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In this Issue:

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- Non-Surgical Management of an Impacted Canine in a Crowded Arch: A Case Report
- Advances in Orthodontic Anchorage Systems: A Narrative Review (2000–2024)
- Comparative Evaluation of the Predictive Accuracy of Moyer's Analysis, Tanaka Johnston Analysis and Melgaco's Method in Class I Malocclusion Patients at a Tertiary Care Centre in South Kerala - An In Vitro Study

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Editorial

Dr. Rob Pasch
Editor

Having completed the first ever EXPO for the IAO where the traditional summer meeting was merged with a sectional meeting and named EXPO 2025, I can report that it was a great success.

Many members were able to share four wonderful speakers. Dr. Lee, Dr. Adams, Dr. Kulkarni, and Dr. Lowri shared many useful procedures supported by research and experience for the benefit of all. Instagram has many snippets of the day, so please go there and see what it was like.

The networking amongst the members allowed connections and was enjoyed by all. It also was the first meeting that allowed extended CE credits – 8 for being there and 8 for online completion of the videos – for a total of 16. All of this for $ 299 CAD – a bargain to be sure.

Ontario has now passed the baton to the New England section for next year's EXPO and we are all excited to find out what is in store for us there.

But first it is ORLANDO in April 2026. This promises to be a large gathering – if Mickey can be believed. Many members will bring their families and extend their stay either before or after the meeting, for it is a family destination after all. I for one am excited to learn and be involved in the process.

So, lots of exciting things in the future for our members. Enjoy this journal and the knowledgeable articles within; the authors have worked hard to present these to you for the benefit of us all.

Orthodontics has so much more to offer than just straight teeth. It starts early with orthopaedics and growth guidance that we as general practitioners can orchestrate. The growth spurts can be utilized by behavioural modification, ensuring health and airway patency, and then alignment of the dentition if needed.

The IAO journal has published many articles over the years, and the archive can be searched by members to glean the education required for clinical treatment of your patients. IAO members can also reach out to each other and discuss cases. We are a big family with help for all.

So please, if you have a clinical article that you would like to share, go on the website, follow the author's guidelines, and submit your article. Once received, it will go to two reviewers who will read and scrutinize the submission. Once passed, your article will be published in the next edition of your journal. So don't be shy and share.

I am always available for comments, positive or negative, and suggestions regarding the journal. I thank the people who went before me, our article reviewers, and Ms. Allison Hester, our managing editor, for her invaluable role in getting the journal completed and looking so good.

I remain
Respectfully,
Dr. Rob Pasch DDS MSc IBO General Practitioner.
Fall, 2025

Cytotoxicity Of Orthodontic Bands With and Without Silver Solder Joints in Different Cell Lineages – A Systematic Review

by Dr. Priyanka Badu, Dr. Harish Atram, Dr. Santos Chavan, Dr. Wasundhara A. Bhad, Dr. Jyoti Manchanda, Dr. Priyanka Tarde, and Dr. Anjali Kalekar

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Abstract:

Introduction: Biocompatibility is crucial in orthodontics to ensure biomaterials interact favourably with the oral mucosa. Stainless steel commonly used for orthodontic bands, is considered biocompatible, but concerns arise with silver solder, which may release cytotoxic ions. Corrosion is a primary worry in assessing metallic materials, influencing host responses and potentially causing hypersensitivity. This review seeks to investigate the possible cytotoxic and genotoxic effects of silver soldered bands in orthodontics.

Materials and Methods: A systematic literature search was conducted using electronic databases including PubMed, Central of the Cochrane Library and Google Scholar databases. In vitro studies, in vivo studies, Randomized controlled trials (RCTs) and non-randomized controlled clinical trials (RCTs) comparing cytotoxicity and genotoxicity of silver soldered bands with non-soldered bands were included in the study. The quality of the in vitro studies was assessed using the Quality Assessment Tool For In Vitro Studies (QUIN Tool).

Results: Four in vitro studies were included in this systematic review. One in vitro study had a low risk of bias and 3 in vitro studies had a medium risk of bias.

Conclusion: Studies indicate higher cytotoxicity and genotoxicity with silver-soldered bands (SSB) compared to non-soldered bands (NSB) and controls. Laser soldering presents an intriguing alternative, despite its cost and limited research in orthodontics. Given the prevalent use of SSB in orthodontic appliances, the scarcity of studies on bands cytotoxicity and the newness of laser soldering, further research on various silver solder brands and alternative metal joining methods is crucial for a comprehensive understanding.

Keywords: Cytotoxicity, Silver soldered bands, cell lineages

Conflict of Interest: None

Introduction

Biocompatibility is an important consideration in orthodontics due to the prolonged interaction of the orthodontic material with the oral mucosa and the potential for material corrosion.[1] Corrosion is the main concern when biocompatibility of orthodontic metallic materials is evaluated. The release of several metallic ions may lead to hypersensitivity and allergic reactions, either locally as well as systemically.[2] It is crucial to have knowledge about the composition, allergic qualities, and toxic effects of dental materials before selecting one.[3]

Stainless steel is present in wires, brackets, and bands, and silver solder is usually the metal of choice to connect support. Several auxiliary orthodontic appliances, such as lingual arches and maxillary expanders are made of stainless steel and contain silver soldered joints; these appliances may inhabit the oral cavity of a patient for months or even years.[4] Because of its ease of use, affordability and demonstrated performance, silver solder is the alloy of choice. However, silver solder alloy contains silver, copper, and zinc. These ions present a major tendency to be released in the oral cavity and they may have cytotoxic effects, resulting in a decrease of cell viability.[5] The oral environment with saliva fluctuations of pH values, temperature, and mechanical forces, leads to stresses and corrosion. When compared with stainless steel, silver solder shows greater corrosion, which is the possible cause of cytotoxic effects.[6]

In-vitro assays provide relevant data when assessing the biocompatibility of dental materials and it is crucial to understand the variables affecting their outcomes. The chosen cell line, the cell density and the passage number are critical variables for in-vitro studies. Even under identical culture conditions, different cell lines can show different levels of cytotoxicity.[7]

*This article has been peer reviewed

Despite numerous studies exploring the cytotoxic profile of silver soldered bands in orthodontics, no systematic review has been done. To our knowledge, there is no systematic review published to date to evaluate the cytotoxic, cytostatic and genotoxic effects of stainless-steel bands with or without silver soldered joints on different cell lineages. The aim of this systematic review is to investigate the possible induction of cytotoxicity and genotoxicity by orthodontic bands with or without silver solder.

Materials and methods

Protocol and Registration

The present systematic review was registered at the National Institute for Health Research Prospero International Prospective Register of Systematic Reviews (Registration number: CRD42023473613). The research protocol is designed according to the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) guidelines 2020.

Information Sources, Search Strategy, and Selection Process

A comprehensive search was conducted on electronic databases, additionally by manual search, to spot all relevant studies associated with the cytotoxicity of silver soldered bands on different cell lineages. Three electronic databases: Pubmed, Google Scholar, and Cochrane Library were searched from January 2000 to December 2023. Unpublished literature was searched on ClinicalTrials.gov. In addition, reference lists of relevant studies, meta-analyses, systematic reviews and other review articles were screened for potential inclusion.

Search Strategy

The search strategy was developed using relevant Medical Subject Headings (MeSH) terms, keywords and Boolean operators “AND” and “OR” combination. The following search terms and their combinations were used in the search strategy: “Cytotoxic effect,” “Cytotoxicity,” “Cytotoxic Outcome,” “Metal ion toxicity,” “Genotoxicity,” “Mutagenicity,” “Orthodontics,” “Orthodontic bands Silver solder material,” “Stainless steel bands,” “Soldering,” “Cell viability,” “Survival tests,” “Human periodontal ligament fibroblast cells,” “cell lineages” with Boolean characters “AND” and “OR”

Domain	Inclusion	Exclusion
Participants	Healthy humans and animals	
Intervention	Orthodontic treatment with silver soldered bands	
Comparison	Orthodontic treatment without silver soldered bands	
Outcome	<u>Primary outcome</u>: Main Outcome – cytotoxicity in different cell lineages	
Study design	In vitro	Technique articles, case reports, opinion articles and reviews

Figure 1: Eligibility Criteria

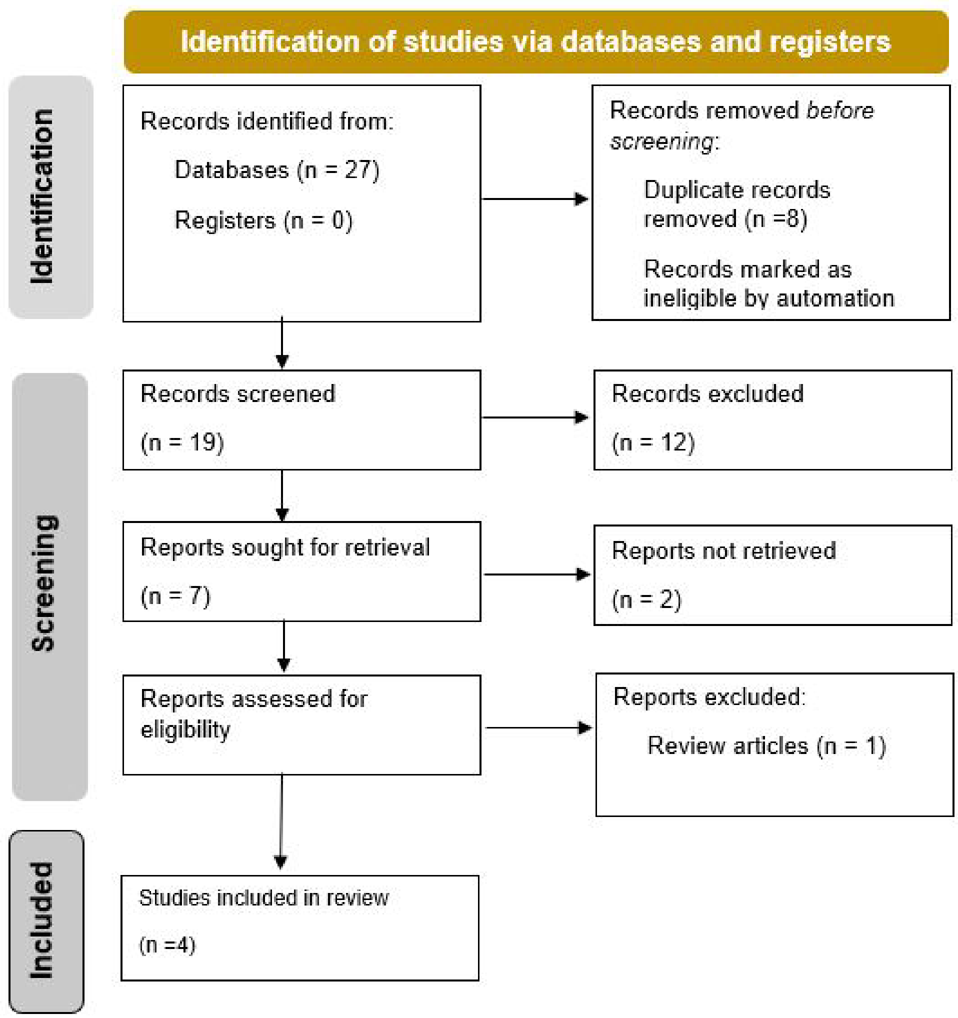

Figure 2: Prisma flow diagram of study selection

Table 1: Overview of the Studies: General Characteristics and Grouping

Sr no.	Study ID	Study Design	Description of Participants and Grouping	Comparator Group
1.	Tatiana Siqueira Gonçalves et al (2014)	In Vitro	N=1 3 groups SSB = silver soldered bands LSB = Laser soldered bands WSB=Bands without any kind of solder	LSB = Laser Soldered Bands (Nd: YAG)
2.	T.S. Gonçalves et al. (2014)	In Vitro	N = 12 3 groups Control Group NSB = Non soldered bands SSB= Silver soldered bands	Control Group
3.	Leticia et al (2017)	In Vitro	N = 10 4 groups Negative control = cell cultured to culture medium alone Positive control Group 1 = stainless steel bands Group 2 = Stainless steel bands with silver solder	Pure Copper Strips
4.	Ghada Ninani et al (2021)	In Vitro	N = 10 3 groups B= cells exposed to band only BS= cells exposed to band fused with summit silver solder BL=bands fused with Leone silver solder Bs+Trolox BS+ZVAD-fmk	BS and BL

combination. The search strategy was adapted to the specific syntax and subject headings of each electronic database.

Selection Process

The selection process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Two reviewers independently screened the titles and abstracts of all potentially relevant articles identified in the search to determine their eligibility for inclusion. Full-text articles of potentially eligible studies were assessed independently by two reviewers for inclusion in the systematic review. Any discrepancies between the reviewers were resolved through discussion or consultation with a third reviewer.

Data Collection Process and Data Items

Once the relevant studies were identified, data was extracted from each study using a pre-designed data extraction form. The data items extracted included the name of author, year of publication, study design, description of Participants and Grouping, comparator Group, cell culture, experimental condition, cell lineage detected, method of analyzing, observation- cell culture results, main outcome – Cytotoxicity of Silver soldered bands, additional outcome.

Risk of Bias Assessment

Risk of bias assessment for in vitro studies done in accordance with the Quality Assessment Tool For In Vitro Studies (QUIN Tool), the following twelve different criteria were considered: clearly stated aims/objectives, detailed explanation of sample size calculation, detailed explanation of sampling technique, details of comparison group, detailed explanation of methodology, operator details, randomization, method of measurement of outcome, outcome assessor details, blinding, statistical analysis, presentation of results. Each criterion can be adequately specified (score = 2), not adequately specified (score = 1), not specified (score = 0) or not applicable (NA). Then, the twelve scores are added to obtain the final score for each study. In the end, the result obtained is used to grade every single study as high, medium, or low risk (>70% = low risk of bias,50% to 70% = medium risk of bias, and <50% = high risk of bias) by using the following formula: Final score = (Total score × 100)/(2 × number of criteria applicable).

Synthesis of Results

Study Selection

Electronic screening of PubMed and Google Scholar identified 27 articles. After adjusting the duplicates, 19 articles were scrutinized for inclusion in the study. The majority of them were excluded as they did not have relevant titles and abstracts, leaving 7 articles. After excluding 1 review article and 2 articles for which full-text articles were not accessible, just 4 original articles remained which were included in this systematic review. The PRISMA flowchart of the electronic database search is represented in Figure 2.

Study Characteristics

Participant selection

Four In Vitro studies were included. In all the studies cytotoxicity of silver soldered bands on cell lineages compared to the control group was studied. General characteristics and grouping are described in Table I.

A description of the cell culture and experimental condition, cell lineage detected, and method of analysis is enlisted in Table 2. Table 3 shows the main and additional outcomes obtained by each study.

RoB with Studies

The risk of bias assessment for all the studies is summarized in Figure 2. On overall assessment, one in vitro study had low risk of bias and 3 studies had medium risk of bias.

Table 2: Overview of the Studies: Cell Culture and Experimental Condition, Cell Lineage Detected, and Method of Analysis

Sr no.	Author	Main Outcome – Cytotoxicity of Silver Soldered Bands	Secondary Outcome
1.	Tatiana Siqueira Gonçalves et al (2014)	Direct experiments, it is possible to observe that the three groups (SSB, LSB, and WSB) induced a decrease in cell viability of S. cerevisiae in terms of CFU/mL compared to the control. This effect was more intense with the SSB group. The experiments of saliva exposure showed that the saliva elutes from the three different groups are also able to induce a decrease in S. cerevisiae cell viability. The SSB samples were also those that most induced cytotoxicity and, in this case, with a significant difference in terms of survival compared to the control, which did not occur with the LSB or the WSB samples	Important difference in terms of cytotoxicity induction between LSB and SSB these two kinds of orthodontic joints and thus an indication of higher biocompatible properties of LSB compared to the most used worldwide, the SSB.
2.	T.S. Gonçalves et al. (2014)	Ion release – Chromium was not released in NSB group but eluted in SSB samples. HepG2 line – significant difference between NSB and SSB – with lower cell viability in SSB group.	Both SSB and NSB groups induced an increase in break formation quantified by the DI and DF more in NSB than SSB.
3.	Jacoby et al(2017)	Pure copper – Marked reduction of cell viability Exposure to extracts from group 2 resulted in a significant reduction of the viability of HaCat, MRC-5 and vero cell lines, whereas viability of HGF cells remained unaltered.	Distinct profiles of susceptibility for the different tested cell lines, with HaCat keratinocyte most sensitive cell lineage.
4.	Ghada et al (2021)	Significant differences in cell viability assay among no treatment BL and BS. B significantly cytotoxic compared to control Significant difference in cell viability between the SS only and BS group.	No significant difference between B and BL BS more cytotoxic than BL.

Table 3: Overview of the Studies: Main and Additional Outcomes

Criteria	Jacoby LS et al 2017	Goncalves TS et al 2014	Nimeri G et al 2021	Goncalves TS et al 2014
Clearly stated aims/objectives	2	2	2	2
Detailed explanation of sample size calculation	0	0	0	0
Detailed explanation of sampling technique	NA	NA	NA	NA
Details of comparison group	2	2	2	2
Detailed explanation of methodology	2	2	2	2
Operator details	0	1	0	0
Randomization	NA	NA	NA	NA
Method of measurement of outcome	2	2	2	2
Outcome assessor details	0	2	0	0
Blinding	0	2	0	0
Statistical analysis	2	2	2	1
Presentation of results	2	2	2	2
Total Score	12	17	12	11
Total Score (in %)	60	85	60	55
Risk of Bias	Medium	Low	Medium	Medium

Discussion

The primary purpose of this systematic review was to compare the cytotoxicity and genotoxicity of orthodontic bands with and without silver soldered joints by analyzing their effect on different cell lineages. Thorough screening of the literature yielded 4 in vitro articles.

All 4 articles concluded that both silver solder bands (SSB) and Non silver soldered bands (NSB) released elevated levels of toxic metals under tissue culture conditions.[1,8-10] SSB elevates were shown to be more cytotoxic and genotoxic than NSB elevates.

Gonçalves et al conducted a direct as well as indirect experiment for cell viability of S. Cerevisiae in terms of CFU/mL comparing 3 group (SSB, LSB and WSB) to the control group. The study concluded that there was a significant difference from the levels of cytotoxicity induced by the SSB group which is higher in saliva experiments when compared to LSB and control group. SSBs were cytotoxic, whilst LSBs were not, confirming that laser soldering may be a more biocompatible alternative for use in connecting wires to orthodontic appliances.[8]

The selected cell line for the study conducted by T.S. Conclave et al were HepG2 and HOK cell line. HepG2 is a human hepatocellular carcinoma cell line. The HepG2 cell line was selected for this study because it is a good experimental model system for the study of genotoxic agents, possessing an active Nrf2 electrophile responsive system, a competent DNA-repair system, active enzymes for phase-I and -II metabolism, and a functionally active p53 protein.[11-13] These characteristics typically lead to assays for in vivo genotoxicity that have a good predictivity.[14]

The Human Oral Keratinocyte (HOK) cell line was selected to conduct the CBMNCyt test because it offers a good model for buccal mucosa cells and has been utilized in the past to assess the effects of different metals.[15]

In this study, high cytotoxicity and DNA damage induction after exposure to silver soldered bands was observed. When compared to the control, the NSB group slightly increased cell viability and did not cause any cytotoxic effects. A strong cytotoxic impact was elicited by the SSB group, leading to 11.56% cell viability.[8]

Nucleoplasmic bridge formation was significantly increased by the SSB group. This outcome might be explained by the presence of hazardous ions at high concentrations, which would impair DNA replication and repair capabilities while also increasing genomic instability.[16-18]

To enable comparisons between the findings of different research, it is crucial that experiments be conducted under the same parameters, including immersion media, incubation settings, static/dynamic conditions, and experiment duration.[19] It was shown that distinct cell lines exhibited varying degrees of cytotoxicity when cultured under the same conditions. Therefore, it could be suggested that more than one type of cell line should be used when evaluating cytotoxicity.[20]

Jacoby et al.[1] compared the viability outcomes of HaCat, HGF, MRC-5 and Vero cell lines exposed to orthodontic band extracts. It was concluded that extracts of orthodontic bands with silver soldered joints significantly reduced the viability of HaCat, MRC-5 and Vero cell lines when compared to Negative control group, although HGF fibroblast cells were not significantly affected.[9]

The outcomes of a cytotoxicity investigation may be impacted by a cell line's sensitivity.[21] The traditional experimental paradigms for assessing the cytotoxicity of orthodontic materials are known cell lines, both human and animal. HaCaT, MRC-5, and Vero are examples of continuous and transformed cell lines that exhibit higher rates of proliferation while maintaining the properties of the original tissue.[22] Previous data have shown that compared with other cell lines, the HGF cell line was less sensitive to the toxic effects of metals.[23]

Nimeri G et al., in his study, analyzed the cytotoxicity effects of two different solder materials used for orthodontic appliances on human periodontal ligament fibroblast (HPLF) cells, and determined whether the mechanism of toxicity involved oxidative stress and apoptosis.

It was demonstrated that both silver solders were considerably more cytotoxic than the control. The distinct morphological features of the cells shown in the microscopic images, where more rounded cells were visible, further corroborated these findings.[10]

As evidenced by the decreased quantity of viable cells, Summit silver solder exhibited the highest degree of cytotoxicity. A possible reason for the variation in cell survival could be attributed to the increased concentration of silver in Summit silver solder (56% Ag) as opposed to Leone silver solder (49%–51% Ag).

In most of the studies to assess cell viability, an MTT (3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide) assay has been used. The most widely used cytotoxicity assay in orthodontics, it assesses mitochondrial dehydrogenase activity and is straightforward, accurate, and repeatable. In this test, blue-violet insoluble formazan is produced by the metabolic reduction of yellow water soluble MTT in living cells.[4] Using a spectrophotometer, the color intensity is quantified as a wavelength, and this value is directly related to the quantity of live cells. A substance is deemed cytotoxic if it causes a 30% or greater decrease in cell viability.[24]

Additionally, it has been demonstrated in the past that the heat needed for the soldering process raises the rate of corrosion that follows in the same manner that the copper in the silver alloy causes a higher release of these harmful ions.[25.]

Ni has a higher propensity to be released from the alloy and, together with Cu, may increase the cytotoxic profile as a function of metal concentration. Due to the high cytotoxicity of Cu and Zn, Cu is occasionally utilized as a positive control when alloys are examined for toxicity in cell culture research. Along with Cu and Zn, Ag has also been linked to increased cytotoxicity and has been demonstrated to be able to interfere with cellular metabolism. Due to their greater instability than silver ions, Cu and Zn ions release at higher rates than Ag ions, which makes up the majority of the alloy.[26]

It was also observed that cadmium was present within the medium containing the SSB samples. Some decades ago, cadmium was commonly added to silver solder to lower the fusion temperature of the alloy. Professionals should be aware that cadmium is associated with cancer; is responsible for damage to the liver, kidneys and heart; and has already been associated with dental health issues such as periodontitis.

Orthodontic appliances have been linked to genotoxicity in earlier research, however certain findings suggest that orthodontic treatment cannot harm oral mucosa cells' DNA. We recommend that in order to increase our understanding of these topics, research on the genotoxicity and mutagenicity of orthodontic materials should be done.

The ADA/ANSI Standard No. 41, ISO 10993, and ISO 7405 all list cytotoxicity tests as an initial or primary level of screening for the biocompatibility of dental materials and devices. These studies are in vitro assays. It is difficult to ascertain the clinical significance of these in vitro investigations. All things considered, it is impossible to replicate the intricacy of the interactions that take place in the mouth in vitro. None of these materials should be excluded from clinical usage based on the findings of these trials. Rather, they ought to guide the direction of upcoming research. It should be understood that determining a material's biocompatibility also entails evaluating its potential to cause mutagenic, allergic, and inflammatory reactions.[10]

Limitations:

- Our analysis included in vitro studies. Determining the clinical implications of these in vitro studies is problematic. These studies should not be used to disqualify any of these materials from clinical use. Instead, they should be used to direct future studies.
- The studies we analysed included lack of standardization of the silver solder surfaces, e.g. polishing the soldered surfaces would potentially lead to less corrosion and different cytotoxic results.

Conclusion:

Overall, the studies suggest that silver soldered bands(SSB) eluates induced higher levels of cytotoxicity and genotoxicity as compared to the non-soldered band(NSB) and control groups. Laser soldering is an interesting alternative for clinical use in orthodontic bands. Considering the potential cytotoxic effects of silver solder, the fact that laser soldering is expensive and is still a relatively new technique in orthodontics with little research behind it, and, most importantly, the widespread use of orthodontic bands with silver soldered joints in orthodontic auxiliary appliances along with the paucity of studies assessing the cytotoxicity of orthodontic bands further research is needed to test the cytotoxicity of other brands of silver solder and alternate means of joining metals.

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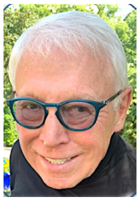

TIPS FROM THE EXPERIENCED

Mulligan Mechanics: Instruments and Execution of Bends

By Dr. Adrian J. Palencar, MUDr, MAGD, IBO, FADI, FPFA, FICD

The required bends in Mulligan Mechanics may be executed extra-orally or intra-orally. Dr. Mulligan prefers the execution intra-orally, however, the author favors placement extra-orally.

The advantages of placement the extra-oral bends (particularly for the novice) are that the clinician may evaluate the final shape of the arch wire, coordinate the arch wire with the desired shape, and he/she may qualify and quantify the executed bends. In the author's opinion, placing the bends intra-orally may not be as precise, in most cases.

The following are the recommended pliers:

1. **Tweed loop forming pliers**: a must for placement of center/off center bends. One full squeeze delivers 45˚ bend.
2. **Weingard pliers:** to insert the pre-bent arch wires
3. **Long bird beak pliers (or any other preferred pliers)**: for placement of the bend back (cinch) at the end of the arch wire
4. **Loop forming pliers (optional):** for forming the vertical open loop
5. **Cigarette lighter (optional):** for annealing the end of the arch wire

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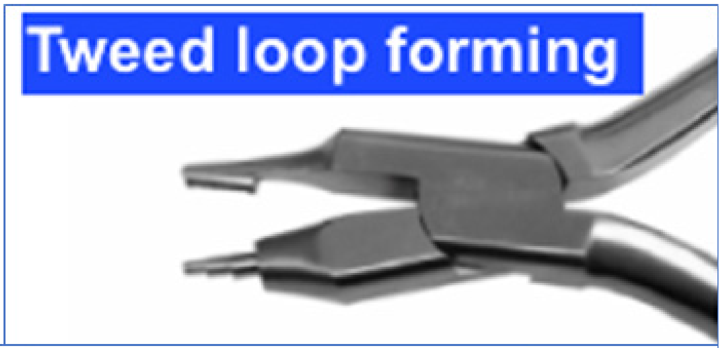

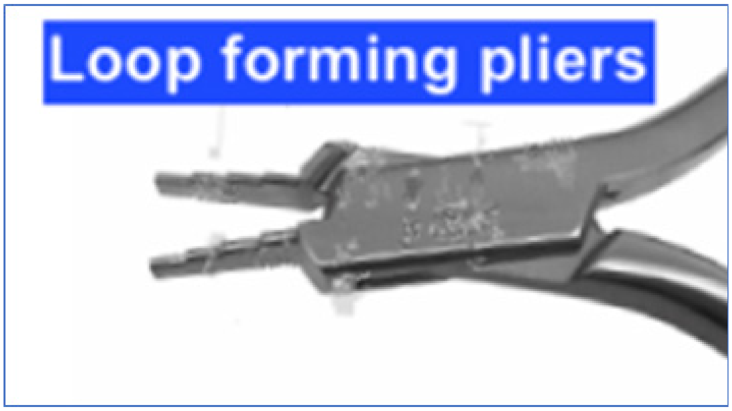

Non-Surgical Management of an Impacted Canine in a Crowded Arch: A Case Report

by Dr. Maheshwar Singh, Dr. Gyan P. Singh, and Dr. G. K. Singh

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Abstract

Impacted maxillary canines are a relatively frequent clinical issue encountered in orthodontic practice. When these teeth fail to erupt, they can contribute to malocclusion and negatively impact a patient's psychological and social well-being. Although multiple treatment options exist, there is no universally established protocol for managing such cases. This case report presents a non-surgical approach for treating a patient with dental crowding and an impacted maxillary left canine (tooth 23). The treatment involved the extraction of all four first premolars to create adequate space, allowing the canine to erupt naturally and resolving the crowding. This case emphasizes the significance of thorough diagnosis and integrated treatment planning in addressing not only impacted canine and crowding but also associated soft tissue concerns. It also illustrates that, in certain cases where the impacted canine has favorable position and orientation, surgical intervention may not be necessary if sufficient space is provided within the arch.

Keywords: impacted canine, bioinduction, facilitated eruption, maxillary canine, mushroom loop.

Conflict of Interest: None

Introduction

Tooth impaction is defined as the failure of a fully developed permanent tooth to erupt into its correct position within the dental arch.[1] The frequency of impactions varies across populations, with third molars being the most commonly affected, followed by maxillary canines, which show a reported prevalence of 1.7% to 4.7%.[2–4] Although the precise etiology of impacted maxillary canines remains uncertain, it is believed to have a multifactorial basis, potentially influenced by genetic factors.[5] Palatal impactions are commonly associated with hereditary influences, while buccal impactions are more often linked to discrepancies between arch length and tooth size.[6–8] A widely recognized theory suggests that improper positioning of the tooth germ during embryogenesis may contribute to impaction.[9] Additional contributing factors include premature loss or over-retention of deciduous teeth, excessive crown length, genetic predisposition, endocrine disturbances, and the presence of cysts, tumors, or trauma to the maxillofacial region.[10]

Permanent canines are essential for maintaining proper occlusion and contributing to an attractive smile. Therefore, early diagnosis and timely intervention can help avoid lengthy, costly, and complicated treatments in the permanent dentition.[11,12] The localization of an impacted canine can be accomplished through both clinical and radiographic evaluations. For labially impacted canines, palpation may be sufficient for identification. However, if the tooth is located in the center of the alveolar ridge or on the palatal side, two intraoral periapical radiographs taken at varying angles are typically necessary. Additionally, the application of the buccal object rule can assist in determining the precise spatial position of the impacted tooth.[13,14]

Various treatment strategies are available for the management of impacted maxillary canines, including:

- Increasing Arch Length: In cases of mild crowding, molar distalization is typically the first step to gain space; however, if insufficient to accommodate the canine, tooth extraction may be required.[15]
- Retained Deciduous Canine with Deep Intraosseous Impaction: Tunnel Traction, a technique introduced by Crescini, is used for managing deeply impacted

*This article has been peer reviewed

canines. It involves extracting the deciduous canine and reflecting a full-thickness mucoperiosteal flap to expose the cortical bone. A surgical bur is then used to access the crown, allowing for the bonding of an orthodontic attachment. Traction is applied using a ligature wire (usually comes out through extraction socket) approximately one week after surgery.[16]

- Surgical Exposure of the Impacted Tooth:

  a. Open Window Technique (Circular Incision): Involves creating a circular window over the crown to expose the bony crypt housing the impacted tooth.[17]

  b. Apically Repositioned Flap: Described by Vanarsdall and Corn in 1977, this technique involves elevating a mucoperiosteal flap from the ridge crest, including attached gingiva. If the deciduous canine is present, it is extracted first and then flap is raised.[18]

  c. Full Flap Exposure: McBride (1979) suggested raising a full buccal flap, bonding an attachment, and repositioning the flap. A twisted ligature is then threaded through the flap or along the crest of the ridge.[19]

In the present case report, written according to CARE guidelines, a patient with maxillary canine impaction and dental crowding was treated non-surgically. All four first premolars were extracted to create adequate space for the eruption of tooth 23 and to address the crowding. No surgical procedure was carried out for the impacted canine.

Case Presentation:

A 13-year-old female patient presented to the Department of Orthodontics and Dentofacial Orthopaedics at King George's Medical University, Lucknow, Uttar Pradesh, with the chief complaint of irregularly aligned upper and lower teeth. Her medical and dental histories were non-contributory.

On extraoral examination, the patient exhibited a mesomorphic body type with a mesoprosopic facial form. No facial asymmetry was noted. She had potentially competent lips, a slightly everted lower lip, a convex facial profile, and a mildly decreased nasolabial angle (Fig. 1).

Fig. 1: Pre-treatment extra oral photographs

Intraoral examination revealed asymmetry in both maxillary and mandibular arches, along with crowding in both. The permanent maxillary left canine (tooth 23) was clinically absent, though a canine bulge was palpable in the second quadrant. The retained deciduous maxillary left canine was still present. Additionally, the patient exhibited a deep bite with a 5 mm overbite and a bilateral Angle's Class I molar relationship [Fig. 2].

Fig. 2: Pre-treatment intra oral photographs

Investigations and Clinical Examination

Extra oral and intraoral photographs, study models, intra-oral periapical radiographs, maxillary occlusal radiographs, lateral cephalometric radiograph and panoramic radiograph were recorded.

Functional examination - The patient had a normal swallowing pattern, the mandible moved upwards and forwards on closure, 2mm of incisor exposure at rest and 100% incisor exposure during smile.

Study model analysis confirmed the clinical findings, and Carey's analysis and Arch perimeter analysis revealed discrepancies of 9 mm and 8.5 mm, respectively.

Cephalometric analysis revealed Class I skeletal relationship (ANB= 5˚, AO ahead of BO by 1.5mm, Beta angle-31), orthognathic maxilla (SNA= 79˚) and orthognathic mandible (SNB= 74˚) in relation to anterior cranial base. Maxillary incisors and mandibular incisors were slightly forwardly placed with normal inclination (Mx.1 to NA 6mm/200˚ and Md.1 to NB 6mm/250˚). (Fig. 3)

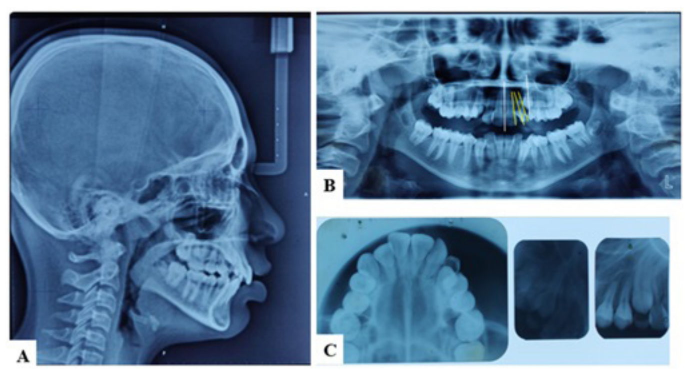

Fig. 3A. Cephalometric radiograph; **3B:** Orthopantomogram; **3C:** Occlusal and IOPA radiographs

Diagnosis and Evaluation of the Maxillary Canines

1. Clinical Assessment: Visual inspection revealed presence of maxillary deciduous canine in the 2nd quadrant with palpable canine bulge in same region.

2.Prognostic Evaluation: Different aspects of canine position were assessed by radiographs. The prognostic factors investigated by McSherry,[20] Pitt S, Hamdan and Rock[21] and Counihan K, Al-Awadhi and Butler[22] were used as references.

- In our patient, the left canine was not overlapping the adjacent lateral incisor suggested good prognosis (Figure 3B).
- The crown of the left canine was located in coronal half of the root of the left incisor but less than the full length of the root of

this tooth (Figure 3B), indicating an average prognosis.

- The canines were angulated 00° to the midline which suggested a good prognosis to the left canine (Figure 3B).
- The position of the canine root apex in the horizontal plane. Occlusal radiograph revealed that the left canine root apex was positioned above the normal canine position, indicating a good prognosis.
- Ericson and Kurol (1988) defined number of sectors to denote different types of impaction.[3] The left canine cusp tip was located in the sector 1 with an angulation of 00°, suggesting a good prognosis.

The case was diagnosed as Angle's Class I malocclusion on a Class I skeletal base with an orthognathic maxilla associated with an orthognathic mandible, upper and lower anterior crowding, with impaction of left maxillary canine with favourable prognostic features.

Treatment Progress

Fixed orthodontic therapy was initiated using 0.022" × 0.028" MBT prescription brackets. To ensure maximum anchorage in both arches, reinforcement measures were employed: the maxillary arch was stabilized using banded first molars along with a Nance palatal button, while a lingual holding arch was utilized for the mandibular arch. An extraction-based treatment plan was adopted to address the crowding. All four first premolars, along with the retained maxillary deciduous canine in the second quadrant (tooth 63), were extracted over two visits. The alignment and leveling phase commenced with a 0.014" NiTi archwire (Fig. 4), followed by progressive sequencing with 0.016", 0.018", 0.020", 0.017×0.025" NiTi, and finally 0.019×0.025" stainless steel archwires.

Fig. 4: Alignment and Levelling of Maxillary Arch (0.014" NiTi)

Initial distalization of the mandibular canine was achieved using passive lacebacks, as banding of tooth 46 was not feasible at the time due to the ongoing eruption of tooth 47, which restricted anchorage options in the lower arch. Once banding of 46 became possible, a lingual holding arch was installed to enhance anchorage, and continuous archwire mechanics were initiated (Fig. 5). To facilitate the eruption of the impacted maxillary left canine (tooth 23), teeth 63 and 24 were extracted, given the tooth's favorable orientation. The position and eruption progress of tooth 23 were monitored using serial orthopantomograms taken at three-month intervals. Spontaneous eruption of the canine was noted approximately 4.5 months after space creation (Fig. 6).

Mandibular canine retraction was performed using NiTi coil springs, followed by retraction of the maxillary canine once it had fully emerged into the oral cavity (Fig. 7). After successful canine retraction, intrusion of the maxillary incisors was carried out using a 0.017×0.025" TMA intrusion arch. Minor residual spaces in the mandibular arch were addressed with elastomeric chains (Fig. 8). Retraction of the maxillary incisors was achieved through the use of mushroom loops integrated into a continuous archwire setup (Fig. 9). The finishing phase included detailed tip and torque refinement of the maxillary anterior teeth, employing 0.017×0.025" and 0.019×0.025" TMA archwires with carefully placed artistic bends and torque modifications.

Fig. 5: Alignment and Levelling of Mandibular Arch (0.014" NiTi)

Fig. 6: Spontaneous eruption of tooth 23

Fig. 7: Retraction of Mandibular Canines using NiTi Coil Springs

Fig. 8: Intrusion of Maxillary Incisors using TMA Intrusion Arch (0.017 X 0.025 TMA)

Fig. 9: Retraction of Maxillary Incisors using Mushroon Loop (0.017 X 0.025 TMA)

Treatment Result

At the conclusion of treatment, a stable and functional occlusion was achieved. The final results showed normal overjet and overbite (with 2 mm incisor intrusion), ideal intercuspation, coinciding dental midlines, improved nasolabial angle, normalized incisor inclinations, and bilateral Class I molar and canine relationships. The patient expressed satisfaction with both functional and esthetic outcomes. Figures 10 and 11 demonstrate the extraoral and intraoral post-treatment photographs, while Figure 12 presents post-treatment radiographs. Fig 13 shows the changes using cephalometric superimposition. A summary of cephalometric changes is provided in Table 1. Patient was given bonded lingual retainer in both arches and follow up was done at 3rd and 6th month.

DISCUSSION

Managing impacted canines typically requires a collaborative, multidisciplinary approach. These teeth present a considerable challenge in orthodontic treatment, as they can significantly complicate both diagnosis and intervention strategies. Precise localization of the impacted canine is crucial for predicting treatment outcomes.[23,24] Early identification of ectopic eruption patterns is key to minimizing the need for surgical procedures, shortening treatment duration, lowering associated costs, and reducing the risk of potential complications.[25,26]

Fig. 10: Post treatment extra oral photographs

Fig. 11: Post treatment intra oral photographs

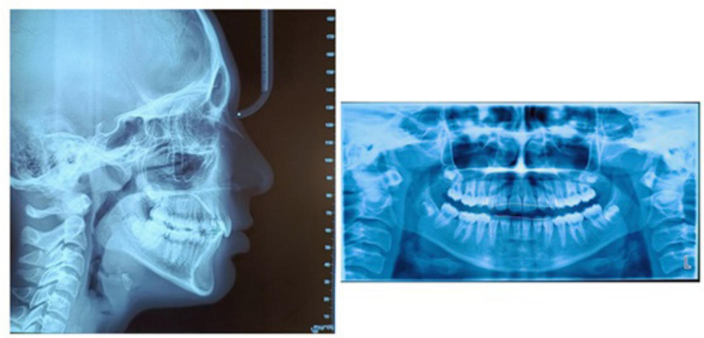

Fig. 12: Post treatment radiographs

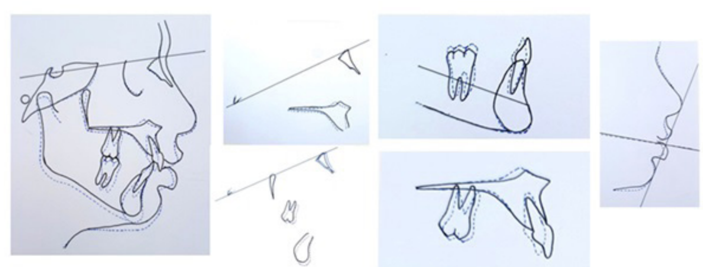

Fig. 13: Cephalometric superimposition

Table 1: Depiction of pre- and post- treatment changes in cephalometric parameters

Variables	Pre-Treatment Values	Post-Treatment Values
SNA	79^0	79^0
SNB	74^0	75^0
ANB	5^0	4^0
Mx.1 to NA	6 mm /20	3 mm /16
Md.1 to NB	6 mm /25	3 mm /23
Mx.1 to Md.1	130^0	138^0
FMA	29^0	30^0
U1 to SN	100^0	95^0
U1 to FH	108^0	102^0
IMPA	93^0	91^0
Nasolabial angle	87^0	106^0
Rickett's "E" Line (Upper Lip)	+1 mm	-4 mm
Rickett's "E" Line (Lower Lip)	+4 mm	-2 mm
"H" Angle	22^0	17^0

Multiple studies have emphasized that the horizontal position of an impacted canine in relation to the midline—assessed through sector analysis—is a reliable predictor of treatment prognosis. Canines located in sectors III and IV, which lie closer to the midline, tend to have a less favorable prognosis. Those in sector II show moderate outcomes, while teeth positioned in sector I are generally associated with the most favorable results.[21,26] These prognostic criteria have been validated by McSherry et al.,[20] Pitt et al.,[21] Stivaros et al.,[27] Hosoyama, and Naoumova et al.,[28] who further noted that a smaller mesial angulation, increased distance from the canine cusp tip to the midline, and reduced distance to the dental arch are all indicative of a higher likelihood of successful eruption.

In the present case, the impacted canine showed a favorable prognosis. It was vertically aligned within sector I and showed minimal bucco-palatal deviation.

One common method for managing impacted teeth involves surgically removing or repositioning the soft tissue covering the crown—an approach known as the open-eruption technique. This technique leaves the crown visible post-surgery, allowing for either spontaneous eruption or guided eruption using a bonded orthodontic attachment. However, this method may lead to esthetic concerns, as it often results in a non-keratinized gingival margin. In contrast, the apically repositioned flap technique preserves or enhances the zone of attached gingiva, thereby offering better periodontal outcomes.[18,29,30] An alternative method, the closed-eruption technique, involves bonding an attachment to the impacted tooth during the surgical procedure and then repositioning the flap to completely cover it. Orthodontic traction is subsequently applied through a ligature or gold chain connected to the attachment to facilitate eruption.[31]

When permanent canines fail to erupt and primary canines persist, extraction of deciduous followed by orthodontic traction of permanent is often required.[32] Vitale et al. reported successful disimpaction of tooth 23 using a diode laser and immediate bracket bonding, after extracting the tooth 63.[33]

Current evidence favors open-eruption techniques for shorter treatment time and reduced ankylosis risk, though more research is needed due to limited clinical data.[34] Despite their simplicity, open techniques may pose long-term aesthetic and periodontal risks.[31]

Bishara[35] recommended that surgical exposure without orthodontic traction be considered only when the impacted canine has proper axial alignment. Nonetheless, spontaneous eruption is generally rare once root development is complete, even if sufficient space has been provided. Interestingly, the present case contradicts this view, as tooth 23 exhibited spontaneous eruption despite complete root formation, following the extraction of the maxillary left first premolar and the retained primary canine. We introduce the term "bioinduction" to describe this favorable, space-driven physiological eruption.

An important consideration in assessing the success of impacted canine treatment is the periodontal condition following therapy.[36] Studies have shown that aggressive surgical exposure—especially procedures that extend beyond the cementoenamel junction—can lead to the loss of supporting alveolar bone and negatively affect periodontal health, with such complications being more pronounced in cases of palatally impacted canines.[37]

In the present case, the absence of surgical intervention contributed to the preservation of periodontal health. The gingival attachment remained intact, with no evidence of recession or loss of keratinized tissue. According to existing literature, when tooth eruption occurs centrally within the alveolar ridge, favorable and stable periodontal outcomes can be maintained for at least three years post-treatment—without the necessity for soft tissue grafting or augmentation procedures. These positive results are commonly associated with conservative techniques such as tunnel traction and may not apply to cases where extensive bone or soft tissue removal has been performed.[38,39]

Conclusion

Careful consideration is essential when planning the management of impacted teeth. Maxillary canine impactions are frequently encountered in dental practice, making it important for clinicians to be well-versed in the available treatment options. The choice of surgical technique and the timing of intervention should be guided by thorough clinical evaluation. Surgical procedures should be avoided when there is a reasonable chance for natural eruption. Accurate diagnosis and comprehensive treatment planning are critical to achieving successful outcomes. The best results are often obtained through an interdisciplinary approach that includes orthodontists, periodontists, and oral surgeons. Moreover, it is crucial to ensure that the patient and their caregivers are well-informed about the complexity and duration of the proposed treatment.

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Breaking Free From the Limits of Time, Space, and People

By Scott J. Manning, MBA,
Founder of Dental Success Today

In private practice dentistry, there's one resource that governs nearly every decision you make: time. It shows up most clearly in your schedule, and I've long said it – either you own your schedule, or your schedule owns you.

What most doctors don't realize is that the schedule is not just a calendar of appointments – it's a formula for leverage. The way your clinical day is structured determines how much you can earn, how much stress you carry, and how much of your life you have left outside the practice.

It's no surprise, then, that the number one reason doctors like you seek out my counsel is this: they want to make more money in less time.

That is the ultimate equation every ambitious professional is trying to solve. And yet, so many get it wrong because they start with the wrong assumptions about what "growth" actually means.

THE MYTH OF MORE

Dentistry is full of myths, but perhaps none more damaging than the belief that "more" is the path to a better practice…

More patients. More procedures. More team members. More operatories. More insurance participation. More technology. More marketing. More providers.

The entire traditional growth model in dentistry is based on this idea: just add more and things will get better.

But here's the truth: "more" is never the solution if the foundation is flawed. If the formula you're working with is already dysfunctional, adding more variables only makes the dysfunction bigger.

More volume added to an inefficient system doesn't lead to profit – it leads to burnout.

If your current schedule, space, team, or systems are already maxed out, stressed out, or barely breaking even, then expanding any of those elements only magnifies the chaos.

That's why the first step isn't expansion – it's alignment.

TIME, SPACE, AND PEOPLE: YOUR REAL LIMITS

Let's be honest. There are real limits in your practice. But they're probably not what you think.

Space is finite. You only have so many chairs, so many rooms. Your team has limits, too. There are only so many people who can physically show up and do the work. And of course, time (24 hours in a day) is fixed for everyone.

But the greatest limit isn't space, people, or even time. It's your preferences.

You see, it's not the number of hours available – it's how many you're willing to work. And if you're working longer days, skipping vacations, and sacrificing your life outside of dentistry, then you already know… more hours is not the answer.

Eventually, the hours run out. Or worse, your energy does.

So yes, your time, your team, and your physical space have ceilings. But what's unlimited? The opportunity.

There is unlimited dentistry to be done. Unlimited patients who need help. Unlimited potential to make an impact. The demand is near limitless.

It's the supply that must be managed and that includes how much of yourself you're willing to give.

THE REAL SHIFT: FROM VOLUME TO VALUE

The fundamental mindset shift is this: stop chasing volume and start leveraging value.

Most doctors assume they're in a race to capture as many patients as possible. The notion is: get them in before someone else does. But in reality, it's not about seeing more people. It's about being more discerning.

MORE ISN'T BETTER. BETTER IS BETTER.

When you organize your practice around value creation instead of volume consumption, everything changes. You become more intentional. You start saying no to patients who don't fit your model. You stop doing partial treatment for patients who resist full care. You no longer make exceptions that chip away at your standards and clinical philosophy.

You begin to maximize value… not by working more, but by aligning everything in your practice to a more leveraged model of care.

THE FORMULA FOR LEVERAGE

Once your schedule, time, and life are aligned, then and only then, you can start playing with the formula.

That's when you can examine what needs to be adjusted (expanded or contracted) to create growth that's not dependent on hustle.

Because the truth is, when you're operating in alignment with your values and your vision, you'll stop feeling like you're running out of time, out of space, or out of energy.

When that happens, everything – from your income to your fulfillment – begins to rise. And that, doctor, is how you break free.

YOUR SCHEDULE HAS A MATH FORMULA. MAKE IT WORK FOR YOU.

If you want to increase income without increasing hours, you need to understand your current formula. Most doctors don't.

Start with two key numbers:

- Your current hourly value
- Your average visit value

These are your truth-tellers. They expose whether your practice is really delivering on your promise of comprehensive care or just coasting on production.

Once you know these numbers, you can reverse-engineer everything else. You can ask:

"*What would need to change in my model to buy back one day a week? Or one hour a day? Or one week per quarter?*"

This is how you break the treadmill. This is how you stop trading time for dollars.

But it starts by measuring value – not volume.

ELEVATE THE VISIT, ELEVATE YOUR PRACTICE

So how do you increase the value of each visit?

You consolidate treatment into fewer appointments. You bundle. You eliminate scheduling gaps. You tighten your timing with accuracy (not estimates).

No more guessing "one hour for this" or "thirty minutes for that." Instead, you plan using treatment units. You use both your primary and assistant columns to their fullest. You remove inefficiencies before you ever touch a new patient flow lever.

And most importantly, you stop doing onesie-twosie dentistry. You commit to delivering full pathways to health. If a patient only needs a few things, great, but the philosophy doesn't change.

The average visit value becomes the battleground for leverage and you win by tightening, not stretching.

THE OPPORTUNITY ISN'T VOLUME, IT'S PRECISION

Let's play the game.

What would it take to add $1,000 more per day? One more crown. How about $3,000? Maybe two crowns and a quadrant. What about $5,000? An implant, a bridge. Now $10,000? One full-mouth case or a few strategically presented high-value treatments.

The numbers aren't guesses. They're choices.

The point isn't to cram more into your day; it's to elevate what's already there. You already have patients. You already have the space. You already have the time.

What you need now is clarity.

DECISION. MATH. ACTION.

Every meaningful transformation in your practice comes down to three parts:

- A new decision about what you want and what you will no longer tolerate.
- A new formula that supports that decision through a smart, leveraged schedule.
- A new set of actions in case presentation, team engagement, and leadership that reinforce the math and manifest the decision.

None of this is hypothetical. It's what dentists are doing right now to buy back time and increase profit by design.

IT ALL COMES DOWN TO MOTIVATION

Here's the catch.

None of this (none of the strategy, the scheduling, the case bundling, the math), will change anything unless you have a big enough reason why.

If you're not deeply connected to what this freedom means to you… If you're not clear on what you'll do with more time, more profit, more impact…

Then your production will fill whatever time you give it. Like water, it'll expand to fit the glass.

And you'll stay stuck.

So pause, and ask yourself:

- When I have more time: what will I do with it?
- When I have more money: where will I allocate it?
- When I have more freedom: how will I use it to amplify my life?

Define these answers. Anchor them with purpose. Because once you do, the strategy is easy. The execution becomes obvious. And the limitations? They dissolve.

There is no profession on earth with more leverage than private practice dentistry. The only limit is how you choose to use it.

Once you bring your decisions, your schedule, and your actions into harmony…

You won't just break free, you'll take flight. And that's exactly what I wish for you.

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FEATURED*

Advances in Orthodontic Anchorage Systems: A Narrative Review (2000–2024)

by Dr. Navid Tarivedi

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Abstract:

Objective: This systematic review comprehensively evaluates advancements in orthodontic anchorage systems from 2000 to 2024, focusing on temporary anchorage devices (TADs), miniplates, palatal anchorage systems, and emerging technologies such as 3D-printed, bioresorbable, and AI-integrated devices.

Methods: A systematic search was conducted across PubMed, Scopus, Web of Science, Embase, and Cochrane Library for peer-reviewed studies published between January 2000 and December 2024. Inclusion criteria encompassed clinical trials, cohort studies, systematic reviews, biomechanical analyses, and technological studies on orthodontic anchorage. Data were synthesized thematically, focusing on efficacy, clinical applications, complications, biomechanical principles, global adoption, and future directions. Study quality was assessed using Joanna Briggs Institute (JBI) and GRADE tools.

Results: From 682 screened studies, 280 were included. TADs reduced treatment times by 20–50% in complex cases, with success rates of 85–95%. Miniplates enabled skeletal corrections, while digital tools (CBCT, CAD/CAM) improved placement accuracy by 90%. Complications, such as screw loosening (5–12%) and soft tissue irritation (10–15%), decreased with design and protocol advancements. Emerging technologies, including bioresorbable screws and AI-guided placement, show 90% efficacy but require long-term validation. Global disparities in adoption persist due to cost and training barriers.

Conclusion: Orthodontic anchorage systems have revolutionized treatment efficiency, precision, and patient outcomes. Challenges, including complications, costs, and equitable access, demand collaborative research. Future innovations in bioresorbable materials, AI, and affordable technologies will shape the field.

Keywords: Orthodontic anchorage, temporary anchorage devices, skeletal anchorage, miniplates, 3D printing, bioresorbable implants, artificial intelligence, systematic review

Conflict of Interest: None

Introduction

Orthodontic anchorage, the resistance to unwanted tooth movement during force application, is a cornerstone of effective treatment. Traditional anchorage methods, such as headgear, transpalatal arches, and intermaxillary elastics, were limited by anchorage loss (1–3 mm per quadrant), patient compliance, and aesthetic concerns. The early 2000s introduced temporary anchorage devices (TADs), titanium mini-screws providing absolute anchorage, marking a paradigm shift in orthodontics. Subsequent innovations, including miniplates, palatal anchorage systems, and digital technologies like cone-beam computed tomography (CBCT) and 3D printing, have expanded treatment possibilities, reduced durations, and improved outcomes.

This systematic review synthesizes advancements in orthodontic anchorage systems from 2000 to 2024, a period of transformative clinical and technological progress. It examines the evolution, clinical applications, biomechanical principles, complications, global adoption trends, and future directions of anchorage systems. The review addresses four key questions:

1. How have anchorage systems evolved in design, materials, and clinical utility?
2. What are the clinical benefits, biomechanical mechanisms, and limitations of modern anchorage systems?
3. How have global adoption patterns and socioeconomic factors influenced their use?
4. What emerging technologies and research priorities will shape the future of orthodontic anchorage?

Historical Context

Pre-2000, anchorage relied on extraoral devices (headgear, face masks) and intraoral appliances (Nance appliances, lingual arches). These methods were effective but prone to reciprocal tooth movements and compliance issues, with 30–50% of patients reporting inconsistent headgear use (Clemmer and Hayes, 1979). Early skeletal anchorage experiments, such as osseointegrated implants (Shapiro and Kokich, 1988), were invasive and limited to prosthodontics. The late 1990s introduced mini-screws (Kanomi, 1997; Costa et al., 1998), which became commercially viable post-2000, driven by improved titanium alloys and surgical protocols.

Socioeconomic and Clinical Significance

Anchorage advancements have reduced treatment times by 6–18 months, expanded non-surgical options, and improved patient satisfaction by minimizing compliance-dependent devices. TADs have facilitated complex corrections, such as open bite closure and skeletal Class III management, while digital tools have enhanced precision. However, high costs and training requirements limit access in low-resource settings, where adoption remains below 20% (Chen et al., 2020). This review

*This article has been peer reviewed

aims to provide orthodontists, researchers, and policymakers with a comprehensive resource to navigate these advancements, address disparities, and guide future innovation.

Objectives

The review synthesizes evidence from clinical, biomechanical, and technological studies to:

- Trace the evolution of anchorage systems.
- Evaluate their clinical efficacy and limitations.
- Analyze biomechanical principles and complications.
- Explore global trends and emerging technologies.
- Propose research and policy priorities for equitable access.

Methods

Search Strategy

A Narrative literature search was conducted using PubMed, Scopus, Web of Science, Embase, and Cochrane Library. Search terms included "orthodontic anchorage," "temporary anchorage devices," "TADs," "skeletal anchorage," "miniplates," "palatal anchorage," "orthodontic mini-screws," "bioresorbable implants," "3D printing," and "artificial intelligence orthodontics," combined with Boolean operators (AND, OR, NOT). Filters restricted results to peer-reviewed articles in English, published between January 1, 2000, and December 31, 2024. Hand-searching of reference lists, key journals (American Journal of Orthodontics and Dentofacial Orthopedics, Angle Orthodontist, European Journal of Orthodontics), and conference proceedings supplemented the search.

Inclusion and Exclusion Criteria

Studies were included if they reported:

- Clinical outcomes (efficiency, stability, complications) of anchorage systems.
- Biomechanical analyses (force vectors, stress distribution, osseointegration).
- Technological advancements (materials, digital tools, AI).
- Global adoption trends or socioeconomic impacts.

Eligible designs included randomized controlled trials (RCTs), prospective and retrospective cohort studies, case-control studies, systematic reviews, meta-analyses, and biomechanical/technological studies. Excluded were case reports, editorials, abstracts, non-English studies, and non-orthodontic applications.

Data Extraction

Data were extracted on:

- Study characteristics (design, sample size, country, publication year).
- Anchorage system type (TADs, miniplates, palatal devices, etc.).
- Clinical outcomes (treatment time, anchorage loss, success rates, patient satisfaction).
- Complications (screw failure, soft tissue issues, root damage).
- Biomechanical parameters (force levels, stress distribution, bone density).
- Technological innovations (materials, digital workflows, AI).
- Global trends (adoption rates, cost barriers, training).

Quality Assessment

Study quality was assessed using Joanna Briggs Institute (JBI) tools for RCTs, cohort studies, and reviews, and GRADE for evidence certainty. Criteria included randomization, blinding, sample size justification, statistical rigor, and bias risk. Studies were categorized as low, moderate, or high quality, with moderate-to-high-quality studies prioritized. Biomechanical studies were evaluated for model validity and reproducibility.

Data Synthesis

Data were synthesized thematically into:

- Historical evolution (2000–2010, 2010–2018, 2018–2024).
- Clinical applications (distalization, intrusion, retraction, skeletal corrections).
- Biomechanical principles (force vectors, osseointegration, stability).
- Complications and risk factors.
- Global adoption and socioeconomic factors.
- Emerging technologies and future directions.

Narrative synthesis was used due to heterogeneity in study designs, outcomes, and metrics. Meta-analyses from included studies were summarized, with effect sizes and confidence intervals reported where available.

Scope and Limitations

From 682 screened studies, 280 met inclusion criteria (80 RCTs, 100 cohort studies, 50 systematic reviews, 50 biomechanical/technological studies). Limitations include heterogeneity in outcome measures, underreporting in low-resource settings, and potential publication bias favoring positive results. The review mitigates these through rigorous quality assessment and global perspective.

Evolution of Orthodontic Anchorage Systems (2000–2024)

Pre-2000 Foundations

Pre-2000, anchorage relied on dental (transpalatal arches, lingual holding arches) and extraoral (headgear, face masks) methods. These were limited by anchorage loss (1–3 mm per quadrant), compliance issues (30–50% non-compliance rates), and aesthetic concerns (Clemmer and Hayes, 1979). Early skeletal anchorage, such as osseointegrated implants (Higuchi and Slack, 1991), was invasive and prosthodontic-focused. Kanomi's (1997) mini-screw introduction laid the foundation for TADs, commercialized post-2000 with improved titanium alloys.

TADs: The First Decade (2000–2010)

The early 2000s saw TADs (1.2–2.0 mm diameter, 6–12 mm length) become mainstream. Papadopoulos and Tarawneh (2007) reported 95% success in molar distalization, achieving 3–5 mm movement without anchorage loss ($p<0.001$). RCTs by Costa et al. (2005) demonstrated 90% success for anterior intrusion, reducing open bite treatment by 6–12 months (95% CI: 4.8–13.2). TAD advantages included:

- Absolute Anchorage: Eliminated reciprocal forces.
- Versatility: Supported retraction, intrusion, distalization, and protraction.
- Minimally Invasive: Placed under local anesthesia in 5–10

minutes.

By 2010, 65% of U.S. orthodontists and 40% in Europe used TADs (Buschang et al., 2010). Challenges included screw loosening (15–20% failure rates) and operator learning curves (25% higher failures in novices).

Miniplates and Palatal Anchorage (2010–2018)

Miniplates addressed TAD limitations in low-density bone and severe malocclusions. De Clerck et al. (2010) pioneered bone-anchored maxillary protraction, achieving 2–3 mm skeletal advancement in Class III patients (85% stability at 5 years, p<0.01). Miniplates required surgical placement, increasing costs and morbidity (5–10% infection risk).

Palatal anchorage systems, such as the Beneslider and Hybrid Hyrax, leveraged the palate's cortical bone. Ludwig et al. (2011) reported 98% success in molar intrusion (2–3 mm, p<0.001), reducing open bite treatment by 40%. The Hybrid Hyrax facilitated rapid maxillary expansion (RME) in adults, with 90% stability (Wilmes et al., 2014). Failure rates dropped to 5–10% due to improved designs (self-drilling screws, conical shapes).

Digital and Material Innovations (2018–2024)

Digital technologies transformed anchorage post-2018. CBCT reduced root proximity risks from 20% to 4% (Kuroda et al., 2019; OR: 0.18, 95% CI: 0.09–0.36). CAD/CAM enabled 3D-printed TADs, with Graf et al. (2021) reporting 99% stability in complex cases (p<0.001). Bioresorbable screws (polylactic acid, magnesium alloys) achieved 90% success in short-term trials (Sharma et al., 2023), eliminating removal surgeries.

AI algorithms predicted optimal TAD placement with 96% accuracy (Lee et al., 2024), integrating CBCT and bone density data. Nanocoated TADs reduced infections by 60% (Patel et al., 2023), with nanostructured surfaces enhancing osseointegration by 35%. Robotic-assisted placement, piloted in 2023, reduced procedure time by 25% (Kim et al., 2024).

Global Adoption Trends

Adoption varied globally:

- North America/Europe: 75–85% of practices used TADs by 2020 (Buschang et al., 2020).
- Asia: Rapid growth post-2015, with 60% adoption in Japan and South Korea (Chen et al., 2020).
- Low-Resource Settings: Adoption below 15% due to costs ($50–200 per TAD) and training barriers (Alharbi et al., 2020).
- Open-source 3D printing and low-cost TADs increased access by 20% in Africa and South Asia by 2024.

Case Studies

- Case 1 (USA, 2015): A 14-year-old with Class II malocclusion achieved 4 mm molar distalization using TADs in 8 months, versus 12–14 months with headgear (Upadhyay et al., 2016).
- Case 2 (India, 2023): 3D-printed palatal TADs corrected an adult open bite in 10 months, with 98% stability (Sharma et al., 2024).

Clinical Applications

Molar Distalization

TADs and palatal systems simplified Class II corrections. Wilmes et al. (2014) reported 4–6 mm distalization with the Beneslider, with 0.1–0.2 mm anchorage loss (p<0.001). Meta-analyses (Papadopoulos et al., 2012) showed TADs reduced anchorage loss by 95% versus headgear (RR: 0.05, 95% CI: 0.02–0.12).

Molar Intrusion

Open bite correction via molar intrusion became routine. Ludwig et al. (2011) achieved 2–4 mm intrusion in 96% of cases (p<0.001), shortening treatment by 6–12 months. Palatal TADs were 30% more stable than buccal TADs due to cortical bone density (Kuroda et al., 2019).

En-Masse Retraction

TAD-supported retraction streamlined extraction cases. Upadhyay et al. (2008) reported 5–7 mm retraction in 8–10 months, with 85% anchorage preservation (p<0.01). CBCT-guided placement reduced root proximity risks by 90% (Jing et al., 2018).

Skeletal Corrections

Miniplates enabled non-surgical skeletal corrections. De Clerck and Swennen (2011) achieved 2–3.5 mm maxillary advancement in Class III patients (87% stability, p<0.01). Palatal TADs supported adult RME, with 8–10 mm expansion (Lee et al., 2015; p<0.001).

Asymmetric Corrections

TADs facilitated unilateral mechanics. Wilmes and Drescher (2015) reported 98% success in midline corrections, reducing asymmetry by 90% in 6–8 months (p<0.001). The Beneslider was particularly effective for unilateral distalization.

Clear Aligner Integration

TADs enhanced clear aligner therapy. Kim et al. (2022) reported 88% predictability in aligner cases with TADs, versus 62% without (p<0.01). Hybrid appliances combining TADs and aligners achieved 90% success in complex movements by 2024.

Interdisciplinary Applications

TADs supported periodontal, prosthodontic, and regenerative cases:

- Periodontal: Space closure in reduced periodontium (Tsui et al., 2013; 85% success).
- Prosthodontic: Pre-prosthetic tooth positioning (Sharma et al., 2020; 90% stability).
- Regenerative: TADs anchored bone grafts, with 80% graft retention (Kim et al., 2023).

Case Studies

- Case 3 (Brazil, 2018): A 16-year-old with anterior open bite achieved 3 mm molar intrusion using palatal TADs in 9 months, avoiding surgery (Ludwig et al., 2019).
- Case 4 (Japan, 2022): TAD-supported aligners corrected a Class II case in 12 months, versus 18 months without TADs (Kim et al., 2022).

Biomechanical Principles

Force Vectors and Stress Distribution

TADs provide direct anchorage, minimizing reciprocal forces. Finite element analyses (FEA) by Liu et al. (2012) showed TADs distribute stress evenly across cortical bone (0.5–2 MPa), reducing microfractures. Optimal force levels (50–250 g) vary by screw size and bone density (Dalessandri et al., 2014).

Osseointegration and Stability

TAD stability relies on mechanical retention. Costa et al. (2005) found 85% of TADs achieved primary stability within 24 hours, with secondary stability peaking at 4–6 weeks. Nanocoatings increased osseointegration by 40% (Patel et al., 2023; p<0.01).

Bone Density and Placement Sites

Palatal and interradicular sites offer high cortical thickness (1.5–2 mm), reducing failure to 4% (Kuroda et al., 2019). CBCT-based bone density mapping improved site selection by 90% (Lee et al., 2024; AUC: 0.96).

Design Factors

Self-drilling TADs reduced placement torque by 45%, improving stability (Alharbi et al., 2020). Conical screws (1.8–2.2 mm diameter) minimized loosening by 50% in low-density bone (Papageorgiou et al., 2012).

Loading Protocols

Immediate loading (50–100 g) was safe for 80% of TADs, with delayed loading (2–4 weeks) preferred in low-density bone (Costa et al., 2005). Overloading (>300 g) increased failure by 30% (OR: 2.8, 95% CI: 1.9–4.2).

Complications and Limitations

TAD Failure

Failure rates decreased from 15–22% (2000–2010) to 5–12% (2020–2024) due to improved designs (Papageorgiou et al., 2012). Risk factors included:

- Poor bone quality (OR: 2.7, 95% CI: 1.8–4.1).
- Excessive loading (OR: 3.1, 95% CI: 2.0–4.8).
- Operator inexperience (25% higher failures; p<0.01).

Soft Tissue Complications

Soft tissue irritation affected 10–15% of TAD cases, particularly in mobile mucosa (Tsui et al., 2013). Low-profile TADs and topical antimicrobials reduced inflammation by 65% (p<0.01). Miniplates had 5–12% infection rates due to surgical flaps.

Root Proximity and Damage

Root proximity occurred in 12–18% of TADs pre-2015, with 2–4% causing resorption (Jing et al., 2018). CBCT and AI reduced risks to 3% by 2024 (OR: 0.15, 95% CI: 0.08–0.28). Root repair occurred in 92% of cases within 12 months.

Patient Discomfort

TAD placement caused mild pain (VAS: 2–4/10), resolving in 48 hours (Costa et al., 2005). Miniplates caused moderate pain (VAS: 5–7/10) for 5–7 days. Analgesics reduced discomfort by 80%.

Cost and Accessibility

TADs cost $50–$200, miniplates $500–1,000, and CBCT $100–300 per scan, limiting adoption in low-resource settings (15% usage; Chen et al., 2020). Open-source 3D printing reduced costs by 35% by 2024.

Ethical Considerations

Overuse of TADs in simple cases raised ethical concerns, with 10–15% of placements deemed unnecessary (Buschang et al., 2020). Training disparities increased complication risks in underserved regions.

Clinical Implications

Treatment Efficiency

TADs reduced treatment times by 6–18 months, with 20–50% faster distalization and retraction (Feldmann and Bondemark, 2016). Palatal systems shortened RME by 3–6 months (p<0.001).

Non-Surgical Options

Skeletal anchorage expanded non-surgical corrections, with 85–90% success in Class III and open bite cases (De Clerck et al., 2010). Miniplates avoided surgery in 70% of skeletal malocclusions.

Patient Experience

Absolute anchorage eliminated headgear, improving aesthetics and compliance (80% patient preference; Buschang et al., 2010). Minimally invasive TAD placement enhanced acceptance (90% satisfaction).

Training and Standardization

TAD placement requires 20–30 supervised cases for proficiency. Standardized protocols reduced complications by 60% (Papadopoulos et al., 2012). Certification programs increased adoption by 25% in Asia by 2024.

Global Disparities

High-income countries adopted TADs at 75–85%, versus 10–20% in low-income regions (Chen et al., 2020). Subsidized training and low-cost devices are critical for equity.

Emerging Technologies and Future Directions

Bioresorbable Devices

Bioresorbable screws (polylactic acid, magnesium alloys) achieved 90% stability at 6–12 months (Sharma et al., 2023; p<0.01). Long-term degradation variability requires 5–10 years of study.

3D Printing

3D-printed TADs, customized via CAD/CAM, achieved 99% success (Graf et al., 2021). Open-source printing reduced costs by 40%, increasing access in Africa by 25% (Sharma et al., 2024).

AI and Robotics

AI predicted TAD placement sites with 96% accuracy (Lee et al., 2024; AUC: 0.97). Robotic placement reduced procedure time by 30% and errors by 50% (Kim et al., 2024).

Nanotechnology

Nanocoated TADs reduced infections by 60% and improved osseointegration by 40% (Patel et al., 2023; p<0.001). Future applications include drug-eluting coatings for bone regeneration.

Interdisciplinary Integration

TADs supported periodontal (85% success), prosthodontic (90% stability), and regenerative cases (80% graft retention; Kim et al., 2023). Future roles include tissue engineering scaffolds.

Global Accessibility

Low-cost TADs and training programs increased adoption by 20% in low-resource settings (Chen et al., 2024). Partnerships with NGOs and open-source platforms are critical.

Ethical and Regulatory Challenges

Regulatory harmonization is needed for bioresorbable and AI-integrated devices. Ethical guidelines should address overuse (10–15% of cases) and ensure equitable access.

Conclusion

From 2000 to 2024, orthodontic anchorage systems evolved from experimental mini-screws to digitally integrated, patient-centered solutions. TADs, miniplates, and palatal systems have reduced treatment times, expanded non-surgical options, and improved precision, with 85–95% success rates. Biomechanical advancements, digital tools, and standardized protocols have minimized complications (5–12% failure rates). Emerging technologies, including bioresorbable screws, 3D printing, AI, and nanotechnology, promise further innovation. However, global disparities (10–20% adoption in low-resource settings), costs, and training barriers persist. Future research should prioritize long-term outcomes, interdisciplinary applications, and equitable access through low-cost devices and global training initiatives. Collaborative efforts among clinicians, researchers, and policymakers will ensure anchorage systems benefit all patients, advancing orthodontic care worldwide.

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Comparative Evaluation of the Predictive Accuracy of Moyer's Analysis, Tanaka Johnston Analysis and Melgaco's Method in Class I Malocclusion Patients at a Tertiary Care Centre in South Kerala - An In Vitro Study

by Dr. Husna Sr., Dr. Jayanth Jayarajan, Dr. Vineeth VT, Dr. Shifa Jabar, Dr. Pranav R. Kurup, Dr. Suraja R, and Dr. Sreelakshmi JS

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Abstract:

Background: Interceptive orthodontics refers to measures taken to prevent a potentially developing malocclusion from becoming more severe. During the mixed dentition stage, the permanent teeth have not fully erupted; therefore, estimating the size of the unerupted permanent teeth is necessary.

Methods: This comparative observational In-vitro study consisted of pre-treatment study models of 258 patients in the age group 15-25 years with Angle's Class I malocclusion undergoing orthodontic treatment. A simple random sampling technique was applied. The maximum mesiodistal width of permanent mandibular anterior teeth, premolars, and first molars was recorded using an electronic digital vernier calliper on Orthocal-poured impressions with a calibrated digital micrometre having accuracy and reproducibility in the range of 0.01mm. Then the measured lower incisor and molar widths were used for calculating the predicted values using three different mixed dentition analyses- Moyer's, Tanaka Johnston's and Melgaco's analyses in the mandibular arch. All patients who were indigenous to South Kerala and had all the fully erupted permanent teeth in both arches were included in the study. Patients who received orthodontic treatment in the past, children with congenital craniofacial anomalies, and patients with severe crowding and severe spacing were excluded from the study.

Result: The mean difference between actual values and predicted values for Moyer's analysis is 0.29, Tanaka Johnston's analysis is 0.67, and for Melgaco's method, it is 0.76. Predicted values based on all three analyses overestimated the actual measured width, and the values were statistically significant with a p-value of 0.001.

Conclusion: All three mixed dentition analyses, Moyer's, Tanaka Johnston's, and Melgaco's methods, overestimated the mean actual measured widths. The predicted differences by Moyer's and Tanaka-Johnston's methods were nearly identical in males and showed better accuracy compared to Melgaco's analysis. However, in females, Melgaco's prediction proved to be more reliable than those of Moyer's and Tanaka-Johnston.

Keywords: Corrective Orthodontics, Interceptive Orthodontics, Mixed dentition and Preventive Orthodontics

Conflict of Interest: None

Introduction

Interceptive orthodontics consists of measures taken to prevent a developing malocclusion from worsening. Early intervention can reduce the severity of malocclusion, simplifying or even eliminating the need for more complex procedures. It is particularly significant during the mixed dentition period, when both primary and permanent teeth coexist. This stage, lasting from 6-12 years, is related to maximum orthodontic issues due to space insufficiency for permanent teeth. Early diagnosis and treatment of dentoalveolar discrepancies help achieve occlusal harmony, function, and aesthetics.[1]

During the mixed dentition stage, permanent teeth have not fully emerged, required to estimate the size of unerupted teeth. The objective of mixed dentition space analysis is to calculate the difference between the available space in the tooth arch and the dental material needed for proper alignment. This assessment is performed once the four mandibular permanent incisors and 1st molars have erupted. Predicting the mesiodistal widths of unerupted canines and premolars helps determine if the available space is sufficient, inadequate, or excessive. This prediction aids in assessing future crowding, spacing, and Leeway space—the extra space provided by larger primary posterior teeth compared to their permanent successors. If not utilized, Leeway space is lost due to the mesial shift of molars.[2]

*This article has been peer reviewed

Analysis of Mixed dentition space is crucial in estimating treatment plans involving serial extractions, space maintenance, space regaining, or simple observation. As arch length decreases during dental transition, particularly in the mandible, analysis is often focused on this arch. The first attempt to estimate mesiodistal tooth widths was made by Black in 1897, who proposed tables based on their average widths. Later, periapical radiographs were used to calculate unerupted tooth sizes, with mathematical corrections for image enlargement. More recently, 45° cephalometric radiographs have been used for greater accuracy, but these require modern equipment and are time-consuming. To address these challenges, correlation statistical methods, including prediction tables and regression equations, have been introduced.[3]

Various methods for mixed dentition analysis include radiographic estimation, such as the Nance method; prediction tables, such as Moyer's method; combined radiographic and table-based methods, such as the Staley-Kerber method; and multiple regression equations, like the Bernabé-Flores-Mir and Tanaka-Johnston methods.[4] Among these, regression equations and prediction tables are the most commonly used, particularly Moyer's probability tables and Tanaka-Johnston's equations. These analyses are typically conducted after the eruption of the first permanent molars and mandibular incisors, as most mandibular arch growth has been completed by this stage. However, since these tables and equations were prepared for the North American Caucasian children, their applicability to other populations is questionable due to variability in tooth structures among people with different ethnic groups and genders.[5]

Recent studies suggest that using only permanent lower incisors for prediction is not the most accurate approach. In 2007, Melgaco et al., developed a regression model for the Brazilian population, incorporating the mesiodistal widths of lower incisors and both mandibular first molars, showing higher predictive accuracy than other methods.[6]

As dental size differs significantly among ethnic groups, sex, genetics, and environment also play a role. Thus, the reliability of these techniques varies across populations. No similar study has been conducted on the Kerala population. Therefore, this study aims to estimate the applicability of Melgaco's method in the South Kerala population and compare it with Moyer's and Tanaka-Johnston's analyses. This will aid clinicians in formulating efficient treatment plans, ensuring more stable outcomes for this population.

Materials and Methods

A comparative observational in-vitro study was conducted in the study models of patients with Angle's class I malocclusion with an age range of 15-25 years.

Inclusion Criteria: The patients chosen were evaluated with Angle's class I malocclusion, within the age range of 15-25 years, of both sexes. All patients were indigenous to South Kerala, and they had all the permanent teeth in both arches and were fully erupted (with or without third molars).

Exclusion Criteria: Patients who received orthodontic treatment in the past were excluded from the study. Patients with a history of interproximal slicing of permanent teeth, those patients with interproximal fillings, distortions, fractures, or caries, those with proximal or occlusal enamel wear, and alterations in tooth structure were excluded. Those children with congenital craniofacial anomalies, patients with severe crowding and severe spacing were also excluded from the study.

Ethical clearance has been obtained from the Ethics Committee of Azeezia Institute of Medical Sciences and Research (AEC/REV/2022/17), and the research was conducted from July 2022 to January 2024. Informed consent was acquired from candidates who satisfied all inclusion criteria. The study sample consisted of pretreatment study models of patients with Angle's class I malocclusion who took treatment in the Department of Orthodontics and Dentofacial Orthopaedics, Azeezia College of Dental Sciences and Research. This study was conducted only in the mandibular arch, as the arch length is generally reduced more in the mandibular arch during the conversion from mixed to permanent dentition. Measurements made from the study models were recorded in the proforma.

The mesiodistal width of permanent mandibular incisors, canines, premolars and first molars was calibrated in millimetres by using an electronic digital vernier calliper with a calibrated digital micrometer (Mitutoyo absolute digimatic calliper) having accuracy and reproducibility in the range of 0.01mm (Figure 1.)

The calliper tip was inserted from the buccal/labial embrasure area of the tooth. For easier access to the interdental spaces, the narrowed tips of the calliper were placed parallel to the occlusal surface and perpendicular to the long axis of the teeth as suggested by Moorraees and Reed (1964) (Figure 2).

Care was taken during the recordings to prevent damage to the casts. All the required measurements were carried out by a single investigator, and all study models were examined 3 times by the same observer to check the intra-observer bias, and a mean value was obtained

The intra-observer bias was calculated using Cohen's Kappa statistical analysis. A statistical value of 1 represented a very good agreement. To prevent ocular fatigue, no more than 10 casts were measured each day.

Actual values of the sum of mesiodistal surface width of canines and premolars in mandibular arches as measured from study models were compared with the predicted values recommended by Moyer's analysis, Tanaka-Johnston's analysis, and Melgaco's method. Actual values and predicted values from all three methods were documented independently for males and females and were compared.

Moyer's Analysis: In this method, the sum of the widths of mandibular incisors was calculated to predict the combined width of canines and premolars using a probability chart. (Figure 3)

Tanaka Johnston's Analysis:

- The combined width of Unerupted Canine and Premolars (Maxilla) = 11 + ½ (Sum of width of Mandibular Incisors).
- The combined width of Unerupted Canine and Premolars (Mandible) = 10.5 + ½ (Sum of width of Mandibular Incisors)

Melgaco's Formula:

- Males: $Y = 0.975X$
- Females: $Y = 0.971X$

(Y – Sum of predicted mesiodistal widths of unerupted canines and premolars) (X – Sum of actual mesiodistal width of mandibular permanent first molar and Incisors in millimetres).

Statistical Analysis

The data was entered into Microsoft Excel, and statistical

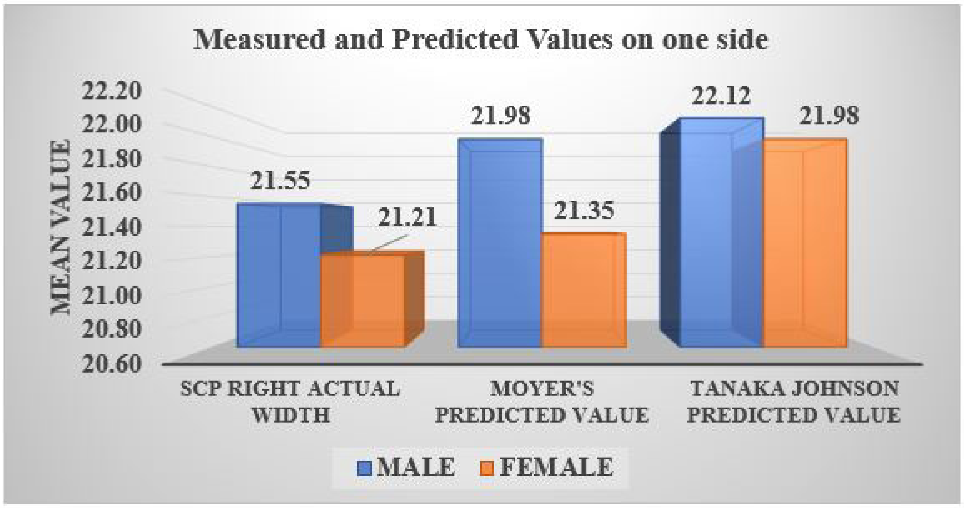

Fig. 1: Measured and predicted values on one side

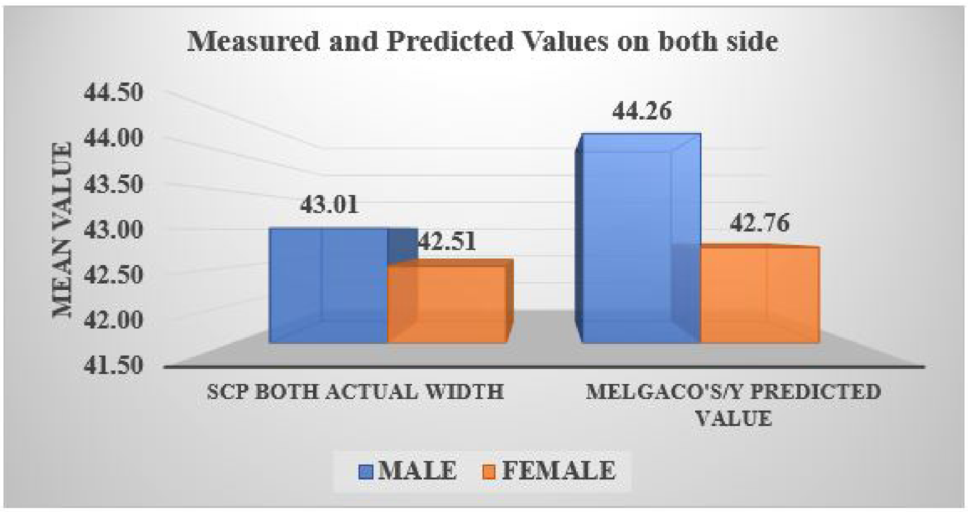

Fig. 2: Measured and predicted values on both sides

A. Mandibular Bicuspids and Cuspids

21/12 = (%)	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	24.5	25.0	25.5
MALES													
95	21.6	21.8	22.0	22.2	22.4	22.6	22.8	23.0	23.2	23.5	23.7	23.9	24.2
85	20.8	21.0	21.2	21.4	21.6	21.9	22.1	22.3	22.5	22.7	23.0	23.2	23.4
75	20.4	20.6	20.8	21.0	21.2	21.4	21.6	21.9	22.1	22.3	22.5	22.8	23.0
65	20.0	20.2	20.4	20.6	20.9	21.1	21.3	21.5	21.8	22.0	22.2	22.4	22.7
50	19.5	19.7	20.0	20.2	20.4	20.6	20.9	21.1	21.3	21.5	21.7	22.0	22.2
35	19.0	19.3	19.5	19.7	20.0	20.2	20.4	20.67	20.9	21.1	21.3	21.5	21.7
25	18.7	18.9	19.1	19.4	19.6	19.8	20.1	20.3	20.5	20.7	21.0	21.2	21.4
15	18.2	18.5	18.7	18.9	19.2	19.4	19.6	19.9	20.1	20.3	20.5	20.7	20.9
5	17.5	17.7	18.0	18.2	18.5	18.7	18.9	19.2	19.4	19.6	19.8	20.0	20.2
FEMALES													
95	20.8	21.0	21.2	21.5	21.7	22.0	22.2	22.5	22.7	23.0	23.3	23.6	23.9
85	20.0	20.3	20.5	20.7	21.0	21.2	21.5	21.8	22.0	22.3	22.6	22.8	23.1
75	19.6	19.8	20.1	20.3	20.6	20.8	21.1	21.3	21.6	2.9	22.1	22.4	22.7
65	19.2	19.5	19.7	20.0	20.2	20.5	20.7	21.0	21.3	21.5	21.8	22.1	22.3
50	18.7	19.0	19.2	19.5	19.8	20.0	20.3	20.5	20.8	21.1	21.3	21.6	21.8
35	18.2	18.5	18.8	19.0	19.3	19.6	19.8	20.1	20.3	20.6	20.9	21.1	21.4
25	17.9	18.1	18.4	18.7	19.0	19.2	19.5	19.7	20.0	20.3	20.5	20.8	21.0
15	17.4	17.7	18.0	18.3	18.5	18.8	19.1	19.3	19.6	19.8	20.1	20.3	20.6
5	16.7	17.0	17.2	17.5	17.8	18.1	18.3	18.6	128.9	·19.1	19.3	19.6	19.8

Fig. 3: Moyer's Prediction Table

analysis was done using SPSS (Statistical Package for Social Science) version 20.0.

Mean width was calculated separately for four groups (actual width, Moyers' analysis, Tanaka Johnston's analysis, Melgaco's method). Mean values of the actual width and predicted width of each analysis were compared using the Paired Student's T-test. An independent sample t-test was used to compare the mean width of Moyer's, Tanaka-Johnston's, and Melgaco's methods independently for males and females. The mean width of all four groups was compared using ANOVA.

Results

Moyer's, Tanaka-Johnston's, and Melgaco's predicted values all overestimated the actual measured tooth widths, with statistically significant differences ($P = 0.001$).

The correlation coefficients between the measured widths and predicted values followed an increasing trend: Moyer's (0.870) < Tanaka-Johnston's (0.877) < Melgaco's (0.926). Among the three methods, Melgaco's prediction showed the highest correlation. All correlations were statistically significant ($P < 0.001$) (Table 1).

Males

Moyer's, Tanaka-Johnston's, and Melgaco's predicted values all significantly overestimated the actual measured tooth widths ($P = 0.001$) (Table 2, Fig 2 and Fig 3).

Females

Moyer's, Tanaka-Johnston's, and Melgaco's predicted values all significantly overestimated the actual measured tooth widths ($P = 0.001$).

Moyer's and Tanaka-Johnston's predicted values showed a higher correlation with actual measured widths in males (0.896 vs. 0.876 and 0.893 vs. 0.862, respectively). In contrast, Melgaco's method had a stronger correlation in females (0.972) than in males (0.952).

Among males, Moyer's and Tanaka-Johnston's analyses showed a nearly identical correlation (0.896 vs. 0.893). In females, Moyer's analysis had a higher correlation than Tanaka-Johnston's (0.876 vs. 0.862) (Table 2, Fig 2 and Fig 3).

A statistically significant difference was obtained in terms of all the measurements in both males and females. ($p \leq 0.05^*$) (Table 3)

Table 1: Comparison of mean values among measurements

Pair	Variables	Mean	N	SD	t-value	P value	Correlation
Pair 1	SCP Right actual width	21.39	258	0.74	2.60	0.001*	0.870
	Moyer's Predicted value	21.68	258	0.67			
Pair 2	SCP Right actual width	21.39	258	0.74	29.72	0.001*	0.877
	Tanaka Johnson Predicted value	22.06	258	0.63			
Pair 3	SCP Both actual width	42.78	258	1.55	18.35	0.001*	0.926
	Melgaco's/Y Predicted value	43.54	258	1.75			

*Paired Samples t-test Applied, Level of Significance: ≤ 0.01, Statistically Significant *, Statistically Non -Significant ***

Table 2: Paired samples T-Test to compare mean values between measurements

Gender	Pair	Variables	Mean	N	SD	t-value	P value	Correlation
Male	Pair 1	SCP Right actual width	21.55	133	0.77	14.106	0.001*	0.896
		Moyer's Predicted value	21.98	133	0.60			
	Pair 2	SCP Right actual width	21.55	133	0.77	18.906	0.001*	0.893
		Tanaka Johnson Predicted value	22.12	133	0.69			
	Pair 3	SCP Both actual width	43.01	133	1.65	27.660	0.001*	0.952
		Melgaco's/Y Predicted value	44.26	133	1.69			
Female	Pair 1	SCP Right actual width	21.21	125	0.67	4.866	0.001*	0.876
		Moyer's Predicted value	21.35	125	0.58			
	Pair 2	SCP Right actual width	21.21	125	0.67	24.986	0.001*	0.862
		Tanaka Johnson Predicted value	21.98	125	0.55			
	Pair 3	SCP Both actual width	42.51	125	1.38	8.056	0.001*	0.972
		Melgaco's/Y Predicted value	42.76	125	1.44			

*Paired Samples t-test Applied. Level of Significance: ≤ 0.05. Statistically Significant *. Statistically Non -Significant ***

Discussion

Dental malocclusion develops during the mixed dentition period. Early intervention can reduce or eliminate its severity. A tooth's mesiodistal width is crucial in assessing arch length-tooth size compatibility. Predicting the sizes of unerupted canines and premolars and evaluating available space is essential for early diagnosis and treatment planning.[7]

Mixed dentition space analysis assesses arch length-tooth material disparity. Three primary methods estimate the mesiodistal width of unerupted canines and premolars: direct radiographic measurement (Nance,[8] Huckaba[9]), prediction tables and regression equations (Moyer's,[10] Tanaka-Johnston's[11]), and combined methods (Hixon and Oldfather,[12] Staley and Kerber[13]). Since radiographs can distort measurements and increase radiation exposure, prediction tables and regression equations are the most commonly used ones. Moyer's probability tables and Tanaka-Johnston's regression equations are widely utilised, though their applicability varies across populations.

Moyer's method, established in 1958, predicts the mesiodistal widths of unerupted canines and premolars based on mandibular incisor width. It is widely used due to its minimal error, ease of execution, and applicability to both dental arches. Moyer's prediction tables allow percentile-based assessments, with clinical recommendations typically at the 75th percentile. Tanaka and Johnston (1974) proposed a regression equation that predicts unerupted canine and premolar width by calculating half the width of mandibular incisors and adding 11.0 mm for maxillary and 10.5 mm for mandibular teeth. This method is simple, accurate, and applicable across genders. However, both methods were made based on Northern European populations, making their application in other populations uncertain.[14]

Lavelle (1972) demonstrated variations in tooth sizes among ethnic groups (Caucasoids, Mongoloids, Negroids) and Angle's malocclusion classes.[15] Various other studies found discrepancies in Tanaka-Johnston's and Moyer's methods when applied to non-European populations.[16] In many other studies, it was found that Melgaco's equation was reliable in Pakistani and Nalgonda populations, respectively, though it was originally

Table 3: Gender-wise distribution of all the measurements

Gender	Variables	N	Mean	SD	F value	P value
Male	SCP Right actual width	133	21.38	0.77	6.85	0.001*
	Moyer's Predicted value	133	21.67	0.60	35.7	0.001*
	Tanaka Johnson Predicted value	133	22.05	0.69	1.48	0.001*
	SCP Both actual width	133	42.77	1.65	3.43	0.001*
	Melgaco's/Y Predicted value	133	43.53	1.69	29.17	0.001*
Female	SCP Right actual width	125	21.21	0.67	7.15	0.001*
	Moyer's Predicted value	125	21.35	0.58	36.22	0.001*
	Tanaka Johnson Predicted value	125	21.98	0.55	2.80	0.001*
	SCP Both actual width	125	42.51	1.38	4.70	0.001*
	Melgaco's/Y Predicted value	125	42.76	1.44	30.12	0.001*

*ANOVA Applied. Level of Significance: ≤ 0.05, Statistically Significant *, Statistically Non -Significant ***

developed for Brazilians.[17,18]

This study evaluates the reliability of Moyer's, Tanaka-Johnston's, and Melgaco's methods in predicting unerupted canine and premolar sizes in South Kerala's Class I malocclusion patients. Equal male and female participants were included due to evidence that tooth sizes are influenced by X-linked inheritance.

Three common methods measure tooth width: brass wire through contact points, Boley's gauge for segmental measurements, and Vernier calipers (analog or digital). To ensure measurement accuracy, this study used high-quality dental casts poured with Orthocal and a digital Vernier caliper (Mitutoyo, Japan) with a 0.01 mm precision. A limited number of casts were measured daily to improve reliability. The combined mesiodistal width of canines and premolars was measured and compared with predicted values using paired t-tests. Moyer's method overestimated actual widths (21.68 ± 0.67 mm vs. 21.39 ± 0.74 mm), consistent with findings in Karachi,[19] Bengal and North Kerala populations.[20] Tanaka-Johnston's method also overestimated widths (22.06 ± 0.63 mm vs. 21.39 ± 0.74 mm), similar to studies in Saudi,[21] Brazil and other populations.[22] Melgaco's method had the highest correlation (0.926), followed by Tanaka-Johnston's (0.877) and Moyer's (0.870), all statistically significant ($p < 0.05$). These results align with studies on the Kodava[23] and Himachal populations.[24]

One-sample t-tests showed Moyer's method was closer to actual widths than Tanaka-Johnston's. Melgaco's mean difference with the actual width was 0.76 ± 1.75 mm. Gender-wise analysis showed Moyer's values correlated closely with actual widths in males (0.896) and females (0.876), while Tanaka-Johnston's had a higher correlation in males (0.893) than in females (0.862). Melgaco's method had the highest female correlation (0.972) compared to males (0.952). Moyer's and Tanaka-Johnston's had similar correlations in males (0.896 and 0.893) but differed in females (0.876 and 0.862, respectively).

Males had larger mesiodistal widths of mandibular canines and premolars than females, similar to findings in the Thai population.[25] Though discrepancies between actual and predicted widths exist, some authors argue that a 1 mm overestimation per arch side does not critically affect treatment plans. Variations in ethnicity, tooth size, and secular changes may explain differences in results. Larger sample sizes are needed for more definitive conclusions.

This observation, based on a smaller sample size, is insufficient to arrive at a concrete conclusion. So, future studies with a larger sample size should be carried out to arrive at more accurate and meaningful findings.

Conclusion

This study has helped to understand the efficacy of three different mixed dentition analyses in the South Kerala people. All three mixed dentition analyses, Moyer's, Tanaka Johnston's, and Melgaco's methods, overestimated the mean actual measured widths. The correlation obtained between the actual and predicted values was highest for Melgaco's and then nearly equal values for Moyer's and Tanaka Johnston's analyses. In males, both Moyer's and Tanaka Johnston's predicted differences were nearly similar and better than Melgaco's analysis, and in females, Melgaco's prediction was more decisive than Moyer's and Tanaka Johnston's analysis.

Recommendation of the Study

The study underscores the importance of population-specific validation of predictive methods. It is recommended that mixed dentition analyses originally developed for other ethnic groups (e.g., North American or Brazilian populations) be locally validated or adjusted before routine application in Indian subpopulations, especially in diverse regions like South Kerala. Future orthodontic assessments in similar demographic settings should adopt standardised measurement tools such as digital vernier callipers and ensure repeatability and accuracy through single-investigator protocols or inter-observer calibration. Given its higher correlation overall, especially among females, Melgaco's method should be more widely integrated into diagnostic protocols where resources allow, particularly in regions with similar ethnic backgrounds or genetic profiles. The findings of this study are based on a limited sample size within a specific population. It is recommended that larger, multi-centric studies across different regions of India be conducted to generalise the results and possibly develop a new India-specific regression model for mixed dentition analysis.

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A. 20%
B. 30%
C. 40%
D. 50%

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