27), subchondral cyst (1.00, 0.76–1.32) and definite osteoarthritis (0.95, 0.71–1.27), none reaching Bonferroni-corrected or nominal significance. Patient-level analyses were similarly null. Wear increased with age (Spearman $\rho = 0.65$, $p < 0.001$).

Conclusion: Tooth wear severity was not associated with ipsilateral TMJ degeneration. The assumed positive link with TMJ osseous change was not observed; wear alone does not appear to be a reliable clinical proxy for joint loading.

1 | Introduction

Tooth wear is common in young adults and has several causes—attrition, erosion and abrasion—though parafunction, and bruxism in particular, are generally regarded as the main contributors [1, 2]. In clinical practice the amount and severity of wear are commonly taken to reflect a history of parafunctional loading and, by extension, to serve as an indirect measure of the mechanical demand placed on the temporomandibular joint (TMJ) [1, 3]. This reasoning feeds a range of decisions, from prescribing an occlusal splint in a heavily worn dentition to the weight given to wear when TMJ symptoms or imaging are interpreted.

The evidence behind equating wear severity with TMJ loading is, however, weaker than its routine use implies. Cone-beam computed tomography (CBCT) studies repeatedly report a high prevalence of degenerative bony change—flattening, osteophyte formation, subchondral cyst and erosion—in patients referred for TMJ or orthodontic assessment, with prevalence tied to age and symptom status [4–7]. Direct attempts to relate wear severity to joint degeneration have been inconclusive: Pergamalian and colleagues found no clear relationship between attrition severity and TMJ pain or dysfunction [8], and multifactorial attrition models developed in differentiated temporomandibular disorder (TMD) subgroups could not separate patients with joint disease or masticatory muscle pain from asymptomatic controls with useful accuracy [9]. The same pattern is seen at population level: among 646 adults sampled from a German national oral health survey, anterior tooth wear was not associated with TMD pain [10]. The evidence is not uniform, however. In habitual betel-nut chewers with severely worn dentitions, generalised severe wear was associated with intra-articular TMD, raising the possibility that a wear–joint relationship emerges only at extremes of parafunctional loading, well beyond the range seen in most clinical samples [11]. The broader premise that occlusal features deterministically govern function and pathology has likewise been reappraised [12–14]. One limitation runs through much of this literature: wear and joint findings are summarised per patient, pooling both sides of the dentition and obscuring the comparison that matters most biomechanically—wear against joint change on the same side.

The present study set out to test that assumption rather than presuppose it. In a cross-sectional cohort of adults attending an orthodontic clinic with concurrent TMD symptoms, we asked whether greater tooth wear accompanies a higher burden of CBCT-detected TMJ degeneration. The design departs from earlier work in three respects: wear is analysed against joint findings on the same side, using generalised estimating equations that respect the clustering of the two joints within each patient rather than a single summed score per person; osseous findings are classified with the TMJ imaging framework of Ahmad et al. [15], which separates definite osteoarthritis (OA) from indeterminate adaptive remodelling; and functional occlusal modifiers—working-side guidance scheme and balancing contacts—are included as exploratory correlates of wear. All confirmatory models were adjusted for age, sex and Angle classification, with correction for multiple comparisons across the prespecified primary outcomes.

2 | Materials and Methods

2.1 | Study Design and Participants

This cross-sectional study was performed in the Department of Orthodontics, Faculty of Dentistry, Istanbul Kent University, which serves as the referral pathway for orthodontic patients presenting with concurrent TMD symptoms. This was a retrospective analysis of archival records. The archive was searched for all consecutive patients who had been referred for temporomandibular or orthodontic evaluation and imaged between January 2024 and December 2025, and every retrieved record was assessed against the eligibility criteria; no sampling, matching or selection beyond these criteria was applied. Inclusion criteria were: (i) adult patients aged ≥ 18 years referred to the Department of Orthodontics with concurrent TMD-related complaints (e.g., joint sounds, masticatory muscle or joint pain, limited or altered mandibular function) requiring clinical and CBCT assessment prior to orthodontic care; (ii) a full permanent dentition with at least 28 teeth excluding third molars; (iii) availability of a recent CBCT covering both TMJs and acquired according to clinical indication; and (iv) availability of a matching clinical tooth-wear assessment form in the archive. All CBCT examinations had been obtained previously for clinical-diagnostic indications during routine care; no imaging was performed for research purposes. Exclusion criteria were previous TMJ or orthognathic surgery, current fixed-appliance orthodontic treatment obscuring occlusal surfaces, prosthetic or extensive restorative coverage of the surfaces to be scored (full or partial crowns, veneers or fixed partial denture retainers), history of major facial trauma, congenital craniofacial syndromes, and systemic inflammatory or rheumatological conditions known to affect joint structure or bone metabolism (e.g., rheumatoid arthritis, juvenile idiopathic arthritis, psoriatic arthritis). Restored surfaces were excluded because the Smith and Knight index grades the loss of natural tooth substance and cannot be applied to a restorative surface, whose contour reflects the restoration rather than the patient's wear history. No participant had undergone any temporomandibular joint surgical intervention; the prior surgical procedures recorded in the cohort were unrelated to the craniofacial skeleton or masticatory apparatus. This restriction was applied so that the osseous findings under study reflected primary degenerative or adaptive remodelling rather than secondary, post-surgical or systemically driven joint disease. The number of records screened, found eligible, excluded and analysed is reported in Section 3.1 and summarised in Figure 1.

The study was approved by the Istanbul Kent University Faculty of Dentistry Non-Interventional Clinical and Observational Research Ethics Committee (approval no. 2026/2-2, dated 28 January 2026) and was conducted in accordance with the Declaration of Helsinki. As a retrospective analysis of de-identified archival records, the requirement for written informed consent was waived by the ethics committee. The study followed the STROBE statement for observational research.

2.2 | Tooth Wear Assessment

Tooth wear was assessed using the Smith and Knight Tooth Wear Index [16], an ordinal 0–4 scale (0 = no loss of enamel surface characteristics or contour; 1 = minimal loss of enamel surface characteristics or minimal contour change; 2 = enamel loss with dentine exposed on less than one-third of the surface, or cervical defect < 1 mm; 3 = dentine exposed on more than one-third of the surface, or cervical defect 1–2 mm; 4 = pulpal or secondary dentine exposure, or cervical defect > 2 mm), applied to four surfaces per tooth (occlusal/incisal, buccal/labial, palatal/lingual, cervical) across all 28 teeth excluding third molars. Each surface yielded a score from 0 to 4; the tooth-level score was defined as the sum across surfaces, and the patient-level wear score as the sum across all teeth. In the present cohort,

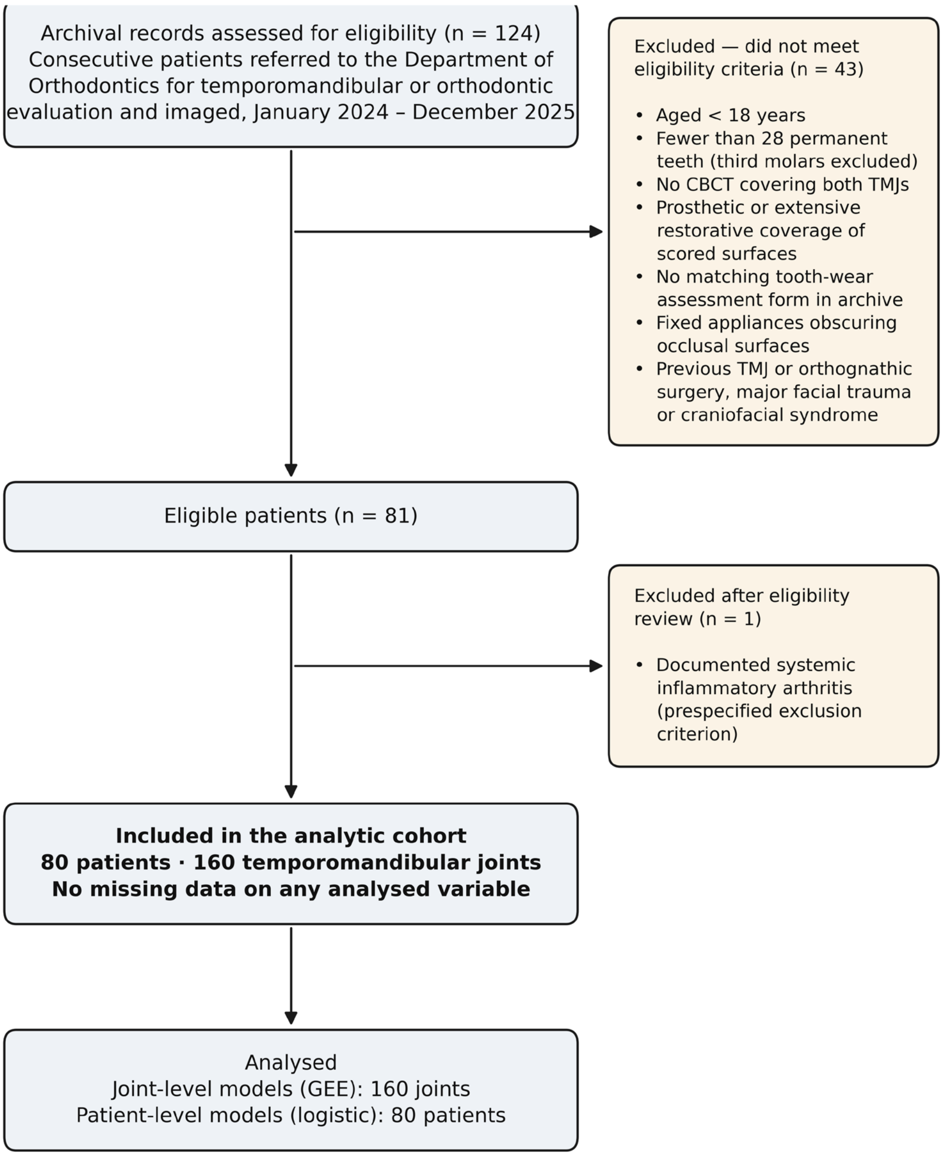

FIGURE 1 | Participant flow (STROBE). Consecutive archival records of patients referred for temporomandibular or orthodontic evaluation and imaged between January 2024 and December 2025 were screened against the eligibility criteria. Exclusions are shown with reasons at each stage. The analytic cohort comprised 80 patients contributing 160 temporomandibular joints, with complete data on all analysed variables.

the highest individual surface score observed was 3; no tooth surface reached score 4.

Tooth wear was scored from the standardised clinical examination records archived for each patient (not from photographs or casts), by two examiners (G.A., an orthodontist experienced in temporomandibular joint imaging, occlusal analysis and tooth-wear assessment; and C.D.Ö., trained and calibrated against G.A. before the start of scoring), both blinded to the CBCT findings. Each surface was independently scored by both examiners, with disagreements resolved by consensus prior to analysis; consensus scores were used for all subsequent statistical analyses. Tooth-wear scoring reliability was evaluated on a random subsample of 20 patients selected using a computer-generated random sequence. Interobserver agreement was estimated from the independent scores of G.A. and C.D.Ö. prior to consensus, and G.A. repeated the scoring after a 4-week interval under blinded conditions to determine intraobserver reliability. Reliability for tooth-level and patient-level wear scores was quantified using intraclass correlation coefficients (ICC[3,1]; two-way mixed-effects model, absolute agreement, single-measure form) and interpreted according to Landis and Koch; numerical values are reported in Section 3.2.

2.3 | CBCT Acquisition and Assessment

CBCT scans were acquired on a Castellini X-Radius Trio unit (Cefla S.C., Bologna, Italy) with a field of view covering both TMJs (exposure parameters: 13 × 10 cm FOV, 0.3 mm voxel size, 90 kVp, 6 mA, 16.2 s exposure time). Images were analysed using iRYS software (version 14.0; Cefla S.C., Bologna, Italy) by an oral and maxillofacial radiologist (F.Y.) and an orthodontist (G.A.), both blinded to the dental wear scores. Disagreements were resolved by consensus, and consensus scores were used in the analyses. Each joint was independently assessed for six osseous findings—condylar flattening, osteophyte formation, subchondral cyst, surface erosion, subchondral sclerosis and ankylosis. Erosion and osteophytic change were graded on the 0–3 semiquantitative severity scale described by Alexiou et al. [4], and findings were required to be visible on at least two consecutive slices to avoid artefactual over-reading. Subchondral cysts were recorded only when a well-defined subcortical radiolucent defect surrounded by cortical bone was visible on at least two consecutive slices. Linear condyle–fossa joint spaces were measured at six sites (coronal medial CMS, central CCS, lateral CLS; sagittal anterior SMS, superior SCS, posterior SLS) on multiplanar reformatted images.

To distinguish degenerative osteoarthritis from non-pathological adaptive remodelling, joints were additionally categorised according to the TMJ imaging criteria proposed by Ahmad et al. [15] into three mutually exclusive tiers: (i) no osteoarthritis (no osseous findings); (ii) indeterminate/adaptive remodelling (isolated condylar flattening and/or localised subchondral sclerosis without any other finding); and (iii) definite osteoarthritis (presence of osteophyte, surface erosion of any grade, subchondral cyst, or generalised subchondral sclerosis). Because the original assessment recorded sclerosis as a single binary variable without explicit localised-versus-generalised differentiation, sclerosis was conservatively treated as an adaptive-remodelling indicator rather than a definitive osteoarthritis marker. Joint-level findings were also enumerated as a count (0–5) to enable a sensitivity definition of severe degeneration (≥ 3 co-occurring findings).

Intra- and interobserver reliability of the CBCT assessments was evaluated on a random subsample of 20 scans (40 joints) selected using a computer-generated random sequence. Two examiners independently re-evaluated this subsample under blinded conditions: examiner 1 (F.Y., an oral and maxillofacial radiologist, who performed the primary CBCT readings) re-scored the scans after a 4-week interval without access to the original readings, providing intraobserver data; examiner 2 (G.A.) independently evaluated the same subsample while blinded to examiner 1's results, providing interobserver data. Both examiners were additionally blinded to the corresponding tooth-wear scores throughout the evaluation process. Agreement for binary degenerative findings (osteophyte, flattening, subchondral cyst and sclerosis) was quantified using Cohen's κ statistics, whereas ordinal erosion grades (0–3) were assessed using quadratic-weighted κ coefficients. Linear condyle–fossa joint-space measurements were evaluated using intraclass correlation coefficients (ICC[3,1]; two-way mixed-effects model, absolute agreement, single-measure form). Agreement levels were interpreted according to Landis and Koch, with κ/ICC values > 0.80 considered excellent, 0.61–0.80 substantial, 0.41–0.60 moderate and < 0.40 poor.

2.4 | Clinical TMJ and Occlusal Examination

A standardised clinical assessment based on the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) [17] was performed by a single calibrated examiner (G.A.) at the time of routine clinical care. Because these examinations were carried out chairside during care and cannot be repeated on archival records, no interexaminer reliability data are available for the clinical variables (joint sounds, mouth opening and Angle classification), in contrast to the tooth-wear and CBCT assessments, for which formal intra- and interobserver testing was undertaken (Sections 2.2 and 2.3). The consequences for Angle classification, which enters every adjusted model as a covariate, are addressed in the Discussion. Joint sounds during opening and closing movements were classified per side as none, click or crepitus. Maximum unassisted mouth opening was recorded to the nearest 0.1 mm using a digital calliper. Angle classification, overjet and overbite were determined from study casts and intra-oral photographs. Probable bruxism was classified according to the international consensus criteria of Lobbezoo et al. [1], on the basis of self-reported sleep and/or awake bruxism together with clinical signs noted during the examination; instrumental confirmation (polysomnography or electromyography) was not feasible in this retrospective design, and classification therefore remained at the probable level. Because probable-bruxism ascertainment and the clinical tooth-wear assessment share overlapping signs, bruxism status was treated only as a descriptive cohort characteristic and was not entered as a covariate (its near-universal prevalence also precluded meaningful adjustment); the wear–TMJ analyses relate measured tooth wear directly to imaging findings and do not depend on the bruxism classification.

Functional occlusal relationships were additionally recorded. The working-side guidance pattern was classified per side as canine guidance, group function, or no contact; the presence of balancing (non-working) side contacts during lateral excursion was recorded per side; and the protrusive guidance pattern was documented. At the patient level, occlusion was summarised as predominantly group-function (group function on both working sides), any-canine-guidance (canine guidance on at least one side), or mixed, and as presence versus absence of any balancing contact. These exploratory occlusal variables were used to characterise the relationship between functional contact patterns and wear severity.

2.5 | Statistical Analysis

Descriptive statistics are reported as mean ± standard deviation (SD) or median (interquartile range, IQR) for continuous variables according to distribution, and as count (percentage) for categorical variables. An a priori sample-size estimation (G*Power) indicated that a minimum of 80 participants would be required to detect a medium effect size ($\alpha = 0.05$, power $= 0.80$). This figure was treated as a minimum, not as a recruitment target: screening was not stopped once it was reached, and every archival record within the predefined study period that met the inclusion criteria was included. Participant flow, with the number of records screened, found eligible, excluded and analysed, is reported in Section 3.1 and Figure 1.

The primary analyses tested the association between ipsilateral side-wear and ipsilateral CBCT osseous findings. Side-wear was defined as the sum of tooth-level wear scores for the teeth of the corresponding side (right or left), summed across both arches; it is therefore the ipsilateral hemiarch restriction of the same summation used for the patient-level score. The Smith and Knight index is a surface-level instrument, and neither its original description [16] nor later tooth-wear evaluation systems [3] define a side-specific aggregate, so this quantity is a study-specific derivation rather than a validated metric. It was adopted because the hypothesis under test is explicitly lateralised—masticatory load borne on one side is transmitted to the ipsilateral joint—so that a hemiarch exposure is the quantity the hypothesis actually concerns, whereas a whole-mouth sum averages across the very contrast of interest. Unweighted summation of ordinal surface scores was retained in preference to any weighting scheme because it assumes nothing about the relative contribution of individual teeth and preserves the arithmetic of the patient-level score. Because side-wear is built from the same surface-level scores as the tooth- and patient-level totals, its reproducibility was evaluated directly at the side level in the same 20-patient reliability subsample and is reported in Section 3.2; its status as a non-validated aggregate is considered among the limitations. Whereas the protocol had specified correlation and multivariable regression analyses, the final analysis used generalised estimating equations (GEE) with exchangeable working correlation and robust sandwich variance estimators to account for the non-independence of the two joints per patient—a more appropriate approach for the side-specific design. A GEE model was fitted for each binary CBCT outcome. The four prespecified primary outcomes were osteophyte, erosion ≥ Grade 1, subchondral cyst, and a composite definite-osteoarthritis variable based on the imaging criteria proposed by Ahmad et al. [15] (presence of osteophyte, erosion ≥ Grade 1 and/or subchondral cyst). Sensitivity analyses additionally examined high-grade erosion (≥ Grade 2), severe degeneration (≥ 3 co-occurring findings), and flattening as a descriptive marker of adaptive remodelling. Models were adjusted for age (years), sex and Angle classification. Adjusted odds ratios are reported per 5-unit increment in side-wear with 95% confidence intervals (CI). Ordinal erosion grade was additionally examined as a continuous outcome using Spearman's rank correlation against side-wear.

Secondary patient-level analyses examined total wear against composite joint outcomes—bilateral osteophyte presence, bilateral definite osteoarthritis (Ahmad framework), and high erosion burden defined as grade ≥2 erosion in both joints—using multivariable logistic regression with the same covariates; odds ratios are reported per 10-unit increment in total wear.

Bonferroni correction was applied across the four prespecified primary joint-level comparisons, yielding a threshold of $\alpha \approx 0.0125$ for confirmatory significance; findings with $0.0125 < p < 0.05$ are reported as nominally significant only. The analyses of functional occlusion (working-side guidance scheme, balancing contacts) and of age were exploratory and hypothesis-generating, were not part of the prespecified confirmatory set, and were not corrected for multiple comparisons. Univariate comparisons of patient total wear distributions by finding status used the Mann–Whitney U test. All analyses were performed in Python 3.12 (statsmodels 0.14.6, scipy 1.17, pandas 3.0).

3 | Results

3.1 | Cohort Characteristics

Of the 124 consecutive archival records screened for the period January 2024 to December 2025, 43 did not meet the eligibility criteria, leaving 81 eligible patients. One of these was excluded during record review because a documented diagnosis of systemic inflammatory arthritis met a prespecified exclusion criterion. The final analytic cohort therefore comprised 80 patients (160 joints), with no missing data on any analysed variable (Figure 1). That this number coincides with the a priori minimum is incidental: cohort size was fixed by the eligibility process, not by the sample-size estimate. The mean age was 26.8 years (SD 8.8; range 18–59); 64 (80.0%) were female. Probable bruxism was documented in 76 (95.0%) participants. Angle classification distribution was: Class I, 29 (36.2%); Class II Division 1, 36 (45.0%); Class II Division 2, 6 (7.5%); Class III, 9 (11.2%). This cohort should not be interpreted as representative of the general young-adult population, but rather of a highly selected, symptomatic TMJ/orthodontic referral population. Additional baseline characteristics are reported in Table 1.

3.2 | Reliability of Wear and CBCT Assessments

Tooth-wear scoring demonstrated substantial-to-excellent reproducibility. Intraobserver ICCs were 0.87 for tooth-level wear scores, 0.92 for the side-specific aggregated score (95% CI 0.84–0.96) and 0.94 for the patient-level total wear score, whereas interobserver ICCs ranged from 0.82 to 0.91. CBCT assessments likewise showed high reproducibility: intraobserver Cohen's κ values for binary osseous findings ranged from 0.81 to 0.93 and interobserver κ values from 0.78 to 0.90, while quadratic-weighted κ values for erosion grading ranged from 0.84 to 0.91.

TABLE 1 | Demographic and clinical characteristics of the analytic cohort ($n = 80$ patients).

Characteristic	Value ($n = 80$)
Age, years—mean (SD)	26.8 (8.8)
Age, years—range	18–59
Sex—female, *n* (%)	64 (80.0)
Sex—male, *n* (%)	16 (20.0)
Probable bruxism, *n* (%)	76 (95.0)
Angle Class I, *n* (%)	29 (36.2)
Angle Class II Division 1, *n* (%)	36 (45.0)
Angle Class II Division 2, *n* (%)	6 (7.5)
Angle Class III, *n* (%)	9 (11.2)
Total wear score—median (IQR)	21.0 (13.8–32.0)
Total wear score—mean (SD)	25.5 (17.7)

Note: Values are *n* (%) unless otherwise stated.
Abbreviations: IQR, interquartile range; SD, standard deviation.

ICC values for condyle–fossa joint-space measurements ranged from 0.88 to 0.95, indicating excellent agreement overall.

3.3 | Tooth Wear Topography

Tooth wear was clinically apparent but generally mild, with a markedly attrition-dominant pattern. Occlusal/incisal surfaces accounted for nearly all clinically detectable wear, with mean wear scores at least an order of magnitude greater than those on buccal/labial, palatal/lingual, or cervical surfaces (Figure 2; Figure S1).

Wear prevalence and severity differed across tooth types (Figure S1). Canines were the most affected, followed by incisors, premolars and molars. Spatial distribution by FDI position confirmed bilaterally symmetric anterior peaks at canines (Fédération Dentaire Internationale [FDI] notation; teeth 13/23 in the maxilla and 33/43 in the mandible; Figure 2). Quadrant-level mean wear was modestly higher in the mandibular arch than the maxillary arch (Figure S1); right–left asymmetry was negligible.

3.4 | CBCT Osseous Findings

Osseous findings were common at the joint level (Figure 3A). Flattening was identified in 139 of 160 joints (86.9%), osteophyte formation in 80 (50.0%), erosion of any grade in 106 (66.2%), high-grade erosion (grade ≥ 2) in 58 (36.2%), subchondral cyst in 47 (29.4%) and sclerosis in 57 (35.6%). Ankylosis was not observed. Erosion grading distinguished 54 joints with no erosion, 48 with Grade 1, 31 with Grade 2 and 27 with Grade 3.

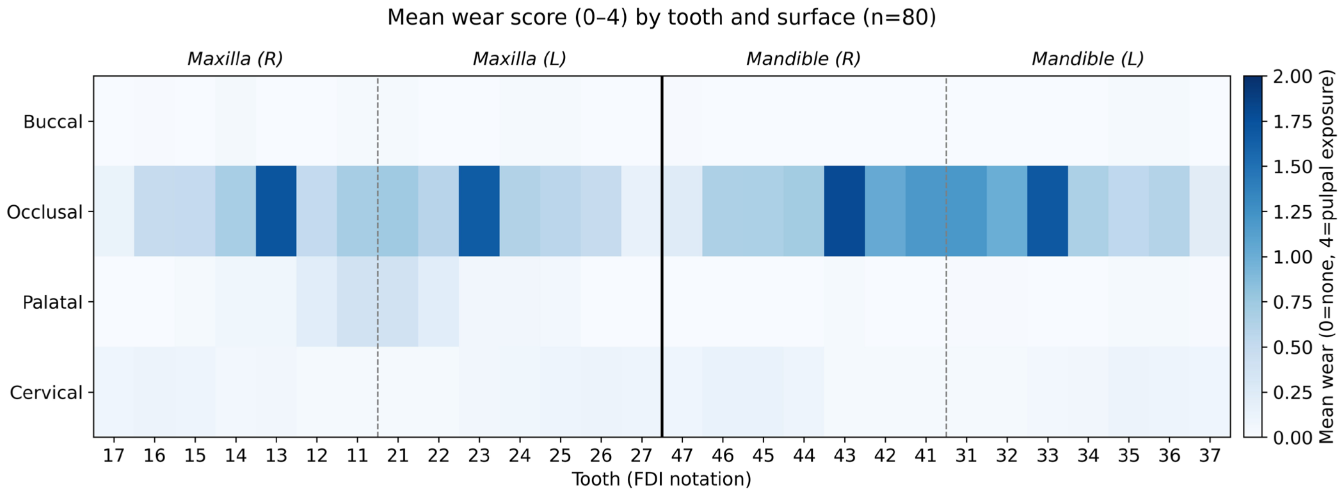

FIGURE 2 | Mean tooth-wear score by FDI tooth position and surface (third molars excluded). Heat map of mean summed wear across four surfaces (28 teeth scored per patient). Colour intensity is scaled to the mean per-surface wear score; mean values are displayed (hence the compressed visual range; scores were applied on the 0–4 Smith and Knight scale, and the highest individual surface score observed in this cohort was 3). The bilaterally symmetric pattern peaks at the canines in both arches and is anteriorly predominant, and wear is almost entirely confined to occlusal/incisal surfaces.

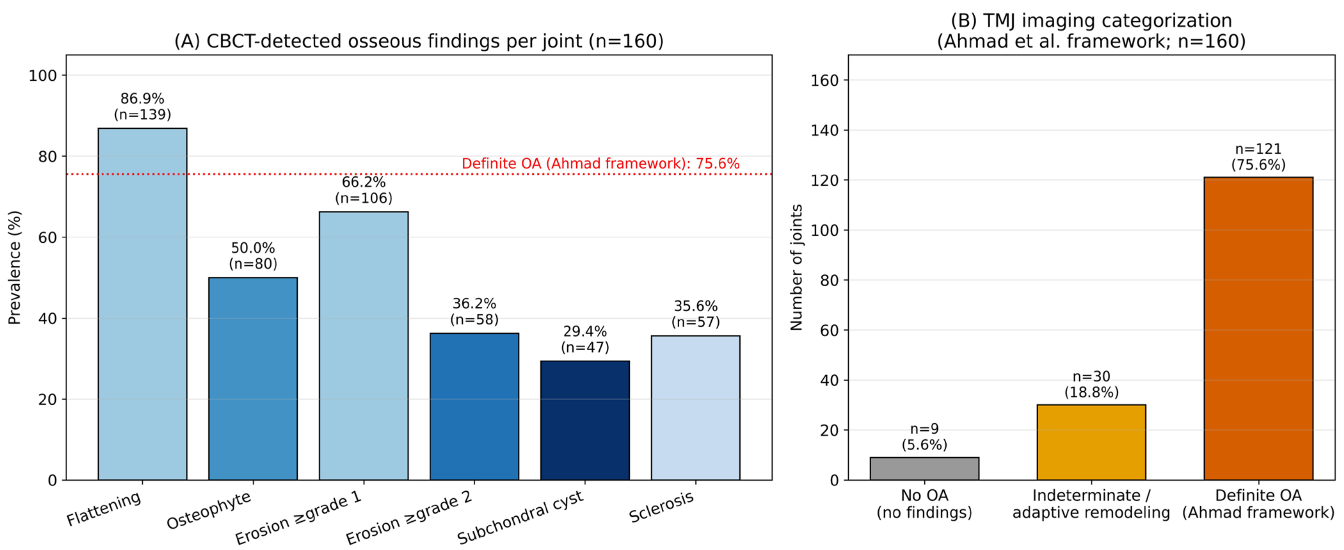

FIGURE 3 | (A) Joint-level prevalence of CBCT osseous findings ($n = 160$ joints), including high-grade erosion ($\geq$ Grade 2); the dashed line marks the definite-osteoarthritis composite per Ahmad et al. Ankylosis was not observed. (B) TMJ imaging categorisation (Ahmad et al. framework): No osteoarthritis, indeterminate/adaptive remodelling and definite osteoarthritis.

Categorisation according to the TMJ imaging criteria proposed by Ahmad et al. classified 9 joints (5.6%) as having no osteoarthritis, 30 (18.8%) as indeterminate/adaptive remodelling and 121 (75.6%) as definite osteoarthritis (Figure 3B). Findings co-occurred: about half of joints (81/160; 50.6%) exhibited ≥ 3 of the five non-ankylotic osseous changes.

TMJ sounds were absent on 23 sides (14.4%), with clicking documented on 41 (25.6%) and crepitus on 96 (60.0%; Figure S2). Mean condyle–fossa joint spaces ranged from approximately 1.8 mm at the coronal-medial site to 2.4 mm at the sagittal-lateral site, with no clinically meaningful right–left asymmetry (Table S1).

3.5 | Association Between Ipsilateral Wear and TMJ Findings (Joint Level)

For the four prespecified primary joint-level outcomes, no association with side-wear was observed: osteophyte (aOR 1.01, 0.79–1.27; $p = 0.966$), erosion ≥ Grade 1 (aOR 0.95, 0.74–1.23; $p = 0.717$), subchondral cyst (aOR 1.00, 0.76–1.32; $p = 0.982$) and definite osteoarthritis (aOR 0.95, 0.71–1.27; $p = 0.724$). None met the Bonferroni-corrected significance threshold ($\alpha = 0.0125$), nor reached nominal significance. The secondary high-grade erosion (≥ Grade 2) outcome was also null (aOR 1.00, 0.77–1.30; $p = 0.995$), as was the severe-osteoarthritis composite (≥ 3 co-occurring findings; aOR 1.02, 0.79–1.31; $p = 0.884$). Adjusted estimates clustered tightly around unity, indicating no detectable association between ipsilateral side-wear and joint-level CBCT findings in either direction (Table 2).

3.6 | Patient-Level Associations

Patient-level analyses paralleled the joint-level findings (Table 2). Higher total wear was not associated with bilateral osteophyte presence (aOR 1.04 per +10 wear units, 95% CI 0.69–1.58; $p = 0.852$), the bilateral definite-osteoarthritis composite (aOR 0.99, 0.67–1.46; $p = 0.958$), or high erosion burden (≥ 2 joints with erosion ≥ Grade 2; aOR 0.90, 0.54–1.48; $p = 0.666$). Univariate Mann–Whitney comparisons (Table S2; Figure S4) confirmed no significant between-group differences in total wear: bilateral osteophyte present 17.0 versus absent 22.0 ($p = 0.592$), bilateral definite osteoarthritis 21.0 versus 21.5 ($p = 0.893$) and high erosion 17.5 versus 22.0 ($p = 0.601$). Across all joint-level and patient-level analyses examined (six primary or sensitivity outcomes at the joint level and three at the patient level), adjusted point estimates clustered around unity (range 0.90–1.04), and none indicated a positive association in the direction predicted by a simple loading model (Figure 4).

3.7 | Wear, Age and Functional Occlusion

Total wear increased steeply with age (Spearman $\rho = 0.65$, $p < 0.001$), rising from a median of 14.0 in participants aged 18–20 years to 20.0 at 21–30 years and 38.0 above 30 years, consistent with cumulative exposure to attritional wear over time (Figure S3). In contrast, definite osteoarthritis was near-universal across the entire age range, including the youngest participants, indicating that osseous degeneration in this cohort was not driven by the age gradient that governed wear.

TABLE 2 | Adjusted associations of tooth wear with TMJ osseous findings ($n = 80$ patients; 160 joints).

Outcome (per wear increment)	Model	aOR (95% CI)	p[a]
Osteophyte, ipsilateral (per +5)	GEE	1.01 (0.79–1.27)	0.966
Erosion ≥ Grade 1, ipsilateral (per +5)	GEE	0.95 (0.74–1.23)	0.717
Erosion ≥ Grade 2, ipsilateral (per +5)	GEE	1.00 (0.77–1.30)	0.995
Subchondral cyst, ipsilateral (per +5)	GEE	1.00 (0.76–1.32)	0.982
Definite OA composite, ipsilateral (per +5)	GEE	0.95 (0.71–1.27)	0.724
Severe OA (≥ 3 findings), ipsilateral (per +5)	GEE	1.02 (0.79–1.31)	0.884
Bilateral osteophyte (per +10)	Logistic	1.04 (0.69–1.58)	0.852
Bilateral definite OA composite (per +10)	Logistic	0.99 (0.67–1.46)	0.958
High erosion burden ≥ 2 joints grade ≥ 2 (per +10)	Logistic	0.90 (0.54–1.48)	0.666

Abbreviations: aOR, adjusted odds ratio; CI, confidence interval.
[a]Models adjusted for age, sex and Angle class. Joint-level models use generalised estimating equations (GEE) with exchangeable working correlation and robust sandwich variance estimators; patient-level models use multivariable logistic regression. Bonferroni correction was prespecified across the four primary joint-level outcomes (osteophyte, erosion ≥ Grade 1, subchondral cyst, definite osteoarthritis composite; $\alpha \approx 0.0125$); no outcome reached either Bonferroni-corrected or nominal significance.

In secondary exploratory analyses (occlusal analyses, $n = 80$), canine wear was common, with measurable wear in approximately 70% of patients. The working-side guidance scheme was not associated with wear severity (median total wear 23.0 with bilateral group function versus 20.0 with any canine guidance; Mann–Whitney $p = 0.063$), and canine-specific wear did not differ between schemes. The presence of balancing (non-working) side contacts showed a non-significant trend towards lower wear (median 20.0 vs. 24.0; $p = 0.058$ unadjusted), and remained non-significant after adjustment for age, sex and Angle class (adjusted mean difference −5.6 wear units, 95% CI −11.5 to +0.3; $p = 0.061$). These occlusal analyses were exploratory and uncorrected for multiple comparisons; they suggest that wear severity in this cohort tracked age and functional contact stability more closely than the canonical guidance scheme, and are interpreted as hypothesis-generating only (Figure S3).

4 | Discussion

In this cross-sectional study of orthodontic patients with concurrent TMD symptoms, we found no evidence that tooth wear

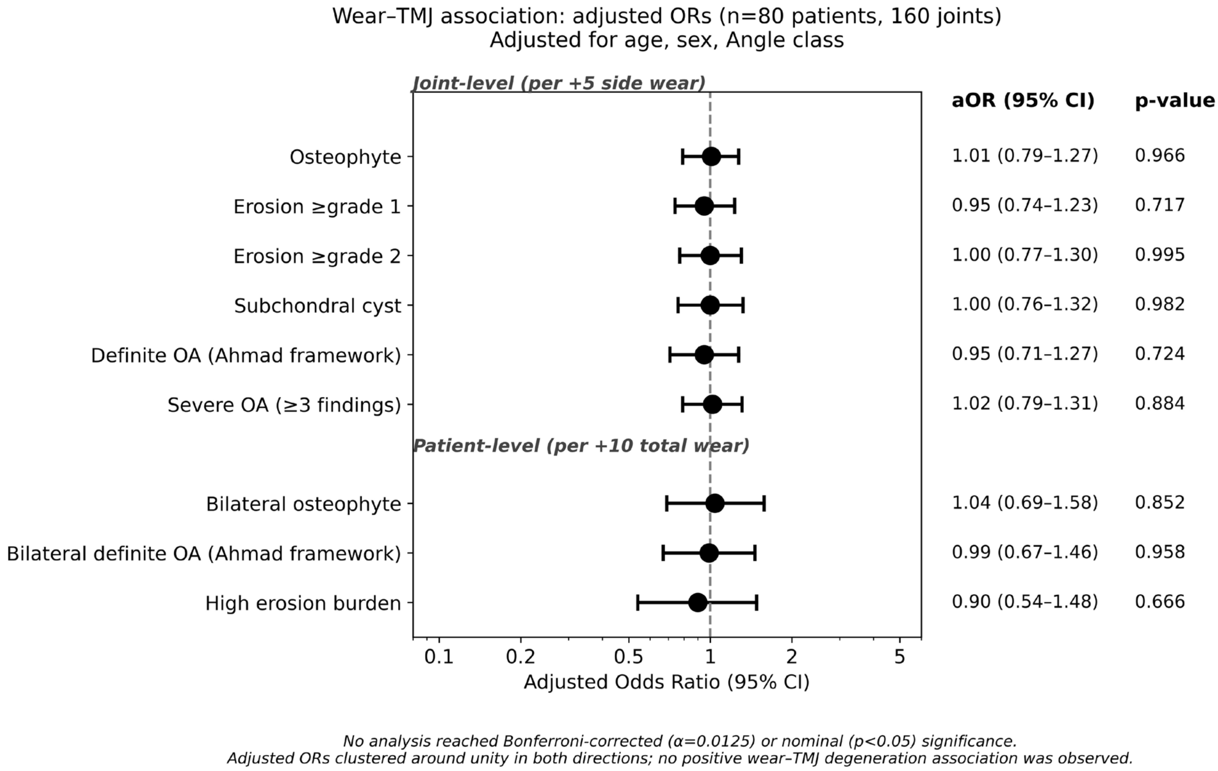

FIGURE 4 | Forest plot of adjusted odds ratios (aOR) for wear–TMJ associations. Joint-level analyses (top, generalised estimating equations) report aORs per 5-unit increase in ipsilateral side-wear for six osseous outcomes including the Ahmad-framework definite-osteoarthritis composite and the severe-osteoarthritis (≥ 3 findings) sensitivity outcome. Patient-level analyses (bottom, logistic regression) report aORs per 10-unit increase in total wear for three composite outcomes. All models adjusted for age, sex and Angle class. The vertical dashed line marks the null effect (aOR = 1). Squares depict point estimates; horizontal bars depict 95% confidence intervals. Bonferroni correction was prespecified across the four primary joint-level outcomes ($\alpha \approx 0.0125$). All adjusted point estimates clustered around unity; no outcome reached either Bonferroni-corrected or nominal significance, and no positive wear–TMJ degeneration association was observed.

severity tracks ipsilateral CBCT-detectable TMJ degeneration. The cohort carried a heavy burden of both wear and osseous change, yet the positive association predicted by simple loading models—and, in our clinical experience, widely assumed in everyday practice—did not emerge. Adjusted estimates across all six joint-level and three patient-level analyses, including the composite definite-osteoarthritis outcome based on the Ahmad et al. imaging criteria, sat at the null, and none reached Bonferroni-corrected or nominal significance. The finding is a clear negative one: a standardised 0–4 ordinal wear score summed across 28 teeth did not predict CBCT-detected joint degeneration on the same side.

How we read the prevalence figures depended on the Ahmad et al. framework. Isolated condylar flattening and localised sclerosis fall into the indeterminate adaptive-remodelling category rather than the osteoarthritis category, and scoring them as degenerative would have inflated the apparent prevalence without changing the pattern. Even on this conservative basis, 75.6% of joints met the definite-osteoarthritis criteria. Because our patients were adults referred with TMD complaints, the appropriate comparators are other symptomatic CBCT cohorts, not population-based or asymptomatic samples, in which bony TMJ change is far less frequent. Set against the TMD literature, our values fall within the symptomatic range. Al Turkestani et al. [18], in a clinically diagnosed TMJ osteoarthritis cohort, reported joint-level prevalences of 97% flattening, 82% sclerosis, 79% erosion/osteophyte and 76% subchondral cyst—all higher than ours, consistent with their more advanced disease stage. Alexiou et al. [4] and Vasegh et al. [5] reported condylar osteophyte rates of 26%–64% and erosion rates of 19%–40% in broader TMD samples, and Pattugayathri et al. [19] identified osteoarthritic change in 65% of joints in a CBCT screening series. Our own profile (flattening 86.9%, osteophyte 50.0%, erosion ≥ Grade 1 66.2%, subchondral cyst 29.4%) falls between these series, pointing to a moderately rather than extremely enriched degenerative burden. The high background rate reflects whom we studied, not where we set the diagnostic threshold.

Our null result sits with the larger part of the wear–TMD literature. Schierz et al. found no association between anterior tooth wear and TMD pain among 646 adults sampled from a German national oral health survey [10], and the attrition models of Seligman and Pullinger could not separate patients with joint disease or masticatory muscle pain from asymptomatic controls [9]. What the present data add is that this dissociation extends beyond self-reported pain to imaged osseous pathology, and holds when wear and joint are examined on the same side. Where a positive signal has been reported, it comes from populations at the extreme of masticatory loading: Liu et al. found severely worn dentitions in habitual betel-nut chewers to be associated with intra-articular TMD [11], a degree of generalised wear far above the mild, attrition-dominant pattern seen here, in which no surface exceeded Grade 3. Read together, these studies suggest that any wear–joint relationship is confined to the upper extreme of the wear spectrum and does not operate across the range met in routine orthodontic and TMD practice.

Several mechanisms could account for the absence of a positive association. Wear accumulated with age (Spearman $\rho = 0.65$), but osseous degeneration was already near-universal even in the youngest participants, so the two outcomes are not bound together by the shared age gradient that so often drives wear–osteoarthritis correlations in mixed-age samples. And in an established, symptomatic joint, reduced bite force, pain-related avoidance of demanding chewing and altered mandibular kinematics may each blunt ongoing functional contact and slow further attrition independently of joint status—though a cross-sectional design cannot test these pathways directly.

The high prevalence of osseous findings also imposes a ceiling effect that compresses between-joint variance and limits the power to detect modest associations: with 75.6% of joints meeting definite-osteoarthritis criteria, the comparison group is small, and the null estimates do leave room for small residual effects. Even so, the joint-level GEE, the patient-level logistic regression and the univariate comparisons all converged on the null in both directions, which makes a clinically meaningful undetected effect unlikely.

The 75.6% definite-osteoarthritis prevalence should not be read as a community estimate. Every patient had been referred for TMJ-related complaints and imaged during routine care, so the cohort was deliberately enriched for TMJ pathology, and the study addressed within-cohort wear–TMJ associations rather than prevalence.

Clinically, the message is straightforward. In this cohort, tooth wear severity on its own said little about ipsilateral TMJ osseous status. Decisions about splint therapy, occlusal adjustment, or prognosis should not lean on wear severity as a proxy for joint loading; the joint itself still has to be assessed directly—through clinical examination, structured symptom inventories and, where indicated, imaging.

Several limitations apply. The cross-sectional design cannot establish temporal sequence, so longitudinal data would be needed to determine whether wear and TMJ degeneration progress independently or whether established joint pathology shapes subsequent attrition. The cohort is also narrow—young, predominantly female adults from a single orthodontic clinic, all with concurrent TMD symptoms and a high prevalence of probable bruxism and osseous findings—which limits generalisability to older or less symptomatic populations. The high definite-osteoarthritis prevalence brings a ceiling effect that reduces sensitivity to small effects. Wear severity was also generally low—no surface exceeded Grade 3 and the pattern was attrition-dominant—so advanced wear was under-represented; cumulative side- and patient-level wear nonetheless spanned a wide range and tracked age strongly (Spearman $\rho = 0.65$), indicating that the exposure retained sufficient dynamic range to reveal an association had one been present. Acidic dietary exposure and gastro-oesophageal reflux can drive attrition independently of joint status, and because these were not recorded systematically, residual confounding of the wear estimates cannot be excluded. Magnetic resonance imaging was not routinely available, so disc displacement and effusion—which CBCT cannot depict and which may mediate the wear–TMJ relationship—were not assessed; our focus was osseous degeneration, for which CBCT is an accepted modality. Sclerosis was recorded as a single binary variable, so the Ahmad-framework distinction between localised and generalised sclerosis could not be applied per joint, and sclerosis was conservatively excluded from the definite-osteoarthritis composite; given the dominance of osteophyte, this is unlikely to have changed the prevalence picture meaningfully. The clinical DC/TMD examination—joint sounds, mouth opening and Angle classification—was performed by a single calibrated examiner during routine care, and no interexaminer reliability data are available for it, in contrast to the formally tested wear and CBCT assessments. Angle class enters every confirmatory model as a covariate, so imprecision in its assignment would carry into the adjusted estimates as residual confounding. Two considerations bound the likely impact. Angle classification was determined from study casts and intraoral photographs rather than from chairside inspection alone, which is the more reproducible route; and the examination was performed during routine care, independently of and blind to both the wear scores and the CBCT readings analysed here, so any misclassification is non-differential with respect to exposure and outcome. More directly, the univariate, covariate-free comparisons were null as well (Table S2; Figure S4), so the conclusion does not rest on the covariate adjustment. A related caveat applies to the exposure: side-wear is a study-specific aggregation of the Smith and Knight surface scores rather than a validated index, and although its side-level test–retest reproducibility was excellent (Section 3.2), reproducibility is not the same as validity. A differently constructed side-specific exposure—weighted towards posterior teeth, for instance, or restricted to functional contact areas—might behave differently, and this remains to be established. Finally, the occlusal analyses were exploratory and uncorrected for multiple comparisons, and wear scoring remains a qualitative ordinal assessment that does not separately quantify attritional, erosive and abrasive contributions.

The study also has strengths. To our knowledge, it is among the first to test ipsilateral wear–joint associations at the joint-side level, with multilevel analysis and covariate adjustment, in a CBCT-characterised cohort. Wear and CBCT assessments were independent and mutually blinded, the Ahmad et al. imaging framework was applied throughout, several complementary outcomes were tested, and the primary outcome set was corrected for multiple testing. Future work should follow individuals longitudinally across a range of baseline wear and joint status, with repeated CBCT and quantitative occlusal contact analysis, and should include older adults and cohorts with lower baseline joint pathology, so that generalisability can be broadened.

5 | Conclusion

In an adult orthodontic cohort with concurrent TMD symptoms and a high prevalence of both tooth wear and CBCT-detectable TMJ degeneration, wear severity was not associated with ipsilateral joint findings on any of the prespecified joint-level or patient-level outcomes, and no analysis reached Bonferroni-corrected or nominal significance. Taken on its own, then, tooth wear severity is not a reliable proxy for mechanical loading of the TMJ in adults, and the commonly assumed positive link between wear and TMJ osseous degeneration should not guide clinical decision-making. Longitudinal work will be needed to clarify whether wear and TMJ degeneration progress independently or are linked indirectly through shared parafunctional load.

Author Contributions

Gizem Altundal: conceptualization, methodology, investigation, data curation, formal analysis, writing – original draft, writing – review and editing, project administration. **Ece Zorlu:** investigation, data curation. **Fatma Yüce:** investigation, methodology, writing – review and editing. **Ceyda Deniz Özdemir:** investigation, data curation. **Sibel Biren:** conceptualization, methodology, writing – review and editing, supervision.

Acknowledgements

The authors gratefully acknowledge the institutional support of the Department of Orthodontics, Faculty of Dentistry, Istanbul Kent University.

Funding

The authors have nothing to report.

Ethics Statement

This study was approved by the Istanbul Kent University Faculty of Dentistry Non-Interventional Clinical and Observational Research Ethics Committee (approval no. 2026/2–2, dated 28 January 2026). All procedures conformed to the principles of the Declaration of Helsinki.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The de-identified dataset supporting the findings of this study is available from the corresponding author upon reasonable request.

Peer Review

For transparency, the peer review documents associated with this article are available at https://doi.org/10.1111/joor.70297.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Figure S1:** (A) Mean wear score by surface (buccal, occlusal, palatal, cervical): wear was almost entirely confined to occlusal/incisal surfaces. (B) Mean wear score by tooth type: canines were the most affected, followed by incisors, premolars and molars. (C) Mean wear score by quadrant: mandibular quadrants showed modestly higher wear than maxillary quadrants; right–left asymmetry was negligible. Bars depict mean ± SEM ($n = 80$ patients). **Figure S2:** Distribution of TMJ joint sounds (none, click, crepitus) by joint (clinical examination; $n = 160$ joints). **Figure S3:** Tooth wear by age and functional occlusion (exploratory analyses; $n = 80$ patients). Left: total wear by age group, increasing with age (Spearman $\rho = 0.65$, $p < 0.001$). Age groups are shown for visualisation purposes only; associations with age were tested using continuous Spearman correlation analyses. Centre: total wear did not differ by working-side guidance scheme ($p = 0.063$). Right: total wear distribution according to balancing (non-working) side-contact status (associational; adjusted $p = 0.061$); this exploratory association is uncorrected for multiple comparisons and should not be interpreted causally. Boxes show median and interquartile range; whiskers extend to 1.5 × IQR; data points jittered. **Figure S4:** Univariate patient-level distributions of total wear by CBCT phenotype: bilateral osteophyte, bilateral definite osteoarthritis (Ahmad framework), and high bilateral erosion burden (≥ 2 joints with grade ≥ 2 erosion). Boxes show median and interquartile range; whiskers extend to 1.5 × IQR; individual data points jittered for visibility. Mann–Whitney *p* values are shown. These univariate distributions are the unadjusted counterpart of the patient-level models in Figure 4 and correspond to the values in Table S2. **Table S1:** Condyle–fossa joint-space measurements (mm) by site and side ($n = 80$ patients; 160 joints). **Table S2:** Univariate patient-level comparison of total wear by CBCT phenotype ($n = 80$ patients), with median wear in patients with versus without each feature and Mann–Whitney *p* values.