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Review Article

Factors influencing treatment duration of impacted permanent maxillary canine- Literature review

Abhishek A Rathod

Ex. Assistant Professor, Government Dental College, Mumbai, Maharashtra, India

Abstract:
Impaction of the permanent maxillary canine is a common clinical problem in orthodontics and is frequently associated with prolonged and complex treatment. The duration of treatment required to align impacted maxillary canines varies considerably and depends on multiple interrelated factors. Prolonged treatment time not only increases the biological and mechanical risks associated with orthodontic therapy but also affects patient compliance, satisfaction, and overall treatment outcomes. Understanding the determinants of treatment duration is therefore essential for effective treatment planning and patient counseling.This narrative review aims to evaluate and summarize the factors influencing the duration of orthodontic treatment for impacted permanent maxillary canines. A comprehensive search of the literature was conducted using electronic databases including PubMed, Scopus, and Web of Science. Relevant studies published up to 2025 were reviewed, including clinical trials, observational studies, retrospective analyses, and systematic reviews that assessed treatment duration or predictors of prolonged management.The literature identifies several key factors affecting treatment time. Anatomical and positional characteristics of the impacted canine—such as angulation, depth of impaction, vertical and horizontal position, proximity to adjacent tooth roots, and palatal or labial location—are among the most significant predictors. Patient-related factors including age at diagnosis, growth status, and biological response to orthodontic forces also play an important role. Treatment-related variables such as timing of intervention, space availability, surgical exposure technique, anchorage management, force magnitude, and the use of adjunctive procedures significantly influence treatment efficiency. Advances in diagnostic imaging, particularly cone beam computed tomography, have improved treatment planning accuracy and contributed to reduced treatment duration.In conclusion, treatment duration of impacted permanent maxillary canines is multifactorial and influenced by patient-specific, anatomical, and clinical variables. Early diagnosis and individualized, evidence-based treatment approaches are critical for minimizing treatment time and optimizing clinical outcomes.

Keywords: Impacted maxillary canine, treatment duration, orthodontic biomechanics, surgical exposure, eruption path, predictors of treatment time.

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Corresponding Author: Abhishek A Rathod, Ex. Assistant Professor, Government Dental College, Mumbai, Maharashtra, India

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INTRODUCTION

The permanent maxillary canine plays a pivotal role in dental esthetics, arch integrity, and functional occlusion due to its strategic position, long root length, and contribution to canine guidance. However, eruption of the maxillary canine follows a complex and prolonged developmental pathway, making it particularly susceptible to eruption disturbances. Impaction of the permanent maxillary canine is one of the most frequently encountered orthodontic anomalies after third molar impaction, with a reported prevalence ranging from 1% to 3% in the general population. The condition poses significant diagnostic and therapeutic challenges and is often associated with extended orthodontic treatment duration (1,2).

The management of impacted maxillary canines typically involves a combination of orthodontic and surgical procedures, including space creation, surgical exposure, and guided orthodontic traction. Despite advances in diagnostic imaging and biomechanical techniques, treatment duration remains highly variable and unpredictable. Prolonged treatment not only increases the risk of complications such as root resorption, periodontal damage, and patient non-

compliance, but also has psychological, financial, and biological implications for patients and clinicians alike. Consequently, understanding the factors that influence treatment duration is of paramount importance for effective treatment planning and outcome optimization (3,4).

Several patient-related factors have been implicated in determining the length of treatment for impacted maxillary canines. Age at diagnosis and initiation of treatment is a critical determinant, as younger patients generally demonstrate more favorable biological responses and greater eruptive potential compared to adults. Skeletal maturity, growth status, and individual variability in bone density and metabolic response to orthodontic forces further influence the rate of tooth movement. Delayed diagnosis, particularly after root development is complete, has been consistently associated with increased treatment complexity and prolonged therapy (5,6).

Anatomical and positional characteristics of the impacted canine constitute some of the most influential predictors of treatment duration. Factors such as the depth of impaction, angulation relative to the midline, vertical and horizontal displacement, proximity to adjacent incisor roots, and palatal or labial position significantly affect the ease of orthodontic traction (7). Palatally impacted canines, which account for the majority of cases, often require longer treatment time due to their deeper position and complex biomechanical requirements (8). Additionally, associated dental anomalies such as peg-shaped lateral incisors, missing teeth, or arch length discrepancies may further complicate treatment (9).

Treatment-related variables also play a decisive role in determining the duration of therapy. The timing of surgical exposure, choice between open and closed eruption techniques, method of force application, anchorage management, and magnitude and direction of orthodontic forces all influence treatment efficiency. Inadequate anchorage or suboptimal force systems may lead to unwanted tooth movement and prolonged treatment. Furthermore, patient compliance with appointments, appliance wear, and oral hygiene instructions is a critical determinant of treatment progress, particularly in lengthy orthodontic interventions (10,11).

Recent advancements in diagnostic technologies, especially cone beam computed tomography (CBCT), have significantly improved three-dimensional localization of impacted canines and assessment of their relationship with adjacent anatomical structures. Accurate imaging facilitates precise risk assessment, individualized biomechanical planning, and early identification of potential complications, thereby contributing to more efficient treatment and reduced duration. Adjunctive techniques such as temporary anchorage devices, corticotomy-assisted orthodontics, and accelerated tooth movement protocols have also been explored to shorten treatment time in selected cases (12-14).

Given the multifactorial nature of treatment duration for impacted permanent maxillary canines, a comprehensive understanding of the influencing factors is essential for clinicians. This narrative review aims to critically analyze and synthesize existing literature on patient-related, anatomical, diagnostic, and treatment-related factors affecting treatment duration. By identifying key predictors and modifiable variables, this review seeks to provide evidence-based guidance to orthodontists for optimizing treatment efficiency, minimizing complications, and improving patient outcomes (15).

Early Concepts and Conservative Approaches

Historically, impacted maxillary canines were treated conservatively or not at all unless they caused pathology such as cyst formation, resorption of adjacent teeth, or infection. Early orthodontists often avoided aggressive traction due to concerns about root resorption, periodontal damage, and unpredictable response to force application. Treatment strategies focused on observation or extraction when impaction caused pathology.

Pioneering works such as those by **Ericson and Kurol** developed classification systems and predictive indices for canine impaction, establishing the need for early diagnosis and influencing treatment timing. Their classic studies emphasized panoramic radiographic predictors, such as the canine angulation relative to the midline and cusp tip overlap with adjacent incisors, as correlates of treatment difficulty and duration (16).

Principles of Treatment Duration

Early literature (pre-2000) suggested that impacted canine treatment duration was primarily influenced by two broad factors:

1. **Biological Response:** The rate of tooth movement varies with age, cellular activity of the periodontal ligament, and bone remodeling capacity.
2. **Mechanical Challenges:** Incorrect mechanics, poor anchorage, or inadequate space creation could drastically prolong treatment.

However, early studies lacked uniform outcome measures, and treatment protocols were heterogeneous, making direct comparison and prediction difficult (17).

Factors Influencing Treatment Duration: Detailed Literature Review

1. Patient-Related Variables

Age and Skeletal Maturity (18)

One of the most consistently reported factors affecting treatment time is **patient age**. Younger patients exhibit higher osteoclastic and osteoblastic activity, facilitating more rapid orthodontic movement. In contrast, adults and older adolescents generally show slower biological responses, prolonging treatment time.

A longitudinal cohort study found that canines in patients under 14 years erupt spontaneously or respond rapidly to traction, whereas eruption in older adolescents and adults often requires extended force systems and longer traction times. Bone density increases with age, and the reduced remodeling capacity in adults likely contributes to lengthier treatment.

Early intervention—ideally during mixed dentition or early permanent dentition—has been advocated to reduce treatment duration and complexity.

Gender Differences

Evidence on gender impact is inconclusive. Some studies report slight delays in males, possibly linked to later skeletal maturation, whereas others find no significant gender effect on treatment time (19).

2. Anatomical and Positional Factors

Degree of Impaction and Angulation (20)

The **angulation of the impacted canine** relative to the midline or the occlusal plane is a robust predictor of treatment duration. Increased mesiodistal angulation requires more complex mechanics and often longer traction time. A systematic review noted that for every 10° increase in angulation, total treatment time increased significantly.

For instance:

- Mildly angled canines, tipping towards the eruption pathway, often align within 6–9 months.
- Severely angulated canines (>45°) may require 12–24 months of orthodontic traction and alignment.

Vertical and Horizontal Position

Distance from the occlusal plane and horizontal displacement also influence duration:

- High impactions (farther from occlusal plane) have increased path length for traction.
- Palatally impacted canines tend to respond slower compared to buccally positioned ones due to thicker cortical bone and less favorable force vectors.

Radiographic studies demonstrate that teeth located centrally over the midline or overlapping lateral incisors often require more intricate mechanics, increasing treatment time (21).

Proximity to Adjacent Roots

Impacted canines that are in close contact with adjacent incisor roots risk root resorption and complicate traction. In such cases, clinicians often apply lighter forces and slower traction to prevent iatrogenic damage, extending overall treatment duration.

3. Diagnostic Imaging and Predictive Assessment (8,22)

Panoramic Versus Cone Beam Computed Tomography (CBCT)

Historically, panoramic radiographs were the mainstay in evaluating impactions. They provide general localization and angulation but are limited in three-dimensional assessment. Several studies indicate that panoramic imaging alone underestimates proximity to adjacent structures, which can lead to unforeseen challenges and longer treatment times.

With the advent of **CBCT**, clinicians gained precise 3D localization of impacted canines, enabling:

- Improved assessment of spatial relationships
- Early detection of root resorption in adjacent teeth
- Accurate planning of surgical exposure pathways

Studies show that **CBCT-guided planning reduces treatment time** by informing more efficient mechanics and minimizing trial-and-error adjustments mid-treatment.

4. Space Management and Arch Preparation (8,23)

Adequate **space creation** in the dental arch prior to or during traction is critical. Lack of space leads to:

- Unwanted incisor proclination
- Mesial displacement of adjacent teeth
- Necessity for space opening mechanics or extraction, all of which prolong treatment.

Space can be created through:

- Extraction of premolars or deciduous canines
- Arch expansion
- Interproximal reduction

Controlled space management — especially when initiated early — correlates with shorter treatment times.

5. Surgical Exposure Techniques (24)

Open vs. Closed Exposure

Surgical exposure is necessary when the impacted canine fails to erupt spontaneously. The two main approaches are:

- **Open Exposure:** The canine is uncovered surgically, and an attachment is bonded immediately.
- **Closed Exposure:** After exposure, the flap is repositioned and traction is applied via a bonded attachment beneath the gingiva.

Evidence suggests that **closed exposure techniques** often result in shorter treatment times. Closed exposure preserves keratinized gingiva, reduces tissue remodeling, and provides more controlled force application. In contrast, open exposure can have slower traction response due to scar formation and reduced periodontal support.Meta-analyses comparing both techniques show that closed exposure reduces treatment time by up to 20% in cases with palatal impactions.

6. Orthodontic Mechanics and Anchorage (9)

Force Magnitude and Direction

Light, continuous forces are foundational in minimizing biological resistance and preventing root resorption. Excessive forces, often applied in attempts to expedite treatment, paradoxically slow movement by compressing periodontal ligament blood flow and delaying remodeling.

Orthodontic literature supports the use of **bio-compatible force vectors** oriented to:

- Minimize tipping
- Encourage bodily movement
- Reduce periodontal stress

Anchorage Strategies (11)

Using effective anchorage systems — including headgear, transpalatal arches, and modern skeletal anchorage (miniscrews/TADs) — provides stable resistance units during canine traction. Skeletal anchorage, in particular, reduces reciprocal movements and undesired tooth drift, shortening overall treatment time.

A randomized clinical study demonstrated that TAD-supported mechanics reduced total treatment duration by over 15% compared to conventional anchorage in impacted canine cases.

7. Adjunctive and Accelerative Therapies (16, 27)

Corticotomy and Periodontal Accelerated Osteogenic Orthodontics (PAOO)

Surgical adjuncts such as corticotomy enhance bone turnover, reducing resistance to tooth movement. PAOO has been shown to significantly accelerate alignment in impacted canine cases when combined with controlled forces.

Clinical trials report up to 25–40% reduction in treatment time using corticotomy-assisted protocols, particularly in adult patients with slower remodeling dynamics.

Laser and Vibration Modalities

Emerging adjunctive therapies — such as low-level laser therapy (LLLT) and vibrational devices — have been investigated for enhancing cellular response. While individual studies indicate modest reductions in movement time, larger controlled trials are ongoing to validate efficacy conclusively.

8. Patient Compliance and Behavioral Factors (23, 27)

Patient behavior — including attendance at appointments, maintenance of oral hygiene, and adherence to instructions (e.g., wearing elastics) — indirectly influences treatment duration. Poor compliance often leads to:

- Breakages
- Plaque accumulation and gingival inflammation
- Delays in force application and mechanical adjustments

Orthodontic practice research stresses patient education and motivation as criticalcomponents in minimizing unnecessary treatment extensions.

9. Interdisciplinary Coordination

Impacted canine treatment often involves surgical, periodontal, and restorative disciplines. Efficient interdisciplinary collaboration can reduce redundant appointments and streamline sequence of care. For example:

- Coordinated timing of surgical exposure and orthodontic forces
- Shared diagnostic planning with CBCT
- Periodontal maintenance to prevent inflammation

Studies show that interdisciplinary planning reduces overall treatment time and enhances outcomes.

10. Future Perspectives

Advanced Imaging and Prognostic Models

Integration of 3D imaging (CBCT) allows precise assessment of canine orientation and proximity to adjacent roots, enabling development of predictive algorithms for treatment duration. Machine learning models trained on large data sets could provide individualized time estimates.

Biological Modulators of Tooth Movement

Research into biomolecules (e.g., prostaglandins, low-dose laser therapy) and pharmacologic agents that modulate bone remodeling may accelerate tooth movement without increased risk.

Improved Biomechanical Systems

Orthodontic systems that combine robotics or smart wires that adjust force vectors automatically could optimize traction efficiency. Customized appliances from digital planning platforms may reduce chair time and uncertainties.

Patient-Centered Outcome Measures

Future studies should incorporate patient-reported outcomes like pain, quality of life, and satisfaction, alongside traditional clinical endpoints, to better tailor treatment plans.

Genetic and Molecular Predictors

Identifying genetic markers associated with eruption difficulty may allow early stratification of patients for targeted interventions

CONCLUSION

The treatment duration of impacted permanent maxillary canines is influenced by a complex interplay of biological, anatomical, diagnostic, mechanical, and behavioral factors. Early detection, precise imaging, appropriate surgical exposure, controlled biomechanics, effective anchorage, and patient compliance each contribute to reducing treatment time and improving outcomes. Interdisciplinary collaboration and emerging

adjunctive therapies offer promising avenues for further optimization. A personalized, evidence-based approach to treatment planning is essential to manage impacted canines efficiently, safely, and with predictable timelines.

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