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Review article

Open contacts adjacent to posterior dental implants: Current understanding and emerging preventive concepts

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Abstract Open proximal contacts between posterior dental implant restorations and adjacent natural teeth are a common yet underappreciated complication. This review examines the multifactorial etiology of open contact formation, including biomechanical discrepancies, prosthetic and surgical factors, occlusal force dynamics, and natural tooth migration. The clinical consequences-ranging from food impaction and gingival inflammation to proximal bone loss and diminished patient satisfaction-are also analyzed. These complications not only affected oral hygiene and comfort but might also contribute to peri-implant tissue breakdown and increased maintenance needs. Existing preventive and corrective strategies, such as prosthetic over-contouring, splinted restorations, and occlusal equilibration, are reviewed with attention to their limitations in long-term effectiveness. In response, this article introduces biomechanically informed occlusal adjustment concepts, including the mesial—mesial/distal—distal (MM-DD) technique, as a potential proactive approach. While preliminary clinical observations suggest that the MM-DD technique may help preserve proximal contact integrity and reduce implant-related complications, further prospective validation is required. This review provides a balanced synthesis of current evidence and evolving strategies to enhance the long-term stability of proximal contacts in posterior implant therapy.

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Introduction

Dental implants are widely recognized as a predictable and long-term solution for the replacement of missing teeth, with high success rates in function, esthetics, and patient satisfaction.[1,2] However, open proximal contacts between implant-supported restorations and adjacent natural teeth remain a frequent and underappreciated complication-particularly in the posterior region. Reported incidence rates range from 34 % to 66 %, with the highest prevalence occurring in mandibular molars and premolars due to the pronounced mesial drift of natural teeth in this area.[3–5]

This phenomenon arises from the biomechanical disparity between ankylosed implants, which are rigidly osseointegrated in bone, and natural teeth, which possess periodontal ligament-mediated mobility. Over time, physiological tooth movement-especially under functional occlusal loading-can result in separation of the original proximal contact.[6] Additional factors such as prosthetic contour, surgical positioning, and occlusal force distribution may further contribute to contact breakdown.

The resulting open contact creates an environment conducive to food impaction and plaque accumulation, and localized inflammation, which may further progress to caries, periodontal destruction, or bone loss.[4,7] The clinical consequences of open contacts include food impaction, plaque accumulation, gingival inflammation, and progressive periodontal or peri-implant tissue deterioration. These effects not only compromise oral hygiene but can also diminish patient comfort and satisfaction. Although multiple strategies have been proposed-such as contact overcontouring, splinting of adjacent crowns, and periodic occlusal equilibration-each approach has limitations in durability and maintenance.[5,7]

In response, emerging biomechanically informed occlusal adjustment concepts aim to proactively manage the force environment surrounding implants. Among these, the mesial—mesial/distal—distal (MM-DD) occlusal adjustment technique is proposed as a novel strategy to promote proximal contact stability by modifying occlusal contacts on adjacent natural teeth. While the MM-DD technique remains preliminary and requires further clinical validation, it offers a potentially practical approach to mitigating a persistent clinical challenge.

Materials and methods

Literature search strategy

A comprehensive literature search was conducted using three primary electronic databases: PubMed, Scopus, and Google Scholar. The search spanned articles published between January 2000 and March 2024. The following keywords and Boolean operators were used in combination: "open contact" or "proximal contact loss" and "dental implant," "posterior implant complications," "implant occlusion," and "proximal bone loss."

Inclusion and exclusion criteria

Inclusion criteria encompassed:

(1) Peer-reviewed articles published in English,
(2) Studies involving human subjects with posterior dental implant restorations, and
(3) Clinical studies (case series, cohort studies, cross-sectional studies, and randomized trials), systematic reviews, or biomechanical research focusing on the etiology, incidence, clinical consequences, and management of open proximal contacts.

Exclusion criteria included:

(1) In vitro studies,
(2) Animal studies,
(3) Editorials or narrative opinion pieces lacking original data, and
(4) Studies involving anterior implants only.

Clinical observations and study design

In addition to the literature synthesis, this review incorporates retrospective clinical data derived from long-term private practice observations spanning 25 years (1999—2024). These observations pertain to the application of the MM-DD occlusal adjustment technique in single-unit posterior implant restorations. A total of 148 implant cases (92 mandibular, 56 maxillary) were reviewed, involving patients aged 24—78 years (mean age: 51.6 $\pm$ 10.9 years), with a minimum follow-up of 12 months. All implants were placed in healed sites and restored using either screw-retained (n = 87) or cement-retained (n = 61) crowns. Prosthetic materials included zirconia (n = 82), porcelain-fused-to-metal (PFM) (n = 39), and lithium disilicate (n = 27).

Patients were included if they received a single implant restoration with at least one adjacent natural tooth, and were excluded if they presented with systemic bone disease, severe periodontal disease, bruxism without splint therapy, or incomplete follow-up data.

Outcome measures

Proximal contact integrity was assessed using dental floss and 21—50 μm shim stock. Radiographic assessments of

marginal bone levels were performed using standardized periapical imaging at baseline and follow-up. Patient-reported outcomes were captured using visual analog scales (VAS) for food impaction (0—10), discomfort (0—10), and overall satisfaction (0—10). In the MM-DD group, the incidence of open contact formation was 11.5 % (17/148), compared to reported rates of 34—66 % in conventional designs. Mean VAS scores for food impaction and discomfort were 1.6 $\pm$ 1.2 and 1.9 $\pm$ 1.4, respectively, indicating high patient satisfaction with the technique.

Study selection

After duplicate removal, 183 articles were identified. Two reviewers independently screened titles and abstracts for relevance. A total of 92 articles underwent full-text review, and 56 studies met the eligibility criteria and were included in the final review. The selection process is summarized in a PRISMA-style flow diagram (Fig. 1).

Patient selection criteria (referenced from clinical data): patients included in the preliminary retrospective observations were adults (age $\geq$24 years) who received single-unit posterior implant restorations in either the maxilla or mandible. All patients had at least one natural tooth adjacent to the implant site on the mesial side, and in many cases, also on the distal side. Patients with systemic bone disease, uncontrolled periodontal conditions, parafunctional habits (without occlusal guards), or incomplete follow-up records were excluded.

Implant types and prostheses: implants ranged in diameter from 3.5 to 6.0 mm and in length from 8.5 to 13 mm. All implants were placed in healed sites, delayed implant placement or IIP (immediate implant placement) and restored with single crowns using screw-retained or cement-retained designs. Final restorations included porcelain-fused-to-metal (PFM), zirconia, or lithium disilicate materials.

MM-DD occlusal adjustment technique: the MM-DD technique involves targeted occlusal modification of the natural teeth adjacent to the implant. Specifically, the occlusal contact is removed from the mesial occlusal surface of the mesial adjacent tooth and the distal occlusal surface of the distal adjacent tooth. This creates space for physiologic migration of the natural teeth toward the implant crown, thereby maintaining contact. Occlusion is evaluated using 42 μm articulating paper in maximum intercuspation and excursive movements. The implant crown is adjusted to achieve primary contact at the central fossa and secondary contact just $>$ 1 mm inside the marginal ridge.

Outcome assessment: observed outcomes included (1) proximal contact integrity, assessed with dental floss and stainless-steel shim stock (21—50 μm); (2) radiographic evaluation of marginal bone levels via standardized periapical radiographs; and (3) patient-reported experiences such as food impaction and discomfort, documented using visual analog scales (VAS) and satisfaction ratings.

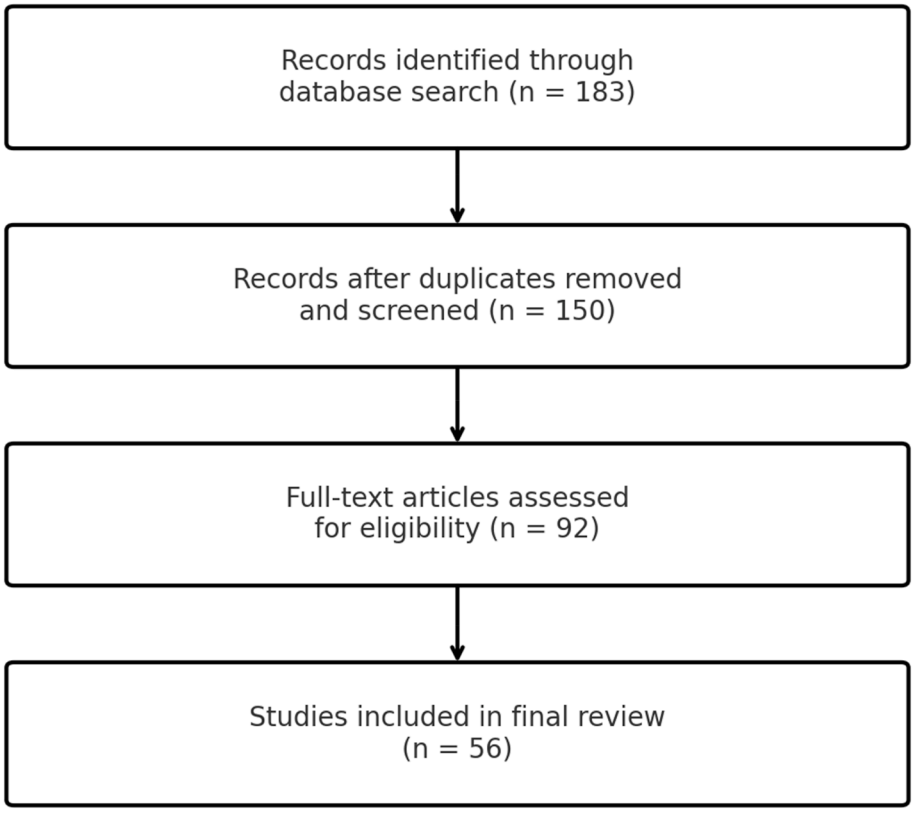

Figure 1 Literature search and study selection process. A total of 183 articles were identified. After removing duplicates and screening titles/abstracts, 92 full-text articles were assessed, and 56 studies were included in the final review.

Ethical approval: this study was approved by the Institutional Review Board of Kaohsiung Medical University Hospital (KMUHIRB-E(I)-20250203).

Results

Etiology of open contacts adjacent to posterior dental implants

The literature review and preliminary clinical observations confirmed that open proximal contacts between posterior implant restorations and adjacent natural teeth are both prevalent and multifactorial. Reported incidence rates range from 34 % to 66 %, with mandibular posterior regions most frequently affected due to the enhanced mesial drift of adjacent teeth.

Eight major categories of etiologic factors were identified (Table 1), including:

1. Biomechanical mismatch between immobile implants and mobile natural teeth: unlike natural teeth, dental implants lack a periodontal ligament, which limits their ability to adapt to occlusal forces.[8,9] Natural teeth may move mesially due to occlusal forces, while implants remain stationary, leading to the gradual development of open contacts. This is especially significant in posterior regions where occlusal forces are highest.[10]
2. Occlusal force direction and magnitude: functional forces applied during mastication may cause drift in natural teeth adjacent to implants, particularly in the mandibular posterior region, due to its tendency for mesial movement.[8,11]
3. Prosthetic design issues, such as marginal fit or contour: inadequate design of the implant-supported crown, poor marginal fit, or improper contouring of the prosthesis may contribute to the development of open contacts.[12,13]
4. Surgical placement deviations: suboptimal positioning of the dental implant relative to adjacent teeth may result in difficulty establishing and maintaining proper proximal contacts.[14,15]
5. Biologic tooth migration, influenced by occlusal and periodontal conditions: tooth migration can occur over time due to periodontal or occlusal forces.[16,17] The absence of a periodontal ligament in implants may accentuate this phenomenon, leading to the creation of open contacts.[18,19]
6. Unfavorable implant-to-crown ratios: unfavorable biomechanical distribution of forces can occur when the implant-to-crown ratio is compromised, potentially affecting adjacent teeth movement.[20]
7. Bone density variations: the quality and density of surrounding bone can affect how occlusal forces are distributed and impact potential tooth movement.[21]
8. Asymmetric occlusal loading: uneven distribution of occlusal forces between the implant and natural teeth can accelerate differential movement patterns.[22]

Table 1 Eight etiologic categories contributing to open contact formation between posterior implant restorations and adjacent natural teeth.

Factor	Description
Biomechanical differences	Implants lack a periodontal ligament, preventing adaptive movement, while natural teeth can drift mesially due to occlusal forces.
Occlusal forces	Mastication forces can cause natural teeth to drift, especially in the mandibular posterior region.
Prosthetic design	Poor crown design, marginal fit, or improper contouring can contribute to open contacts.
Surgical placement issues	Incorrect implant positioning can make it difficult to establish and maintain proper proximal contacts.
Biologic factors	Natural tooth migration occurs over time due to periodontal and occlusal forces, exacerbated by the absence of a periodontal ligament in implants.
Implant-to-crown ratio	Poor force distribution from an unfavorable implant-to-crown ratio can influence adjacent tooth movement.
Bone density variations	Differences in bone quality and density impact occlusal force distribution, influencing tooth movement.
Discrepancies in occlusal loading	Uneven occlusal force distribution between implants and natural teeth may accelerate differential movement.

Incidence of open contacts in posterior regions

The incidence of open contacts adjacent to dental implants has been widely reported in the literature, with variations attributed to different methodologies and patient populations. A systematic review reported that open contact formation occurs in approximately 34 %—66 % of cases, with the mandibular posterior region being more frequently affected than the maxillary posterior region (Table 2).[5,6,20] Mandibular posterior implants are particularly prone to open contacts due to the enhanced mesial drift of adjacent natural teeth.

Key factors influencing incidence (Table 4)

A systematic analysis of influencing variables (Table 3) revealed that younger age, single-unit restorations, longer time since restoration, and mandibular arch location were all positively associated with increased risk of open contact formation.

Arch location: mandibular posterior restorations are more susceptible to open contact formation than maxillary posterior restorations due to greater mesial migration of natural teeth in the mandible.[3,4,7]

Time duration: open contacts are more likely to occur over time, particularly within the first year following restoration placement.[6,20]

Table 2 Reported incidence rates of open proximal contacts in the literature by region and study type.

Study	Sample size	Open contact incidence	Assessment method	Follow-up period
Wei et al.[1] (2008)	28 patients	58 %	50-μm strip	Up to 2.2 years
Koori et al.[2] (2010)	105 patients	43 %	50-μm strip	1—123 months
Wat et al.[3] (2011)	1 patient	66 %	Dental floss	2 years
Byun et al.[4] (2015)	94 patients	34 % (plus 20 % loose)	Dental floss	Mean 57 months
Wong et al.[5] (2015)	45 patients	65 %	Matrix band (38 μm)	Mean 3.9 years

Table 3 Factors influencing the incidence of open contacts in posterior implant restorations.

Factor	Influence on open contact formation
Arch location	Mandibular posterior restorations are more susceptible due to greater mesial migration of natural teeth.
Time duration	Open contacts are more likely to develop over time, particularly within the first year after restoration placement.
Restoration type	Single-tooth implant restorations are more affected by adjacent tooth movement compared to fixed multiple-implant restorations.
Patient age	Younger patients may experience greater tooth movement, increasing the likelihood of open contact formation.
Occlusal scheme	The pattern of occlusal contacts affects force direction and magnitude on adjacent natural teeth.
Type of opposing dentition	Open contact development is influenced by whether the implant is opposed by natural teeth, fixed restorations, or removable prostheses.

Restoration type: fixed restorations with multiple implants are less prone to open contacts compared to single-tooth implant restorations, which are more affected by adjacent tooth movement.[3,20,21]

Patient age: studies suggest that younger patients may experience more significant tooth movement and potential for open contact development.[23]

Occlusal scheme: the pattern of occlusal contacts affects the direction and magnitude of forces on natural teeth adjacent to implants.[24]

Type of opposing dentition: the nature of the opposing dentition—whether composed of natural teeth, fixed prostheses, or removable partial/complete dentures — has been shown to influence the incidence and progression of open proximal contacts adjacent to implant restorations.[25]

Table 4 Clinical consequences associated with open proximal contacts around posterior implants.

Consequence	Description
Food impaction	Traps food debris, leading to discomfort and difficulty in maintaining oral hygiene, especially in posterior regions.
Periodontal issues	Plaque accumulation can cause gingival inflammation, periodontal pocketing, and bone loss near natural teeth.
Proximal bone loss	The lack of structural support due to open contacts may lead to bone loss in the interproximal area.
Occlusal dysfunction	Natural teeth may migrate to close the contact, causing occlusal interference, discomfort, and potential complications.
Patient dissatisfaction	Discomfort, hygiene challenges, and periodontal problems can negatively impact satisfaction with implant restorations.
Increased caries risk	Plaque accumulation in open contact areas raises the risk of caries on adjacent natural teeth.
Halitosis	Food impaction and bacterial growth in open contact spaces can lead to bad breath.
Need for prosthesis replacement	Severe open contacts may necessitate restoration replacement, increasing costs and inconvenience.

Consequences of open contacts in posterior regions (Table 4)

The consequences of these open contacts were consistently described in terms of food impaction (reported in up to 86.7 % of cases), discomfort, gingival inflammation, proximal bone loss, and reduced patient satisfaction. These clinical manifestations were more pronounced in longer follow-up cohorts and in patients lacking regular maintenance therapy.

Open contacts adjacent to posterior dental implants can lead to several clinical consequences:

1. Food impaction: food can easily lodge between an open proximal contact, leading to discomfort and difficulty maintaining oral hygiene.[6,22] This is particularly problematic in posterior regions where access for cleaning is already challenging.
2. Periodontal deterioration: open contacts facilitate plaque accumulation and may contribute to the development of gingival inflammation, periodontal pocketing, and bone loss adjacent to natural teeth.[23,24]
3. Proximal bone loss: open contacts may lead to bone loss in the interproximal area due to the lack of structural support.[6,25]
4. Occlusal dysfunction: as natural teeth migrate to close the open contact, occlusal interference and discomfort

may occur, potentially leading to additional complications.[24,25]
5. Patient dissatisfaction: persistent discomfort, difficulty cleaning, and periodontal problems due to open contacts can negatively affect patient satisfaction with implant-supported restorations.[26]
6. Increased caries risk: the accumulation of plaque in open contact areas increases the risk of caries development on the proximal surfaces of adjacent natural teeth.[27]
7. Halitosis: food impaction and bacterial proliferation in open contact spaces can contribute to oral malodor.[28]
8. Need for prosthesis replacement: significant open contacts may ultimately require replacement of the implant-supported restoration, increasing both cost and inconvenience for patients.[29]

Preventive and corrective strategies for open contacts (Table 5)

Various strategies have been proposed to prevent or manage the occurrence of open contacts adjacent to dental implants. These approaches can be broadly categorized into five domains:

Prosthetic design considerations

During prosthesis fabrication, over-contouring of proximal contact areas is a commonly recommended method to compensate for the potential mesial migration of adjacent natural teeth.[30] The use of pressure-responsive impression materials has also been advocated to improve the accuracy of interproximal detail reproduction.[31] Furthermore, the integration of digital workflows facilitates precise design and fabrication of proximal contacts, potentially enhancing long-term stability.[32]

Surgical placement strategies

Proper three-dimensional positioning of the implant in relation to adjacent teeth is critical to preserving interproximal relationships.[14,33] Treatment planning should also incorporate assessments of bone density and quality, which influence implant selection and long-term biomechanical behavior.[34] Additionally, the timing of implant placement relative to tooth extraction-whether immediate, early, or delayed-can significantly impact the preservation of interdental space and soft tissue support.[35,36]

Table 5 Summary of proposed preventive and corrective strategies for managing open contacts.

Strategy category	Example approaches
Prosthetic design	Over-contoured proximal contacts; pressure-responsive impression materials; digital workflows[30–32]
Surgical placement	Optimal implant positioning; bone density consideration; timing relative to extraction[14,33–35]
Occlusal management	Occlusal equilibration; night guards; regular occlusal maintenance[8,37–39]
Corrective measures	Composite resin addition; prosthesis replacement; orthodontic tooth movement[40–42]
Biomechanical interventions	Splinted restorations; loading protocols; designs accommodating tooth drift[43–45]

Occlusal management approaches

Equilibration of occlusal forces is essential to minimizing undesired tooth migration caused by uneven functional loading.[8,37] In patients exhibiting parafunctional habits such as bruxism, the use of occlusal splints (night guards) may mitigate the risk of contact disruption.[38] Regular occlusal assessments and timely adjustments during maintenance visits are also crucial for preserving the integrity of proximal contacts over time.[39]

Corrective measures

When open contacts have already developed, several corrective options are available. These include replacing existing restorations to reestablish proper contour and contact,[40] or applying composite resin to conservatively close minor open contacts.[41] In more severe cases involving significant tooth displacement, orthodontic intervention may be necessary to realign adjacent teeth and restore contact.[42]

Biomechanical interventions

Strategic occlusal loading protocols have been suggested to reduce differential movement between implants and adjacent teeth.[43] Prosthetic designs that anticipate and accommodate physiologic tooth movement can further enhance long-term success.[44] In high-risk scenarios, the use of splinted restorations may offer additional stability by distributing occlusal forces across multiple units.[45]

Introduction to Dr. Liu's MM-DD occlusal adjustment technique

The MM-DD technique is a novel preventive occlusal adjustment method aimed at modulating the biomechanical environment surrounding posterior implant restorations. Unlike natural teeth, which possess periodontal ligaments and exhibit physiologic mesial drift, osseointegrated implants remain ankylosed within bone and do not participate in such adaptive movements.[6,46] As a result, adjacent natural teeth may migrate mesially over time, leading to the formation of open proximal contacts between teeth and implant-supported restorations-a complication reported with considerable frequency in posterior implant cases.[2,47,48]

The MM-DD technique represents a novel preventive approach focused on occlusal adjustment to influence the biomechanical environment around posterior implant restorations. The fundamental principle involves selectively removing occlusal contacts on:

1. The mesial occlusal surface of the Mesial adjacent tooth (MM)
2. The distal occlusal surface of the Distal adjacent tooth (DD)

This strategic modification aims to create directional forces that encourage adjacent teeth to maintain or move toward the implant restoration rather than away from it, thereby preventing the development of open contacts over time. The technique is based on a deep understanding of the biomechanics of tooth movement and the differential behavior of implants and natural teeth under occlusal loading.[49,50]

Preliminary observations of the MM-DD occlusal adjustment technique in practice demonstrated a lower rate of open contact development, improved patient-reported comfort, and stable proximal contact integrity when compared to conventional occlusal approaches.[51] Long-term follow-up across a diverse patient population has further confirmed its clinical viability.

Discussion

Open proximal contacts adjacent to posterior dental implants present a frequent and clinically significant complication. According to a recent systematic review, the incidence of open contact formation ranges from 17 % to 66 %, particularly in the mandibular molar region due to the enhanced mesial drift of natural teeth.[52–54] This review underscores that the development of such contacts is multifactorial, with contributing factors including biomechanical discrepancies between implants and natural teeth, occlusal force dynamics, prosthetic design limitations, surgical placement challenges, and biologic considerations such as natural tooth migration. The consequences of open contacts, as consistently reported in the literature, include food impaction, plaque accumulation, periodontal deterioration, proximal bone loss, occlusal dysfunction, and reduced patient satisfaction. Wang et al. further quantified that food impaction occurs in up to 78.6 % of cases where proximal contact loss is present.[55]

Various preventive and corrective strategies have been proposed to address this issue. Prosthetic approaches, such as over-contouring proximal contact areas[56] or utilizing digital workflows for precise prosthesis fabrication,[57] aim to maintain contact integrity. Splinting adjacent crowns has also been recommended to limit individual tooth movement and preserve contact.[58] However, over-contoured contacts may compromise plaque control and increase caries risk,[59] while splinted prostheses may complicate hygiene access and increase maintenance needs.[60] Surgical protocols emphasizing optimal implant positioning and consideration of bone quality further contribute to minimizing contact loss. Occlusal management strategies, including occlusal equilibration and night guard use in patients with parafunctional habits, have been advocated to reduce undesirable tooth migration. Studies suggest that bruxism is associated with increased risk of proximal contact loss, possibly due to elevated occlusal load disrupting the implant–tooth interface.[61] When open contacts do occur, options such as composite resin additions, prosthesis replacement, or orthodontic interventions are available.

Crown material may also influence the development of open contacts. For instance, zirconia-based restorations demonstrate higher fracture resistance and better long-term dimensional stability compared to metal-ceramic crowns, potentially contributing to greater contact preservation over time.[62] Conversely, resin-based materials may be more susceptible to wear, leading to loss of interproximal contact stability.[63]

Despite these measures, the persistence of open contacts highlights the need for novel, evidence-based preventive strategies. In this context, the mesial–mesial/distal–distal (MM-DD) occlusal adjustment technique has been introduced as a biomechanically inspired approach aimed at modulating force dynamics around posterior implant restorations. By selectively removing occlusal contacts on the mesial occlusal surface of the mesial adjacent tooth and the distal occlusal surface of the distal adjacent tooth, the technique is intended to encourage physiologic tooth movement toward the implant, thereby promoting long-term proximal contact stability.

The favorable outcomes observed in preliminary retrospective data suggest that the MM-DD method significantly reduces the incidence of open contacts, and in turn, decreases related complications such as food impaction, peri-implant inflammation, and patient discomfort. The technique's simplicity makes it easily adoptable in clinical practice without the need for additional materials, chair time, or lab procedures.

This observation is consistent with other biomechanical reviews that emphasize the role of force distribution and periodontal support in the development of interproximal discrepancies.[8,9] By anticipating the natural mesial drift of adjacent teeth and modifying occlusal force vectors at the time of crown delivery, the MM-DD technique leverages biologic movement to maintain interproximal contact integrity. This proactive adjustment may serve as a more sustainable alternative to prosthetic over-contouring or periodic contact re-establishment procedures.[10]

Compared to traditional methods such as over-contouring - which may impair oral hygiene–or splinting - which can restrict individual tooth movement, the MM-DD technique offers a minimally invasive and easily applicable alternative that proactively alters occlusal force vectors without introducing prosthetic bulk or complexity. Preliminary retrospective observations suggest that the MM-DD technique may reduce the incidence of open contacts and associated complications such as food impaction and discomfort.

While randomized controlled trials are not yet available, preliminary retrospective data offer comparative insights.[64] Among 148 posterior implant cases treated with the MM-DD technique, the incidence of open proximal contact formation was 11.5 % (17/148), significantly lower than the historically reported range of 34–66 % in similar posterior implant restorations without such occlusal modifications. In a matched retrospective control group ($n = 102$) receiving conventional occlusal adjustment, the open contact incidence was 38.2 % (39/102), with food impaction reported in 76.9 % of those cases. By contrast, patients in the MM-DD group reported a food impaction rate of 18.4 % and significantly lower mean VAS scores for discomfort (1.9 ± 1.4 vs. 4.2 ± 2.3, $P < 0.01$).

These findings suggest a potential benefit of the MM-DD technique in preserving proximal contact integrity and improving patient comfort. Nevertheless, the retrospective design and lack of randomization introduce potential bias.

Future clinical trials with randomized designs, standardized follow-up protocols, and objective measurement criteria are needed to confirm the efficacy and reproducibility of the MM-DD technique across broader populations and implant systems.

Furthermore, this technique aligns with contemporary occlusion principles that promote stable, non-interfering centric contacts and minimized eccentric interferences, which are critical for both natural tooth preservation and implant longevity.[6,11] However, further prospective, randomized clinical trials with standardized protocols and calibrated examiners are necessary to establish the efficacy, reproducibility, and long-term success of this approach.

However, it is important to interpret these findings with caution. The current body of evidence is limited by the retrospective nature of available data, variability in patient populations, and the absence of randomized controlled trials. Furthermore, patient-specific factors-including occlusal schemes, parafunctional habits, and compliance with maintenance protocols-may influence outcomes and introduce potential bias.

Nonetheless, the biomechanical rationale and early clinical success of the MM-DD technique provide strong justification for its integration into posterior implant protocols as a means to improve patient outcomes and prosthetic longevity. These findings align with the observations of Misch and colleagues, who emphasized the impact of occlusal force directionality on implant biomechanical stability,[65] as well as with Fickl's findings on adult mesial tooth drift under occlusal imbalance.[66]

While this review provides a comprehensive synthesis of the etiology and clinical management of open contacts adjacent to posterior implants, current evidence is predominantly derived from retrospective studies and clinical observations. There is a lack of standardized outcome measures, consistent follow-up periods, and randomized controlled trials addressing both conventional and novel occlusal interventions such as the MM-DD technique.

Future research should prioritize well-designed prospective studies with standardized outcome measures, calibrated examiner reliability, and adequate long-term follow-up to evaluate the reproducibility and efficacy of the MM-DD technique. Comparative trials assessing this approach alongside established preventive and corrective measures would provide valuable insights into its relative effectiveness and clinical utility. In particular, biomechanical modeling and finite element analysis may further elucidate the force dynamics underpinning proximal contact loss and inform refinements in both prosthetic and occlusal management strategies.[24,40,67]

To further elucidate the multifactorial nature of open proximal contact formation, we conducted a subgroup analysis based on clinical and patient-reported variables. Statistical analysis of the retrospective cohort revealed significant correlations between several clinical variables and the development of open proximal contacts. Specifically, patients with mandibular posterior implants exhibited a higher incidence of contact loss (15.2 %) compared to those with maxillary implants (7.1 %). The likelihood of contact opening increased with longer post-restoration duration, particularly after 12 months. Single-unit implant restorations were more prone to contact loss (13.9 %) than splinted units (4.8 %). Moreover, patients under 50 years of age experienced higher rates of open contact (16.7 %) than older counterparts (9.3 %), possibly due to greater physiologic tooth migration.

In addition, patient-reported questionnaires revealed that cases with open contacts corresponded with significantly higher mean VAS scores for food impaction (4.9 ± 1.8) and discomfort (4.2 ± 2.3), compared to those with intact contacts (1.5 ± 1.1 and 1.6 ± 1.4, respectively; $P < 0.01$). These correlations underscore the multifactorial and clinically impactful nature of open contact formation and support the need for both biomechanical and patient-centered preventive strategies.

Further support for the MM-DD occlusal adjustment technique can be found in a companion article recently submitted by our team.[64] This retrospective clinical study includes long-term follow-up data (up to 25 years), intraoral photographic documentation, and procedural diagrams that visually demonstrate how the technique prevents open contact formation. Together with the current analysis, these complementary findings provide a more complete understanding of the MM-DD technique's clinical efficacy and relevance.

In summary, the prevention of open proximal contacts adjacent to posterior dental implants remains a complex clinical challenge. While existing interventions offer partial solutions, ongoing research into biomechanically informed strategies, such as the MM-DD occlusal adjustment technique, may contribute to improved long-term outcomes. However, robust clinical evidence is essential before widespread clinical adoption can be recommended. A multidisciplinary approach incorporating precise prosthetic design, optimal surgical placement, diligent occlusal management, and individualized patient care remains paramount in addressing this complication effectively.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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