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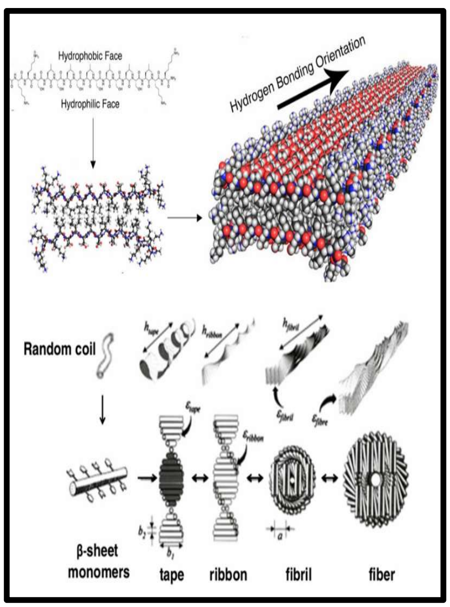

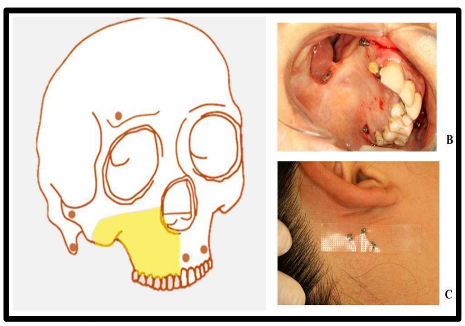

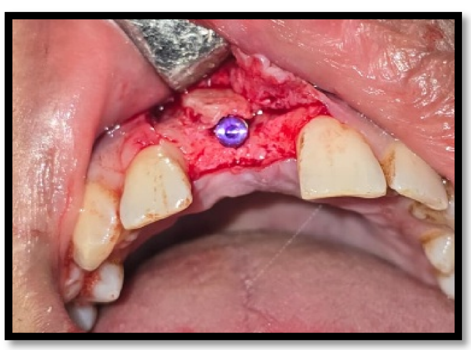

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From the Desk of Editor-in-Chief

With immense pleasure I would like to announce that we are publishing the Volume 07 (Issue 02 – July - Dec 2025) of MIDSR Journal of Dental Research after the successful publication of six volumes. I would like to extend my heartfelt thanks to the authors and our management for their constant faith in me and their utter support.

The Volume 07 (Issue 02 - July – Dec 2025) has been created with the great efforts of providing the quality manuscripts rather than the quantity, the volume contains original articles . It is my great pleasure to welcome you to this edition of our publication. Every issue represents a collective effort driven by dedication, creativity, and a commitment to delivering meaningful and engaging content.

In a world where information is abundant, our goal is to provide insights that are accurate, inspiring, and thought-provoking. We believe that every article has the power to inform, encourage dialogue, and broaden perspectives.

I extend my sincere gratitude to our contributors, editorial team, reviewers, and readers for their unwavering support and trust. Your encouragement motivates us to continually raise the standards of excellence in our work.

As you explore these pages, I hope you discover ideas that inspire, stories that resonate, and knowledge that enriches your understanding. We remain committed to serving our readers with integrity, quality, and purpose.

I dedicate this issue to all the faculty members of MIDSR Dental College, Latur who immediately responded to the call for manuscripts and submitted their valuable work to the journal.

Dr. Suresh K. Kangane
Principal,
MIDSR Dental College, Latur

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ORIGINAL ARTICLES

Dental Professionals' Perspectives on Integrating Special Healthcare Needs Clinics in Dental Colleges: A Cross-Sectional Survey

Dr. Shraddha N. Kasture[1], Dr. Yogesh J. Kale[2], Dr. Mahesh V. Dadpe[3], Dr. Prasanna T. Dahake[4], Dr. Shrikant B. Kendre[5]
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Abstract:
Background: Individuals with Special Health Care Needs (SHCN) experience complex oral health problems and face significant barriers to accessing appropriate dental care due to limited training, inadequate infrastructure, and lack of organized services. Dental colleges, as tertiary care and training centres, may help address these challenges through dedicated SHCN clinics.
Aim: To assess dentists' perceptions regarding the need, feasibility, benefits, and challenges of establishing SHCN clinics in dental colleges.
Materials and Methods: A cross-sectional, questionnaire-based study was conducted among dental professionals from various specialties and practice settings. A structured questionnaire assessing demographics, exposure to SHCN patients, oral health problems, management challenges, and perceptions regarding SHCN clinics was distributed electronically. Data from 106 respondents were analyzed using descriptive statistics.
Results: Most respondents reported encountering SHCN patients in routine practice and experiencing difficulty in their management. Commonly reported oral health problems included dental caries, gingivitis, periodontal disease, malocclusion, and dental anomalies. Key challenges were lack of specialized training, time constraints, complex medical histories, caregiver-related stress, and inadequate infrastructure. A majority of dentists considered SHCN clinics in dental colleges to be important, feasible, and beneficial, citing improved access to care, trained personnel, interdisciplinary collaboration, enhanced student learning, and research opportunities.
Conclusion: The study highlights a clear perceived need for establishing dedicated SHCN clinics in dental colleges. Such clinics may improve access to comprehensive oral healthcare for individuals with special needs while strengthening dental education, clinical training, and research.Keywords: anterior open bite, malplacement, orthognathic surgery, camouflage.

Keywords: Special Health Care Needs; SHCN clinics; Dental colleges; Questionnaire study; Dentist perception

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INTRODUCTION:

One of the most common medical illnesses worldwide, oral diseases significantly affect overall health and quality of life. Individuals with Special Health Care Needs (SHCN), a term that covers a broad range of physical, intellectual, developmental, sensory, and medical impairments, face greater difficulties in accessing oral care,necessitating changes in standard healthcare practices.[1,2]

The WHO estimates that 15% of the global population has a disability, highlighting the size of this vulnerable community.[3] Dental caries, periodontal disease, malocclusion, dental abnormalities, xerostomia, bruxism, traumatic dental injuries, and oral infections are more common among those with SHCN.[4,5] Due to limited motor skills, cognitive impairments, communication challenges, and long-term medication use, these problems are often worsened by difficulties in maintaining dental hygiene.[6] Additionally, during dental treatment procedures, behavioral and environmental factors are just as important as clinical issues. Dental care is especially challenging for many patients with SHCNs, as they may be sensitive to noise and unfamiliar environments, may exhibit anxiety or attention-seeking behaviours, require comfort with dental staff, and may need a quiet or private clinical setting.[7,8]

Even though the need for specialised care is recognised, the population with SHCNs still have limited access to appropriate dental and oral healthcare services, particularly in low-income countries. Barriers such as poor infrastructure, a shortage of skilled personnel, time constraints, complex medical histories, and a lack of interdisciplinary support persist.[9]These challenges are intensified,especially due to the absence of organised special care dentistry services and limited exposure during dental training.[10]

Dental colleges are ideally positioned to address this gap by establishing specialised SHCN clinics, as they are primary centres for tertiary care and education. These clinics can enhance clinical training, foster multidisciplinary collaboration, promote research, and improve access to comprehensive care.[11] There is limited data on dentists' opinions regarding the necessity, feasibility, and challenges of establishing SHCN clinics in dental schools. Assessing these perspectives is essential for guiding policy development, curriculum design, and infrastructure planning.

MATERIALS AND METHODS:

Study Design and Study Population

A descriptive, cross-sectional questionnaire-based study was conducted to assess dentists' perceptions regarding the need for establishing Special Health Care Needs (SHCN) clinics in dental colleges. Dental professionals from various specialities and practice settings were invited to participate in the study; participation was voluntary.

Study Instrument

Data were collected using a structured, predesigned questionnaire developed to evaluate dentists' perspectives on care for the population withspecial healthcare needs. The questionnaire demonstrated apparent validity and was formulated based on a review of existing literature and expert input. It consisted of sections assessing demographic details, professional background, clinical exposure to SHCN patients, commonly encountered oral health problems, challenges faced during management, approaches used in practice, and opinions regarding the feasibility, importance, benefits, and challenges of establishing SHCN clinics in dental colleges. The domains assessed and the structure of the questionnaire used in the study are summarised in Table 1. The questionnaire included multiple-choice questions and Likert-scale responses, with provisions for additional comments.

Data Collection

The questionnaire was distributed electronically using an online survey platform. Before participation, informed consent was obtained electronically from all respondents. Confidentiality and anonymity of responses were ensured. A total of 106 complete responses were received and included in the final analysis.

Inclusion and Exclusion Criteria

Dentists actively involved in clinical practice, academics, or both were included in the study.

Incomplete or duplicate responses were excluded from the analysis.

Statistical Analysis

The collected data was compiled and entered into a spreadsheet for analysis. Descriptive statistics were used to summarise the responses. Frequencies and percentages were calculated to assess dentists' exposure to SHCN patients, perceived challenges, and opinions regarding the establishment of SHCN clinics in dental colleges.

RESULTS

The survey included 106 dental professionals who represented a variety of dental specialities and practice environments. Figure 1 shows the distribution of dental specialities, with general dentists making up the largest group (50%), followed by paediatric dentists (19.8%) and prosthodontists (10.4%). Figure 2 illustrates the respondents' professional roles: 52.8% of them were academicians, 38.7% were private practitioners, and 22.6% were consultant specialists. The majority of participants (51.9%) were in the 25–35 age range, according to the age distribution of participants (Figure 3), and the evaluation of clinical experience (Figure 4) revealed that 67.9% had 0–5 years of experience, indicating early-career exposure to Special Health Care Needs (SHCN) patient care.

Exposure to SHCN Patients

Table 2 and Figure 5 summarise the exposure to SHCN patients in ordinary dental practice. In their professional practice, the majority of respondents (69.9%) reported coming into contact with patients with SHCNs; the remaining respondents did not report any such exposure. People with neurodevelopmental problems, long-term systemic illnesses, and physical or sensory impairments comprised the SHCNs community. Figure 7 illustrates that 89.3% of dentists who had treated SHCN patients said it was difficult to manage them.

Oral Health Problems Observed

Table 3 and Figure 6 summarise the oral health issues that are frequently seen in patients with SHCNs. The most common condition reported was a high caries index (85.3%), followed by gingivitis and elevated periodontal risk (64%). Of the responders, 40% reported orofacial and dental abnormalities, while 54.7% reported dental crowding and malocclusion. These results show that SHCN patients have a significant burden of oral illness as well as unmet treatment and preventative needs.

Challenges in the Management of Patients with SHCNs

The difficulties in managing SHCN patients are shown in Figure 8 and Table 4, in which parental emotions and stress during treatment were the most cited challenge (68.7%), followed by time constraints during dental procedures (62.7%), a lack of SHCN patient management training (58.2%), and complicated medical histories (53.7%). 38.8% of respondents said the infrastructure was inadequate. These obstacles were thought to have a detrimental effect on the effectiveness and calibre of dental care provided.

Perceptions Regarding the Establishment of SHCN Clinics

Table 5 summarises dentists' opinions about the opening of SHCN clinics in dentistry schools, and Figures 10–12 illustrate these opinions. The creation of SHCN clinics was deemed possible by nearly all respondents (99.1%) (Figure 10). Additionally, 32.1% of respondents thought establishing such clinics was significant, and 65.1% thought it was extremely important (Figure 12). The availability of qualified faculty and support personnel (81.1%), better access to dental care for SHCN patients (71.7%), improved learning opportunities for dental students (66%), interdisciplinary collaboration (59.4%), and expanded research scope (53.8%) were among the perceived advantages of SHCN clinics, as shown in Figure 11.

DISCUSSION:

The current study quantitatively shows that SHCN patients are commonly encountered by dentists in theirregular dental practice, even in their early careers. The results show a glaring disconnect between clinical need and professional readiness, with nearly 70% of respondents reporting SHCN exposure and over 90% reporting management challenges. Similar difficulties have been documented in earlier research, highlighting dental professionals' lack of training and confidence in handling SHCN patients.[5,12]

The high rates of periodontal disease (64%) and dental caries (85.3%) among SHCN patients are consistent with research showing that people with special needs have much worse oral health outcomes because of poor oral hygiene, dietary factors, medication side effects, and physical or cognitive limitations.[5,13] These results support the necessity for forms of continuous care that are preventive in nature.

The most frequent issue (68.7%) was parental stress and emotional load, underscoring the psychosocial complexity of SHCN dental treatment.14 This finding is consistent with previous publications that highlight behavioural management issues and caregiver anxiety as significant obstacles to effective therapy. The structural shortcomings of the current dental education and service delivery systems are further reflected in time constraints and a lack of training.

Respondents enthusiastically supported team-based care and training-based solutions, which is encouraging. The literature supporting interdisciplinary and competency-based approaches to special care dentistry is consistent with the strong desire for formal training (75%) and trained supporting staff (75%).15 Strong professional consensus is demonstrated by the nearly complete agreement (99.1%) regarding the viability of SHCN clinics.

The perceived advantages, in particular, better access to care, more student learning, and research opportunities, highlight the combined clinical and educational significance of SHCN clinics. According to international recommendations in special care dentistry, establishing such clinics within dental colleges may therefore be a viable way to enhance oral healthcare delivery, increase dental education, and promote inclusive, patient-centred care.[16]

CONCLUSION:

The findings of this study demonstrate a strong perceived need for establishing dedicated Special Health Care Needs (SHCN) clinics in dental colleges. A majority of dental professionals routinely encounter patients with SHCNs and experience considerable difficulty in managing them due to inadequate training, time constraints, complex medical histories, caregiver-related stress, and limited infrastructure. The high burden of oral diseases among SHCN patients further highlights existing gaps in care delivery. The overwhelming support for the feasibility and importance of SHCN clinics reflects professional consensus that dental colleges are well-positioned to provide structured, multidisciplinary, and patient-centred care. Integrating SHCN clinics within dental college infrastructure may improve access to quality oral healthcare for individuals with special needs while enhancing dental education, clinical training, and management protocols, thereby contributing to more inclusive and equitable oral health systems.

TABLES

Table 1: Questionnaire Used to Assess Dentists' Perspectives on Establishing SHCN Clinics

Section	Domain Assessed	Questionnaire Items
Section I	Demographic and Professional Details	Age, gender, dental speciality, type of practice (academician, private practitioner, consultant), and years of clinical experience
Section II	Exposure to SHCN Patients	Encounter with SHCN patients in routine practice (Yes/No); types of SHCN encountered (e.g., neurodevelopmental disorders, chronic illnesses, physical or sensory disabilities)
Section III	Oral Health Problems in SHCN Patients	Commonly observed dental problems such as high caries experience, gingivitis/periodontal disease, dental anomalies, and malocclusion (multiple responses permitted)
Section IV	Challenges in SHCN Patient Management	Difficulties faced during treatment including lack of specialized training, time constraints, complex medical histories, caregiver-related stress, and inadequate infrastructure (multiple responses permitted)
Section V	Existing Management Approaches	Use of training or courses in SHCN care, availability of trained supporting staff, infrastructure modifications, and referral to specialised centres
Section VI	Perception of SHCN Clinics in Dental Colleges	Opinion on feasibility of establishing SHCN clinics (Yes/No); perceived importance (Likert scale)
Section VII	Benefits of SHCN Clinics	Perceived benefits include improved access to care, availability of trained faculty and staff, interdisciplinary collaboration, enhanced student learning, and research opportunities
Section VIII	Open-ended Feedback	Additional comments or suggestions regarding the establishment of SHCN clinics in dental colleges

Table 2: Exposure of Dentists to SHCN Patients (n = 106)

Variable	Response	Frequency (%)
Encounter SHCN patients in routine practice	Yes	≈88%
	No	≈12%
Types of SHCN encountered	Neurodevelopmental disorders	Common
	Chronic systemic illnesses	Common
	Physical/sensory disabilities	Common

Table 3: Oral Health Problems Observed in SHCN Patients

Oral Health Problem	Dentists Reporting (%)
High caries experience	≈80%
Gingivitis / Periodontal disease	≈70%
Dental crowding / Malocclusion	≈65%
Orofacial / Dental anomalies	≈60%

Table 4: Challenges Faced in Managing SHCN Patients

Challenges Identified	Dentists Reporting (%)
Lack of specialized training	≈70%
Time constraints during procedures	≈65%
Complex medical history	≈60%
Caregiver-related emotional stress	≈55%
Inadequate infrastructure	≈50%
Difficulty in overall management	≈78%

Table 5: Dentists' Perceptions Regarding Establishment of SHCN Clinics

Perception / Benefit	Dentists Agreeing (%)
SHCN clinics are important /very important	≈85%
SHCN clinics are feasible in dental colleges	≈80%
Improved access to care for SHCN patients	≈90%
Availability of trained faculty and staff	≈80%
Interdisciplinary collaboration	≈75%
Enhanced learning opportunities for students	≈85%
Increased research opportunities	≈70%

FIGURES

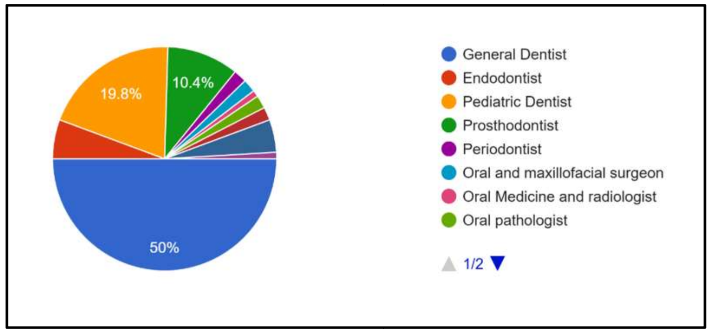

Figure 1. Distribution of dental specialities among study participants (n = 106)

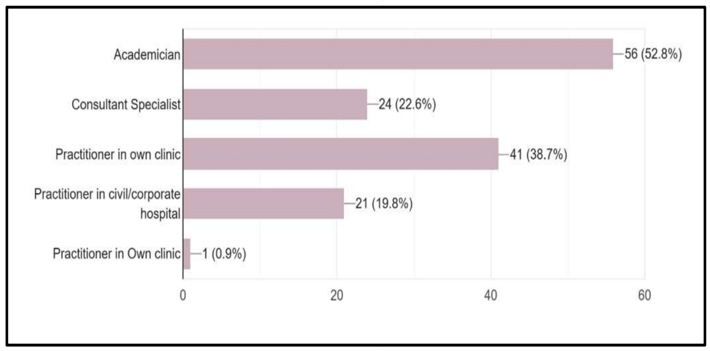

Figure 2. Professional roles of respondents (academicians, private practitioners, consultant specialists, and hospital-based practitioners)

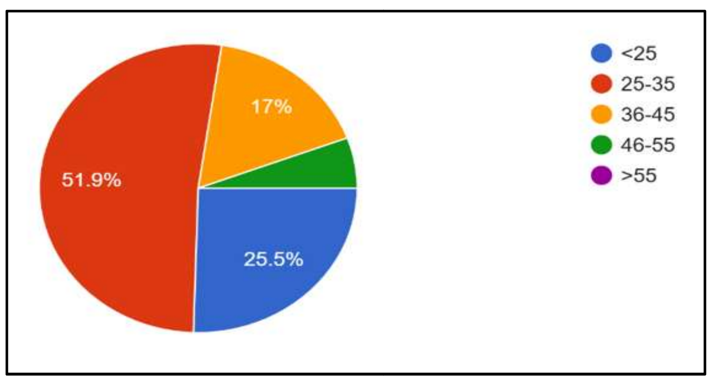

Figure 3. Age distribution of dental professionals participating in the study

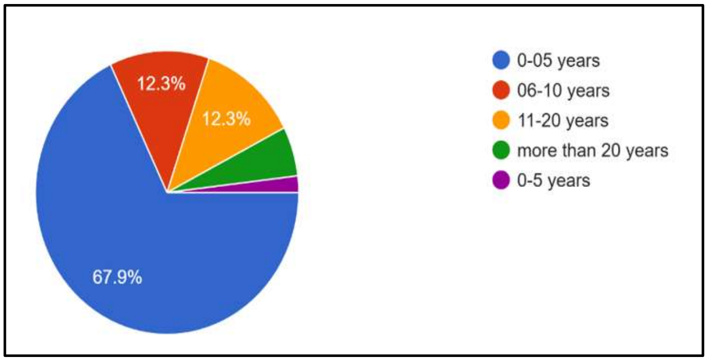

Figure 4. Years of clinical experience of study participants

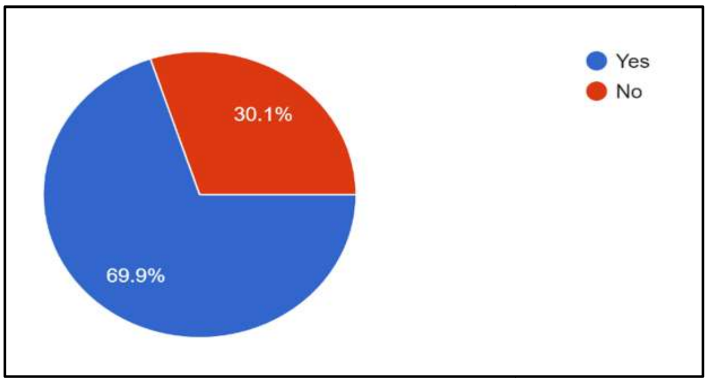

Figure 5. Encounter with children with Special Health Care Needs (SHCN) in routine dental practice

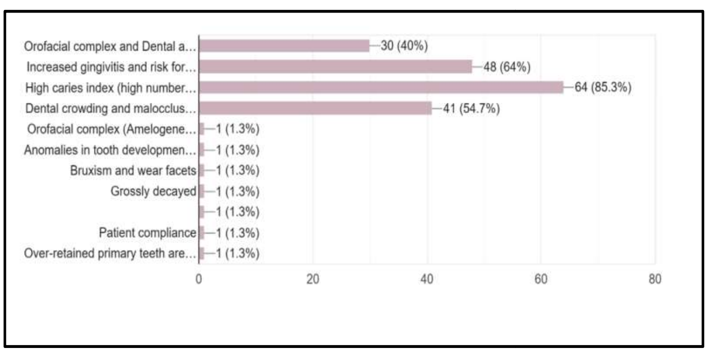

Figure 6. Common oral health problems observed in HCN patients(high caries index, gingivitis / periodontal disease, malocclusion, and dental anomalies)

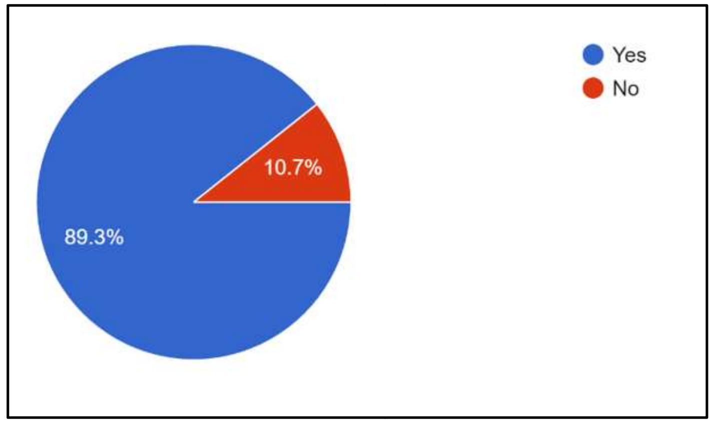

Figure 7. Difficulty faced by dentists in managing SHCN patients

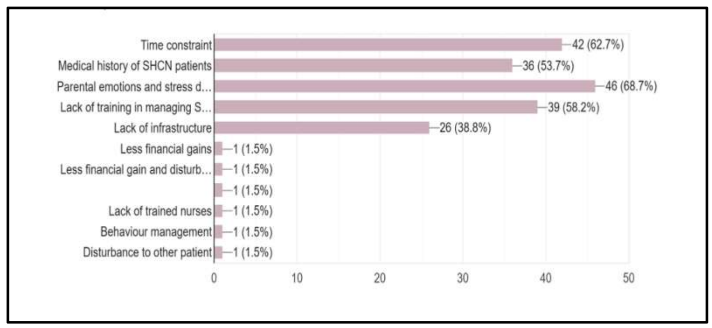

Figure 8. Challenges encountered during dental management of SHCN patients (parental stress, time constraints, lack of training, medical complexity, infrastructure)

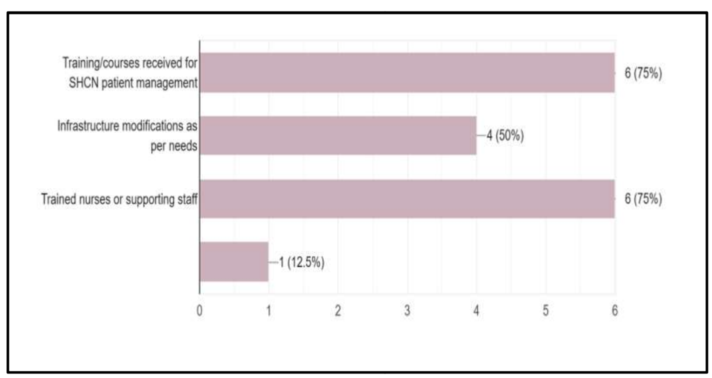

Figure 9. Approaches that aided dentists in managing SHCN patients (training/courses, trained supporting staff, infrastructure modifications)

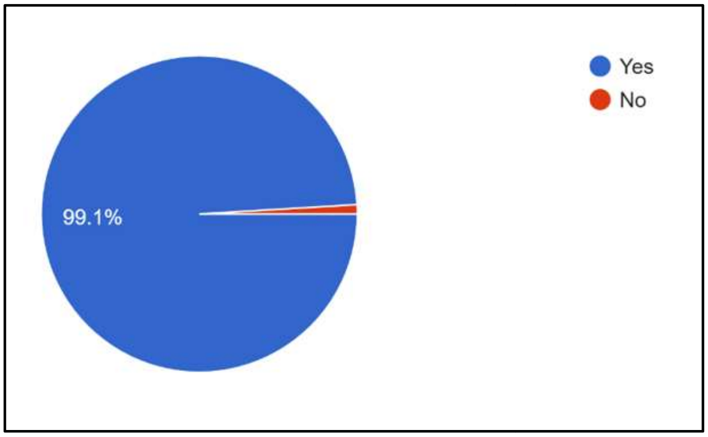

Figure 10. Dentists' perception regarding the feasibility of establishing SHCN clinics in dental colleges

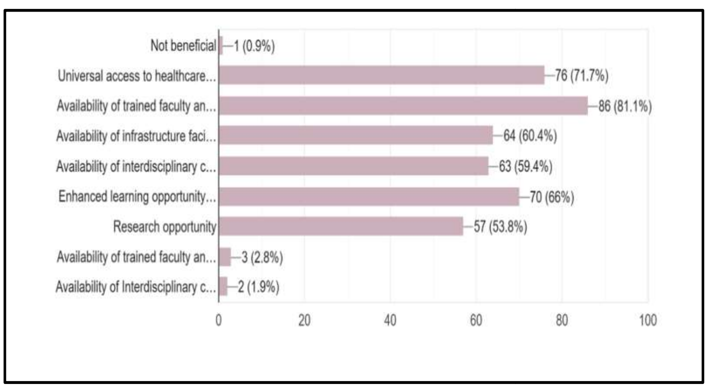

Figure 11. Perceived benefits of establishing SHCN clinics in dental colleges

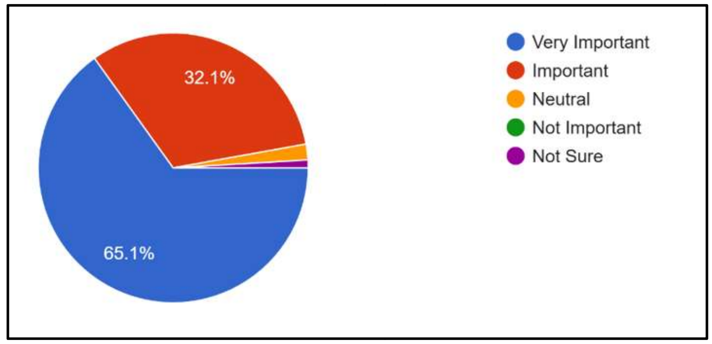

Figure 12. Importance attributed to establishing SHCN clinics in dental colleges

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"DIGITAL PRESENCE IN ORTHODONTICS: A SURVEY OF PRACTITIONER AWARENESS

Dr. Pravinkumar S. Maroore [1], Dr. Kirti Sonawane [2], Dr. Suresh Kagane [3], Dr. Yatishkumar Joshi [4], Dr. Shilpa Kendre [5], Dr. Sujit Zhadake [6], Dr. Swathilekshmi Nair [7], Dr. Krushna Mule [8]
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Abstract:
The questionnaire approach is a powerful and adaptable instrument for gathering data in a variety of study fields. Its structured style makes it easier to collect, organize, and analysis of data in a systematic manner, which is especially helpful for quantitative research projects. This research project is about to evaluate awareness of digital marketing techniques among the orthodontists. Questionnaire study provides accessibility, affordability, and the capacity to contact a large and varied population, allowing for the effective collection of thorough insights. The responses from maximum targeted population give reliable study result through this research type. However, it is important to recognize issues including low response rates, possible bias from non-response, and limitations in guaranteeing respondent representativeness. Notwithstanding these drawbacks, the questionnaire methodology is nevertheless useful since it offers a methodical way to obtain information and enhance knowledge across a range of disciplines.

Keywords: Digital marketing, Awareness, orthodontists.

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INTRODUCTION:

The emergence of social media has radically altered how individuals communicate via social media[1]. Social media refers to online tools and methods that individuals use to exchange ideas, viewpoints, and experiences. Digital and social media networks were first developed for personal use, but companies of all sizes increasingly successfully use them to advertise their goods and services and interact with both present and potential customers. Social media marketing is an engaging, economical, and more effective way to promote goods and services than traditional advertising, especially as more people are spending time online. Social media is a key strategy in dental marketing, and the health care industry is currently reaping the benefits of digital marketing. Reaching hundreds of prospective new patients who are looking for a practitioner's knowledge and services can be done affordably using social media marketing.

AIM:

To Evaluate Awareness Among Orthodontists regarding Digital Marketing Strategies and interrelationship between social and digital media used in orthodontic practice.

MATERIALS AND METHOD:

To assess the several facets of practice marketing, usage, and preferences of social and digital media, a Google Form was developed. Google Forms' questionnaire of a maximum sample size of more than will be circulated among Practicing Orthodontists, Academicians, Consultants, and other practitioners, and 150 responses were collected from various demographic areas in India.

A description of social media and digital media, as well as numerous examples of social media websites, were included in the survey. All participants' demographic data was collected, and the survey included questions on their usage patterns and opinions of social media use in orthodontic practices.

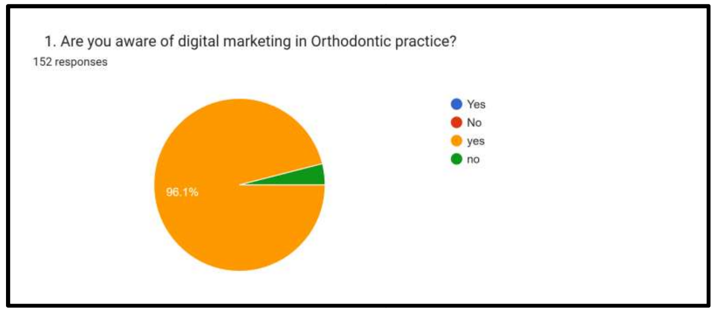
Questionnaire was made to assess the awareness, knowledge and need of the social media and digital marketing required in orthodontic practice. Participants were orthodontists who had more than 2 years of clinical experience after post-graduation. An e-mail was sent out to all orthodontists who were registered with Indian Orthodontic Society also online messages were forwarded to collect responses, so that participants could take the survey at any convenient time.

DATA COLLECTION:

In order to gather data, questionnaire was issued to all India Orthodontic WhatsApp groups, and through their emails those who were in close proximity and orthodontists were asked to complete it.

RESULTS:

A total of 250 orthodontists from private practices and academics were given their responses to survey. Results from the Orthodontists' survey showed that 96 % orthodontists are aware about the digital media driven orthodontic practice (Graph.1).93.4 % participants found online modes of marketing needful (Graph.2). About 54% participants have their own website and almost 96% have their social media page for their practice promotion. Out of these participants



Graph. 1: Depicts awareness of orthodontists regarding digital

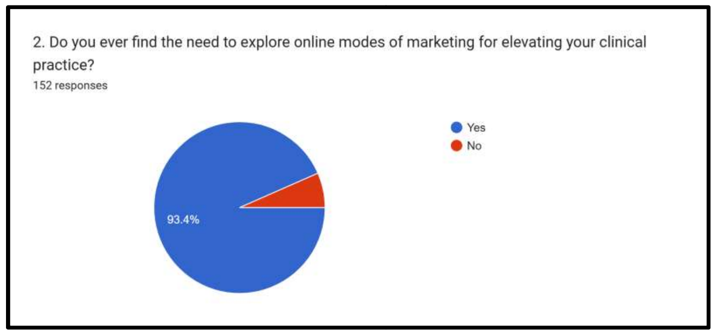


Chart 2. Need to explore online modes of Marketing

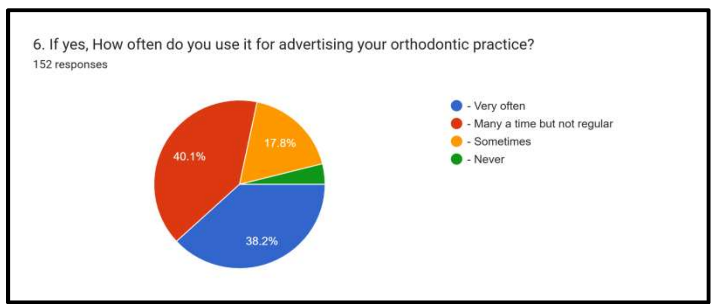


Chart. 3 Depicts Frequency of Social Media Usage for Marketing Purpose

Orthodontic practitioners give thought towards online advertising either through hired agencies or other Medias. Around 43% participants engaged in online advertising and hired agency for the same (Chart 4). Different Medias like Google ads, social media ads and other hired agencies were used by the participants in the study in the given percentage shown in chart 5.

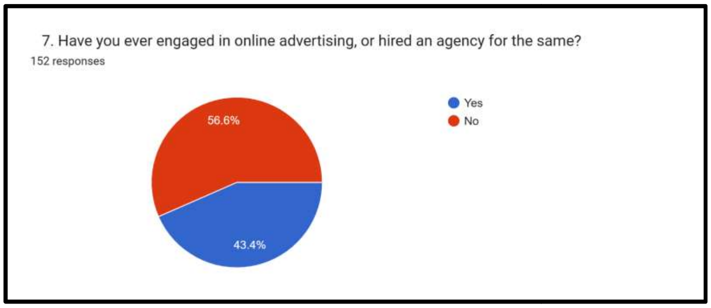


Chart 4. Percentage of participants involved in online advertising for marketing orthodontic practice

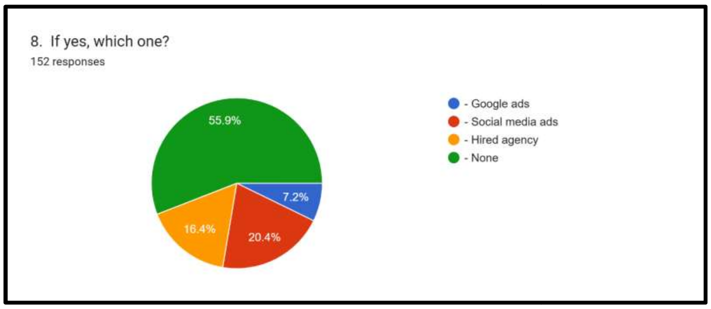


Chart 5. Participants involved in different online advertising

When a survey question asked about modes participants currently using to communicate their patients it shows majority of participants rely on phone calls to communicate with patients, even if every patient now a day's uses social media then also phone calls is the preferred mode of communication for the practitioner(Chart 6)

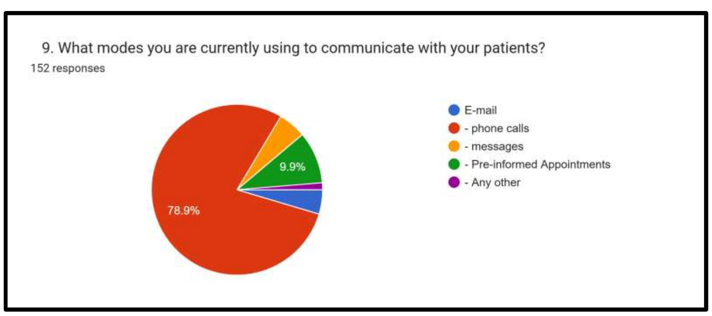


Chart 6. Modes of communication between practitioners

Digital marketing now a day's sets newer trends day by day, on assessing the experience of practitioners/participants regarding digital marketing techniques shows the response depicted in Pie chart 7.At the start, reference of digital marketing tools noticed by the users through various sources like through mouth referral, any advertisement or any webinars or from any articles or news (Chart. 7)The source of reference is important to assess that which mode is popular amongst the practitioners and from where they get the information of the digital marketing tools useful in clinical practice propagation.

Practitioners who referred to digital marketing majority of them found it easy and helpful. Frequency of the practitioners to get updated with digital marketing ideas depicts in chart

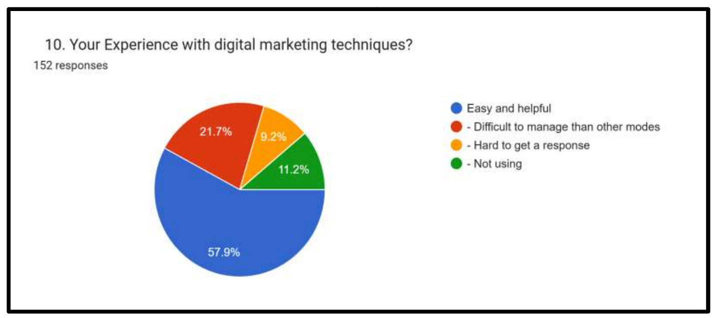


Chart 7.Experience with digital marketing techniques

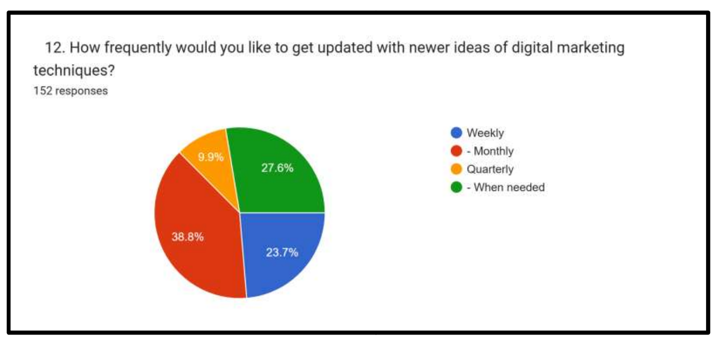


Chart 8. Participants wanted to get updated with Newer Ideas

Contents required to update any clinical practice involves different case studies, visual infographics, written articles or any webinars, participants preferred different sources according to their convenience (Chart 9), also the participants who are seeing digital marketing tools are interested in training session to evolve the practice promotion(Chart 10). There are various courses available on internet to improve digital marketing strategies, those who have referred it found significant improvement in promotional strategy.

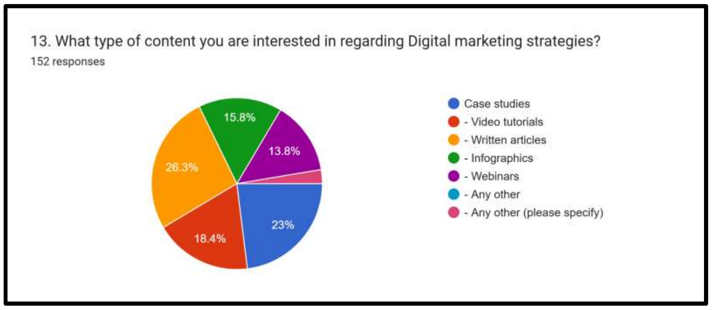


Chart 9.Content to Propagate Through Digital Marketing.

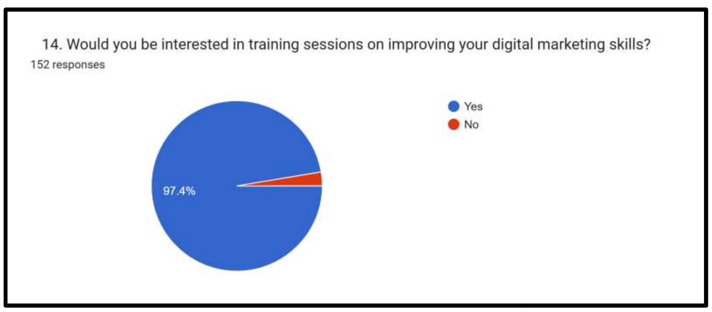


Chart 10. Participants interested in training session on improving digital marketing strategies

DISCUSSION:

Numerous studies have documented the substantial effect that digital media has played in health care in recent years. In dentistry, digital marketing is simply the technique of using the internet and other digital communication channels to reach new patients. As is well known, orthodontists and dentists have made great use of digital marketing to improve their clinical practices. The results of our study suggest that 93.4% of the orthodontists use digital marketing to promote practice.

The present survey highlights a high level of awareness among orthodontists regarding digital media–driven orthodontic practice, with 96% of participants acknowledging its relevance. This finding reflects the growing penetration of digital technology in healthcare marketing and indicates that orthodontists, both in private practice and academia, recognize the importance of an online presence in the modern era. Similar trends have been reported in contemporary dental literature, emphasizing digital platforms as essential tools for patient education, engagement, and practice growth.

A substantial proportion of respondents (93.4%) considered online marketing modes to be necessary, underscoring a positive attitude toward digital marketing strategies. This suggests that orthodontists perceive digital media not merely as an optional adjunct but as an integral component of practice management. The increasing dependence of patients on online sources for healthcare information, clinic selection, and appointment scheduling may explain this strong inclination toward digital platforms.

Despite this high level of awareness and perceived need, a noticeable gap exists between acceptance and consistent utilization. While approximately 54% of participants reported having their own website and nearly 96% maintained at least one social media page for practice promotion, only 38% used digital media regularly for marketing purposes. This discrepancy may be attributed to several barriers, including lack of time, insufficient technical expertise, concerns regarding professionalism and ethical boundaries, or uncertainty about return on investment.

The preference for occasional use of social media by the majority of participants further supports this observation. Social media platforms appear to be the most accessible and widely adopted digital tools; however, their use is often intermittent rather than strategic or sustained. Irregular engagement may limit the potential benefits of digital marketing, such as consistent brand visibility, patient trust-building, and long-term practice growth.

Overall, the findings indicate that while orthodontists demonstrate strong awareness and favorable attitudes toward digital marketing, there is a need to bridge the gap between knowledge and effective implementation. Structured training programs, professional guidelines, and evidence-based strategies for ethical and efficient digital marketing could help orthodontists maximize the benefits of digital media and translate awareness into regular, impactful practice promotion.

CONCLUSION:

Digital and social media were used by the majority of orthodontists, patients, and parents. In an orthodontic office, this could be a useful marketing and communication tool to increase patient traffic. According to orthodontists, patients come to them because of their online notoriety. They use their own website, which is accessible on Google, to advertise their profession. Photos of patients and the clinic are frequently posted on social media, with Facebook and WhatsApp being the most popular platforms. Based on their online popularity, orthodontists estimate that 15–20% of people frequent them.

Regarding the standpoint of the patient, people select orthodontists based on their online popularity, with Google searches being the most popular. They evaluate orthodontists on social media, with Instagram being the most preferred platform, followed by Facebook and WhatsApp groups. Patients of all ages saw a dentist primarily through word-of-mouth recommendations and only when an issue emerged. When selecting an orthodontist, the cost of treatment is also very important because they are knowledgeable about the many types of braces and how much they cost. Facebook and Instagram were the social media platforms where the biggest differences between orthodontists and patients/parents were discovered. The majority of orthodontic practices are missing this opportunity, which might be used as a marketing tool for both existing and future patients.

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To evaluate the knowledge, attitude and perception of an orthodontist towards maintaining orthodontic records in dental clinic: A cross-sectional survey

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Abstract:
Aim: To evaluate the knowledge, attitude, and perception of orthodontists toward maintenance of orthodontic records in clinical practice.

Materials and Methods: A cross-sectional questionnaire-based survey was conducted among 413 orthodontists and postgraduate students across India. The questionnaire assessed awareness, types of records maintained, storage methods, and duration of record retention. Data were analysed using descriptive statistics.
Results: All participants (100%) recognized the importance of orthodontic records. The majority (96.4%) retained records for more than five years. Pre-treatment records were maintained by 90% of respondents, whereas during-treatment and post-treatment records were maintained by 40% and 60%, respectively. Handwritten records were used by 54.9% of participants, followed by digital (30%) and printed formats (15.8%). Despite high awareness, only 40% demonstrated practices above the median level, indicating a gap between knowledge and implementation.

Conclusion: Although orthodontists exhibit strong awareness and a positive attitude toward record maintenance, variability in clinical practice persists. Standardization of protocols and increased adoption of digital record systems are recommended to enhance efficiency and medico-legal compliance.

Keywords: Orthodontic record maintenance; Questionnaire study; Dentist perception.

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INTRODUCTION:

Storage of records when it comes to the field of orthodontics is such an essential aid that it cannot be ignored. Orthodontic diagnosis is based on reliable and accurate orthodontic records. These records that are vital for diagnosing a specific malocclusion and formulate a treatment plan comprise mainly of study models, clinical photographs, radiographs, and clinical examination.[1] Orthodontic record consists of regular updating of dental charts which include the examination of the comprehensive oral and perioral hard and soft tissue transformation made in the particular period of treatment. This documentation comprises of communication emerges between

orthodontist and patient and these records are highly useful in safeguarding against the legal interest of all the parties. A study on record taking concluded that radiographs, photographs and then casts form an integral part of the patient record taking.[2]Technology plays a key role in influencing the impact of every aspect of Orthodontic practices. Many studies assessed the Orthodontic practices, application of computer technology in various tools like digital photographs and then cone-beam computed tomography followed by virtual study models, communication, virtual reality software and network-attached storage devices[3-5]
Orthodontic treatment has the highest clinical risk of malpractices and litigation due to long period of treatment. The overriding message for the clinician is to practice the Orthodontics with the philosophy of prevention and avoidance[6,7]The practice of having dental record is not only for forensic application but also for legal regulations for claiming insurance and consumerism[8]
The study models are the very first to be acquired in the order of records and are of two types: (1) Physical or plaster models, which are made from well-extended good quality alginate impressions and (2) Digital models or E models which are developed from either 3D scanners or 3D CT.[9] Orthodontic photography records includes: (1) Extraoral photographs and (2) Intraoral photographs taken according to the guidelines devised by the American Board of Orthodontics.[10]
Radiographs essential for orthodontic diagnosis and treatment planning include intraoral periapical radiographs (IOPAR), orthopantomogram (OPG), cephalogram (lateral and frontal), and other supplemental radiographs (hand wrist, TMJ views, MRI, CBCT, etc.)[11]
Retention of these records has been done by several methods but in the current literature very little information has been provided regarding the success of these methods, the problems being faced, and the latest methods being followed in terms of developing technology. Therefore, the trends in various methods of storage of orthodontic records form a crucial part from an ethical and professional standpoint as they would give information regarding the current methods of storage which could help secure the records without any problems for the long term. The aim of this study was to understand awareness and practices of orthodontic record maintenance among orthodontists.

MATERIALS AND METHODS:

The necessary permissions for the study were obtained and protocol for the study was also approved. The sampling technique adopted for the study was non-probability sampling in which convenience sampling was chosen. The questionnaire was designed and circulated through social media platforms. The Statistical software, namely SPSS 22.0, and R environment ver.3.2.2 was used for the analysis of the data and Microsoft Word and Excel have been used to generate graphs, tables etc. Descriptive and inferential statistical analysis has been carried out in the present study. Results on continuous measurements are presented on Mea-Max) and results on categorical measurements are presented in Number (%). Significance is assessed at 5 % level of significance.

RESULTS:

A total of 413 orthodontists and postgraduate students participated in the study.
All respondents (100%) acknowledged the importance of maintaining orthodontic records in clinical practice. With regard to record retention, 96.4% of participants reported storing records for more than five years, indicating a strong awareness of long-term documentation requirements.(Fig.1)

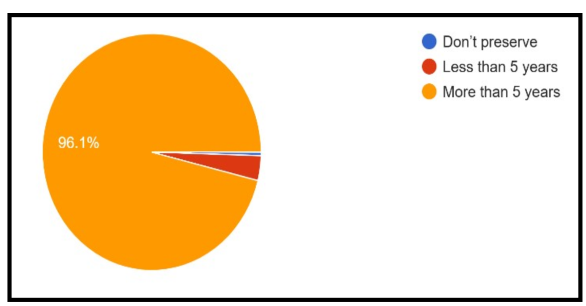

Fig. 1: How long orthodontic record is stored?

Evaluation of the types of records maintained showed that pre-treatment records were routinely documented by 90% of participants. In contrast, only 40% maintained records during treatment, while 60% documented post-treatment records, suggesting a relative decline in documentation during active treatment phases. (Fig.2)

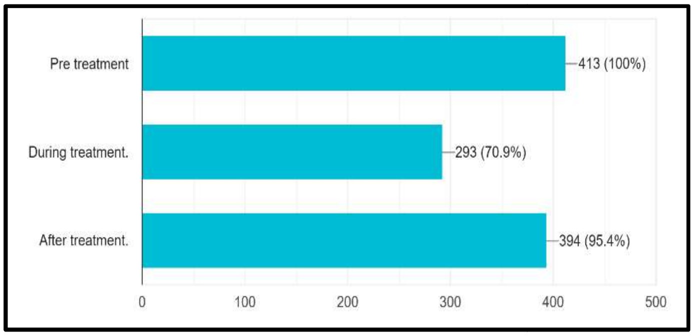

Fig. 2: Preference of taking orthodontic

Radiographic records, including lateral cephalograms and orthopantomograms, were commonly utilized, though not universally recorded in all cases. Intraoral periapical radiographs were the least consistently maintained among radiographic records.(Fig.3)

Photographic documentation was widely practiced, with pre-treatment photographs recorded by most participants. However, documentation during treatment was less consistent compared to pre- and post-treatment stages. Post-treatment photographic records were maintained by a majority of clinicians. (Fig 3)

Study models were routinely preserved before treatment, while their use during treatment was less frequent. Post-treatment models were again maintained by a significant proportion of participants. (Fig 3)

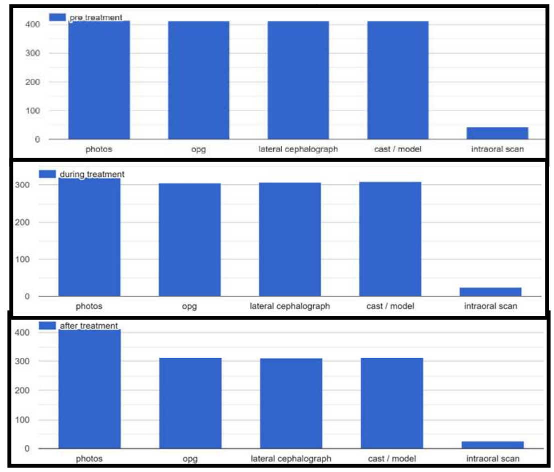

Fig. 3: Orthodontic records taken pre, during and after treatment

The majority of participants preferred cervical vertebral maturation (93.9%) for predicting patient growth, followed by hand and wrist radiographs (83.3%). In contrast, very few respondents relied on serial lateral cephalograms (6.1%) or growth charts (2.4%). (Fig.4)

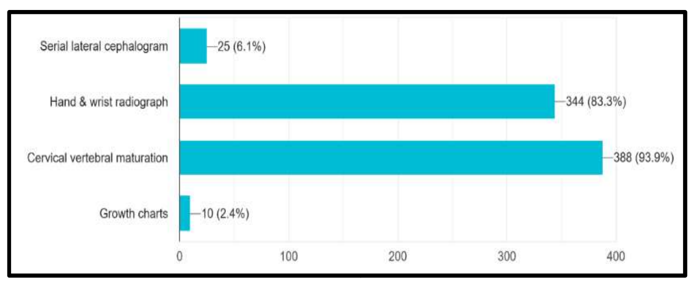

Fig 4: Record taken to predict growth of patient

Regarding methods of record maintenance, 54.9% of participants relied on handwritten records, 30% used digital systems, and 15.8% utilized printed formats, indicating a predominance of conventional methods with gradual adoption of digital technologies. (Fig 5)

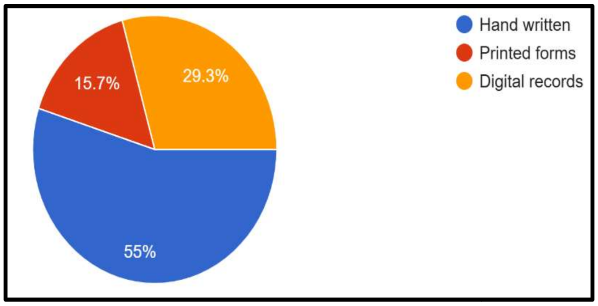

Fig 5: Method of Record maintenance

In terms of storage practices, all participants reported maintaining patient records. Most respondents recognized the legal obligation of record keeping. Records were commonly stored using customized serial numbering systems, followed by alphabetical or date-based organization.

The duration of storage varied, with most clinicians retaining records of active and completed patients for more than one year, while records of inactive patients were more commonly stored for shorter durations. Records related to medicolegal cases were predominantly preserved for longer periods.

Participation in continuing dental education programs on record maintenance was limited, with 65% of respondents reporting no prior attendance.

Overall, comparison of knowledge and practice scores indicated that although awareness of orthodontic record keeping was high, only 40% of participants demonstrated practices above the median level, while 60% fell below the median, reflecting a gap between knowledge and clinical implementation.

DISCUSSION:

The present study demonstrated a high level of awareness among orthodontists regarding the importance of record keeping, with all participants acknowledging its clinical and medico-legal significance. This finding is consistent with previous studies, which have reported good knowledge and awareness among practitioners; however, similar to earlier reports, a gap persists between knowledge and its implementation in routine clinical practice.

Knowledge:

All participants (100%) demonstrated awareness regarding the importance of maintaining orthodontic records. Patient details and oral health status were universally documented, indicating strong foundational knowledge of essential record components.

Radiographic records, including lateral cephalograms and orthopantomograms, were commonly utilized, reflecting awareness of their diagnostic value.

Photographic records were widely recognized as essential, with most respondents obtaining pre-treatment photographs. Similarly, study models were routinely preserved before treatment. Postgraduate students were actively involved in cephalometric tracing for all patients, indicating comprehensive academic training.

Attitude:

Participants exhibited a positive attitude toward orthodontic record maintenance. A vast majority (96.4%) reported retaining records for more than five years, demonstrating an understanding of the importance of long-term documentation.Dental practitioners are considered to be the legal owner of the dental records.12 A good practitioner keeps the record for 10 years.13Astekar stated in his study it is mandatory for the dentists to store the records for 5 years.14 Indian Council of Medical Research states that all records should be maintained carefully for 3 years.15

All respondents reported maintaining patient records in their clinical practice, and most acknowledged the legal obligation associated with record keeping. Records related to medico-legal cases were predominantly preserved for extended durations, further reflecting awareness of their legal significance.

Perception (Practice Patterns):

Pre-treatment records were maintained by 90% of participants, indicating strong compliance at the diagnostic stage. However, documentation during treatment was less consistent, with only 40% maintaining regular records. Post-treatment records were maintained by 60% of respondents, suggesting improved documentation after treatment completion compared to the active phase.

Photographic documentation followed a similar pattern, with high prevalence of pre-treatment records but reduced consistency during treatment. Post-treatment photographs were maintained by a majority of clinicians. Study models were predominantly preserved before treatment, less frequently during treatment, and more commonly after treatment.

In terms of record-keeping methods, 54.9% of participants relied on handwritten records, 30% used digital systems, and 15.8% utilized printed formats. These findings indicate that conventional methods remain predominant, although digital adoption is increasing.

Overall, the findings indicate that while orthodontists possess adequate knowledge and a positive attitude toward record keeping, there is a clear need for standardization of practices and greater integration of digital technologies to ensure comprehensive and consistent documentation.

CONCLUSION:

Orthodontists demonstrate a high level of awareness and a positive attitude toward record maintenance; however, inconsistencies persist in clinical practice, particularly during treatment documentation. The findings highlight the need for standardized protocols and greater adoption of digital record-keeping systems to ensure comprehensive, efficient, and legally compliant orthodontic care.

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Reconstruction of Traumatic Anterior Maxillary Ridge Deficiency Using Autogenous Chin Graft for Implant placement

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Abstract:
Background:

Horizontal alveolar ridge deficiency following trauma presents significant challenge, for ideal implant placement especially in aesthetic zone. Autogenous bone grafts remain gold standard for ridge augmentation due to their osteogenic, osteoinductive and osteoconductive properties. The mandibular symphysis region(chin) serves as a reliable intraoral donor site for localized alveolar defects.

Case Presentation:
This case report describes an 18-year-old male patient with a missing maxillary right central incisor secondary to trauma due to road traffic accident. Cone bean computed tomography revealed inadequate horizontal bone width with 11 regions. Horizontal ridge augmentation was performed using an autogenous chin graft harvested under local anaesthesia with a piezoelectric surgical unit. Graft was secured at recipient site using two titanium screws. Four months postoperatively, CBCT evaluation demonstrated satisfactory graft integration and significant improvement in ridge width. A dental implant was successfully planned and placed.
Conclusion:
Autogenous chin grafting using piezoelectric surgery is a predictable and effective technique for horizontal ridge augmentation in the aesthetic zone, providing adequate bone volume for implant placement with minimal morbidity.
Keywords: Chin graft, Mandibular symphysis, Horizontal ridge augmentation, Dental implant, Piezoelectric surgery, Autogenous bone graft.

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INTRODUCTION:

Traumatic loss of anterior teeth often leads to rapid alveolar ridge resorption, compromising ideal implant placement, particularly in the aesthetic zone. Adequate horizontal bone width is essential to ensure primary implant stability, proper implant positioning and long-term functional and aesthetic success.[1–3]

Among various bone augmentation materials, autogenous bone grafts are considered the gold standard because of their osteogenic, osteoinductive, and osteoconductive properties.[1,3]The mandibular symphysis (chin) is a reliable intraoral donor site for localized ridge defects, providing sufficient corticocancellous bone with favourable healing and minimal resorption.[4,5,17]Recent advances such as piezoelectric surgery have further enhanced graft harvesting by improving precision and reducing trauma to adjacent soft tissues and vital structures.[10–12]

This case report describes the management of a traumatic horizontal alveolar ridge deficiency in the anterior maxilla of an 18-year-old male patient using an autogenous mandibular symphysis graft harvested with a piezoelectric surgical unit, followed by successful implant placement.

CASE REPORT:

An18-year-old male patient reported to department of oral and maxillofacial surgery department with chief complaint of missing upper right front tooth since 3 months. Tooth was lost due to road traffic accident 3 months back. Patient was otherwise healthy with no any medical history.

Clinical and Radiographic Examination:

Extraoral examination showed no any significant findings. Intraoral examination revealed a missing maxillary right central incisor with reduced buccolingual ridge width. CBCT was advised with same region which revealed horizontal bone deficiency (buccolingual width was 3mm) rendering immediate implant placement unfeasible. (Fig.1)

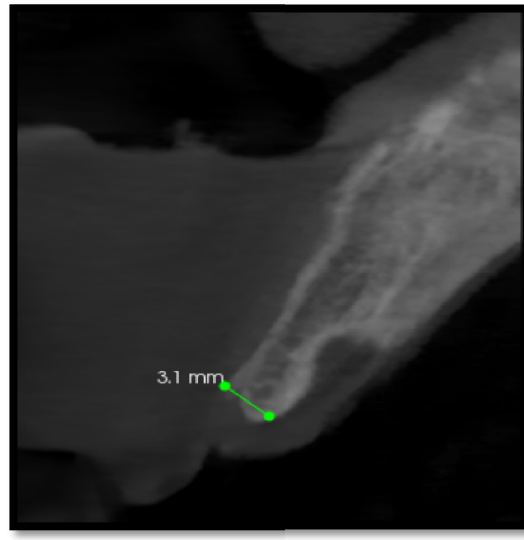

Fig. 1: CBCT section showing deficient bone width buccolingually (3mm)

Considering the patient's young age, localized defect, and aesthetic demands, horizontal ridge augmentation using an autogenous chin graft was planned. Procedure was explained in detail to the patient and written informed consent was obtained.

Treatment Plan:

Horizontal ridge augmentation using chin graft followed by implant placement on subsequent follow up.

Procedure:

Under local anaesthesia, crestal incision was made at maxillary anterior region (recipient site) and full thickness mucoperiosteal flap was elevated. The recipient site was then prepared with round bur (no.8) using straight handpiece (Fig. 2). After this a crevicular incision was given in mandibular anterior region (33-43) with two vertical releasing incision and full thickness mucoperiosteal flap was elevated to expose symphysis region (Fig. 3). Using a piezoelectric surgical unit, a corticocancellous bone blockof size 6mm x 8mm x 5mmwas harvested from the mandibular symphysis, maintaining safe margin of 5mm from the apices of mandibular incisors, mental nerve and inferior border of mandible (Fig. 4). Harvested graft was then contoured with bone file and secured at recipient site using two titaniumscrews measuring 1.5mm x 8mm (Fig. 5).The donor and recipient sites were closed primarily with 4-0 vicryl. Postoperative medications and instructions were given.

Follow-Up:

Healing was uneventful, with no donor-site morbidity or neurosensory disturbances. Four months postoperatively, CBCT evaluation revealed excellent graft integration with significant improvement in horizontal bone width, indicating successful graft acceptance. Width was increased about 3 mm in thickness. (Fig. 6).

Based on the augmented ridge dimensions, a dental implant measuring 3.5 × 11.5 mm was planned and placed in an ideal prosthetic position. (Fig. 7).

Fig. 2: Preparation of Recipient Site with round bur

Fig. 3: Crevicular incision (33-43) with two vertical releasing incisions.

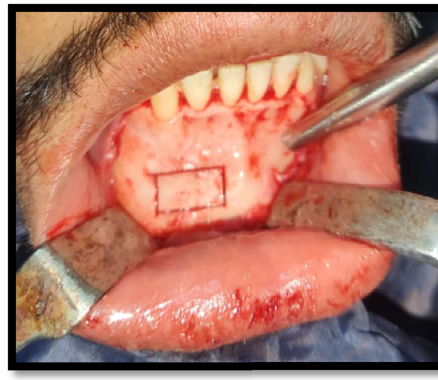

Fig. 4: Graft harvested from chin region using piezo surgery unit.

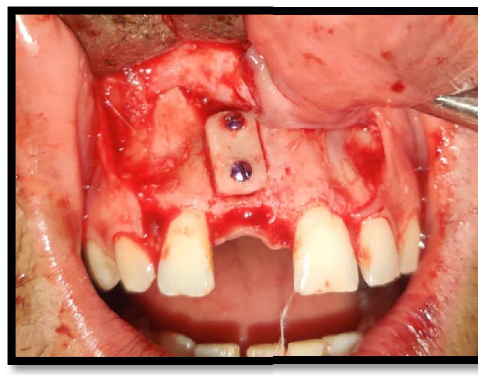

Fig. 5: Graft secured on recipient site using titanium screws.

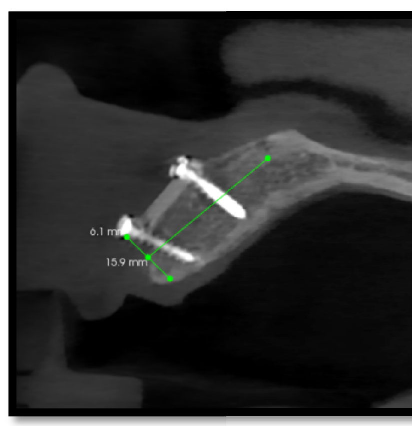

Fig. 6: Four months postoperative CBCT section showing increased width of ridge.

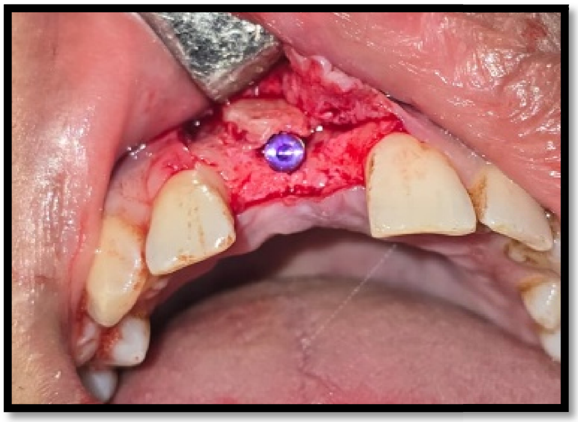

Fig. 7: Implant placed over augmented ridge 4 months post operatively.

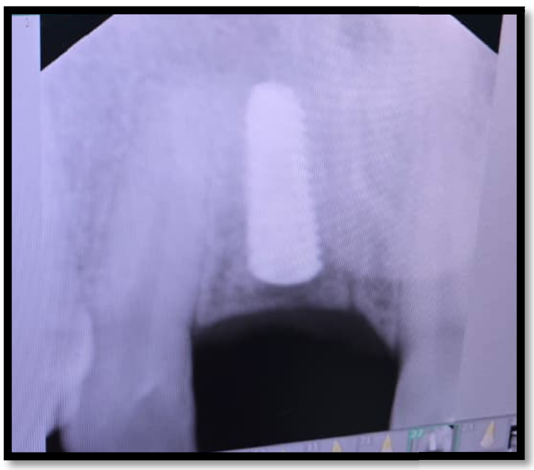

Fig. 8:Post operative IOPA of implant placement.

DISCUSSION:

Horizontal alveolar ridge deficiency is a common sequela following traumatic tooth loss, particularly in the anterior maxilla, where thin labial cortical plates are prone to rapid resorption. This deficiency poses a major challenge for ideal implant placement, as inadequate ridge width can compromise primary implant stability, implant positioning, peri-implant bone health, and long-term aesthetic outcomes.1_3 A minimum buccolingual bone width of 6–7 mm is generally recommended to allow placement of a standard-diameter implant with at least 1–1.5 mm of bone surrounding the implant on both buccal and palatal aspects.13

Various ridge augmentation techniques have been described to address horizontal deficiencies, including guided bone regeneration (GBR), ridge splitting, distraction osteogenesis, and autogenous block grafting.3,13,14 Among these, autogenous bone grafts remain the gold standard due to their inherent osteogenic, osteoinductive, and osteoconductive properties, which no substitute material can fully replicate.1,3,13 Intraoral donor sites such as the mandibular symphysis and ramus offer several advantages over extraoral sites, including reduced surgical time, absence of visible scarring, lower morbidity, and excellent patient acceptance.4,5,8 The mandibular symphysis is particularly well suited for localized horizontal ridge augmentation in the anterior maxilla, as it provides a sufficient volume of corticocancellous bone with favourable biological behaviour.4,5

The corticocancellous nature of chin grafts allows rapid revascularization and incorporation into the recipient site, while the cortical component provides mechanical stability and resistance to resorption.□,18 Previous studies have demonstrated predictable increases in ridge width ranging from 3 to 5 mm using symphyseal block grafts, enabling successful implant placement in prosthetically ideal positions.□,8,13

Donor-site morbidity is an important consideration when harvesting chin grafts. Reported complications include temporary neurosensory disturbances, altered chin contour, and mentalis muscle dysfunction.[1□] However, multiple studies have shown that when appropriate safety margins are maintained—typically 5 mm from tooth apices, mental foramen, and inferior border of the mandible—the incidence of permanent complications is low.[1□,1□] In the present case, no neurosensory deficits or aesthetic concerns were observed, corroborating previous findings.

The use of piezoelectric surgery for graft harvesting represents a significant advancement in bone surgery. Piezoelectric devices selectively cut mineralized tissue while preserving soft tissues, thereby reducing the risk of injury to nerves, blood vessels, and adjacent structures.[1□–12] Additionally, piezosurgery produces minimal heat generation and improves surgical precision, which is particularly beneficial in anatomically sensitive regions such as the mandibular symphysis.10,12 These advantages likely contributed to the uneventful healing and excellent graft integration observed in this case.

Rigid fixation of the graft using a titanium screw is another critical factor influencing graft success. Stable fixation minimizes micromovement, promotes revascularization, and reduces the risk of fibrous encapsulation or graft resorption.□,8,13 In the present case, secure fixation facilitated successful graft incorporation within four months.

Radiographic assessment using CBCT plays a vital role in both preoperative planning and postoperative evaluation of grafted sites. CBCT provides accurate three-dimensional assessment of ridge dimensions, graft integration and proximity to vital structures, making it the imaging modality of choice in implant dentistry.15,16 The postoperative CBCT in this case confirmed a significant increase in ridge width and uniform bone density, indicating successful graft acceptance.

The four-month healing period before implant placement aligns with existing literature, which suggests that intraoral autogenous block grafts typically achieve sufficient revascularization and remodelling within 3–4 months.4,13 This relatively short healing time is advantageous, particularly in young patients with high aesthetic expectations.

Implant placement following ridge augmentation in the anterior maxilla requires meticulous prosthetically driven planning. Successful augmentation in this case allowed placement of a 3.5 × 11.5 mm implant in an ideal position, ensuring favourable emergence profile and long-term aesthetic predictability.19,20

Overall, this case reinforces the reliability of mandibular symphysis grafting for horizontal ridge augmentation and highlights the benefits of combining autogenous grafts with piezoelectric surgery to achieve predictable outcomes with minimal morbidity.

CONCLUSION:

Mandibular symphysis grafting is an effective and predictable technique for horizontal ridge augmentation in the anterior maxilla. When combined with piezoelectric surgery, it ensures precise graft harvesting, reduced morbidity, and excellent graft acceptance, facilitating successful implant placement in aesthetically demanding regions.

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Dynamic Navigation in Dental Implant Surgery: A Contemporary Review

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Abstract:
Dynamic navigation (DN) for dental implant surgery integrates cone-beam computed tomography (CBCT), optical tracking, and dedicated software to guide implant osteotomy and placement in real time [1]. DN has been shown to reduce angular and linear deviations compared with freehand placement and achieves accuracy similar to static guided surgery, while maintaining greater intra operative flexibility [1, 2, 3]. This review summarizes the principles, workflow, clinical applications, advantages, limitations, and future directions of DN in implant dentistry.

Keywords: dynamic navigation, dental implants, computer-assisted surgery, implant accuracy, CBCT, guided implant surgery

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INTRODUCTION:

Accurate three-dimensional positioning of dental implants is critical for avoiding anatomic complications, optimizing esthetics, and ensuring biomechanically favorable prosthetic rehabilitation [1,4]. Traditional freehand techniques rely on visual and tactile cues and are associated with higher rates of positional error, which may translate into nerve injury, sinus perforation, off-axis loading, and increased prosthetic complexity [1,4].
Common complications related to inaccurate implant positioning include:

- Damage to the inferior alveolar nerve
- Floor of mouth hematoma
- Damage to adjacent roots
- Sinus infections secondary to inadvertent sinus perforations
- Fractured implants due to off-axis loading
- Periimplantitis due to food impaction and off-axis loading
- Poor esthetics secondary to thin buccal, labial bone, and soft tissue
- Interproximal bone loss secondary to placing implants too close to adjacent teeth and implants
- Increased prosthetic complexity and cost

Computer-assisted implant surgery (CAIS) was introduced to address these limitations and now includes static guides and dynamic navigation systems [1,4]. DN provides real-time feedback on drill position, angulation, and depth relative to a virtual treatment plan, and is increasingly adopted in office-based implant practice [1,2].

Classification of Implant Navigation
Implant navigation can be broadly classified into static and dynamic systems [1,4].
Static Navigation (Guided Surgery)
Static navigation, also referred to as computer-guided implant surgery or guided surgery, uses computer-aided design and computer-aided manufacturing (CAD/CAM) surgical templates

based on digital planning of implant position [1]. These templates are fabricated prior to surgery and transfer a preoperative plan to the patient intraoperatively but do not allow real-time modification of implant position or size.
Several types of static surgical guides exist:

- Stone cast-based guides: Basic guides that aid in ensuring appropriate restorable position of the implant but do not take into consideration bone morphology.
- Tooth-supported guides: Fabricated from digital models and seated on remaining dentition, offering good stability and accuracy.
- Tissue-supported guides: Seated on soft tissue or mucosa, more easily displaced than tooth-supported guides.
- Bone-supported guides: Require flap elevation and may offer the highest stability but require additional surgical steps.

Static full-guided, half-guided, and pilot-guided templates demonstrate higher accuracy than non-guided freehand surgery, but their precision depends on CBCT quality, guide fit, sleeve tolerance, and support type [1,4]. DN attempts to retain the accuracy of CAIS while overcoming some of these constraints [1,4].

Dynamic Navigation
DN uses optical tracking and software to display a virtual drill and implant in real time on a monitor, allowing intraoperative adjustments without physical guides. This real-time feedback permits modification of implant position, angulation, length, and diameter during surgery, providing greater flexibility than static systems [1,2].

Principles of Dynamic Navigation Technology
Optical Tracking Systems
Most contemporary DN systems used in dentistry employ passive optical tracking [1,2]. An infrared light source illuminates patterned or spherical reflective markers attached to the patient and to the surgical handpiece; a stereo camera system detects these markers and the software reconstructs the spatial position of the drill relative to the patient's CBCT data set in real time [1, 2].

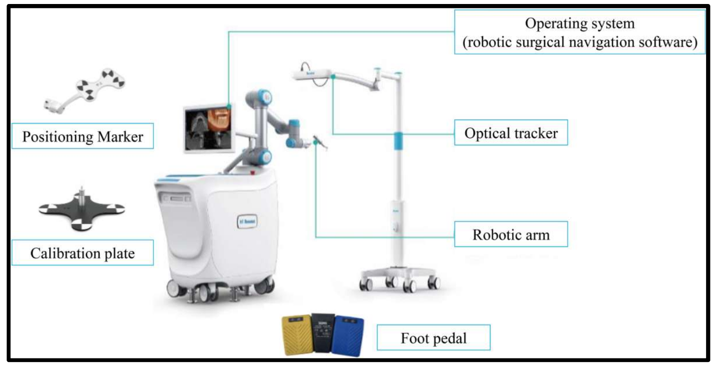

Figure 1: Figure 1: Dynamic navigation system setup showing stereo camera, LED light source, patient tracker, and handpiece tracker positioned for real-time surgical guidance. The overhead camera captures reflective markers to track both patient position and surgical instruments in relation to the planned CBCT coordinate system.

Two types of optical motion tracking systems exist:

1. **Active tracking systems:** Arrays emit infrared light that is tracked by stereo cameras.
2. **Passive tracking systems:** Arrays use reflective spheres or patterned markers to reflect infrared light emitted from a light source back to a camera.

The patient and drill must remain within the line of sight of the tracking camera. Light is projected from a light-emitting diode (LED) light source above the patient, reflects off tracking arrays attached to the patient and the surgical instrument, and is captured by stereo cameras. The DN system then calculates the position of the patient and instruments relative to the presurgical plan in real time [1].

Workflow Overview
The core steps of DN are:

1. Image Acquisition: Obtaining a 3D CBCT dataset including the surgical field and fiducial markers.
2. Virtual Planning: Planning of implant position, angulation, and depth within dedicated navigation software.
3. Calibration: Calibration of the handpiece, drills, and probe to the tracking system to determine the geometric relationship between tracking markers and the instrument tip.

4. Registration: Registration of the patient tracker to the fiducials, linking the physical patient to the virtual CBCT coordinate system.
5. Guided Surgery: Performing osteotomy and implant placement while monitoring real-time position feedback on the navigation screen.

The system displays a virtual drill superimposed on multiplanar views and 3D reconstructions, with numerical readouts of angular deviation and depth relative to the planned implant [1,2].

Clinical Workflow and Technique
Fiducial Strategies

Fiducial markers are essential for linking the patient's physical anatomy to the virtual CBCT coordinate system. Strategies differ for dentate and edentulous patients.

4.1.1 Dentate Patient Fiducial

In dentate patients, a thermoformed or thermoplastic fiducial clip is adapted over several teeth to create a rigid, reproducible support for the fiducial markers and patient tracker[1].

Figure 2: Figure 2: Fiducial clip positioned on maxillary anterior teeth demonstrating proper thermoplastic adaptation with buccal tracker arm. The clip must be firmly seated without rocking and positioned to minimize optical interference from surgeon's hands and instruments during the procedure.

Preparation of the fiducial clip:

The fiducial clip is placed in a hot water bath at a temperature of 60°C–71°C (140°F–160°F) for approximately 3–5 minutes until the thermoplastic becomes clear[1]. The clip is then cooled for approximately 1 minute to reach a surface temperature below 40°C (104°F) before insertion in the mouth[1].

Seating technique:

The fiducial clip should be seated on three teeth, ensuring equal distance on the buccal and lingual sides, with the tracker arm positioned on the buccal side[1]. Vertical pressure is applied until the plastic surface cannot advance further. An adequate impression is confirmed, and the clip is removed without any rocking motion and placed in a cold water bath[1].

Clinical considerations:

The fiducial clip must be:

- Firmly supported by teeth without any mobility when seated
- Placed on teeth that are not mobile, do not serve as pontics on a bridge, and are free of orthodontic wires
- Positioned to minimize optical interference by the surgeon's or assistant's hands and instruments
- Tried again in the mouth to confirm accuracy and ensure there is no impingement of soft tissue

If clinical crowns are short or teeth lack undercuts, composite resin may be added to the buccal and occlusal surfaces of associated teeth to help create immobile fiducial clip insertion[1].

Edentulous Patient Fiducial

An edentulous patient case requires edentulous fiducials (small self-tapping screws) to be placed in the patient's bone to facilitate registration in the CT scan[1].

Figure 3: Figure 3: Distribution of edentulous fiducial screws in a partially edentulous arch. Minimum of 4 screws (1.5 mm diameter, 4-5 mm length) positioned throughout the arch, avoiding planned implant sites, inferior alveolar nerve canal, and tracker plate location. This configuration ensures accurate registration of patient anatomy to CBCT coordinate system.

Fiducial screw specifications:

Edentulous fiducial screws should be:

- Diameter: 1.5 mm
- Length: 4–5 mm (4 mm recommended in posterior mandible or areas of dense cortical bone; 5 mm or greater in maxilla or regions of immature, soft, or grafted bone)
- Self-drilling and self-tapping
- Low profile and stable

When placing fiducials in the mandible, short 4-mm screws should be used to avoid damage to the inferior alveolar nerve[1]. The inferior alveolar nerve and infraorbital nerve must be considered and avoided when placing fiducials[1].

Placement strategy:

A minimum of 4 fiducials should be placed and spread throughout the arch, leaving room for an edentulous fiducial plate to be inserted at the time of surgery[1]. Edentulous fiducials must be placed in the arch where implants will be placed. If implants are to be placed in both the maxilla and mandible, fiducials must be placed in both arches. If vertical bone reduction is anticipated, fiducials must be placed apical to the area of proposed bone reduction [1].

Image Acquisition and Software Planning

CBCT Acquisition

Image acquisition includes obtaining 3D files, usually a CBCT in Digital Imaging and Communications in Medicine (DICOM) format (.dicom)[1]. The field of view of the CBCT should include the surgical site and all fiducials[1]. The scan is obtained with the plane of occlusion of the implant site parallel to the floor [1].

Soft tissue visualization:

An important point related to CBCT acquisition that is often overlooked is the separation of soft tissues while taking the image[1]. For dental implant planning purposes, a cotton roll or radiolucent material placed between the dentition and the buccal/labial mucosa creates an air contrast zone, allowing visualization of the soft tissue in the region of the free gingival margin on the CBCT[1].

Dual Scan Technique

Dual scan is the term used when a dental appliance, such as a set of dentures, is superimposed over a patient's CT scan[1]. If a dual scan technique is utilized, at least five 2-mm fiducials should be applied to the denture. A high-resolution CT scan is obtained of the denture on its own and then a separate CT scan is obtained with the denture in the patient's mouth, ensuring not to disturb the fiducials on the patient and denture[1].

Intraoral Scanner Integration

An alternative to dual scan is the use of an intraoral scanner (IOS)[1]. An IOS provides a 3D surface image of the patient's dentition and occlusion. These are not volumetric images; IOS images are a surface. IOS images have a high degree of accuracy for single and quadrant impressions; when full arches are scanned, the accuracy decreases[1].

The implant team may wish to obtain IOS of the patient before teeth are extracted. If the occlusion is not going to be changed, these images can be saved for later use for planning of ideal implant position and provisional fabrication [1].

Virtual Planning

Once images are acquired and stored, they are loaded into treatment planning software. Several software packages are available, but key features should include the ability to:

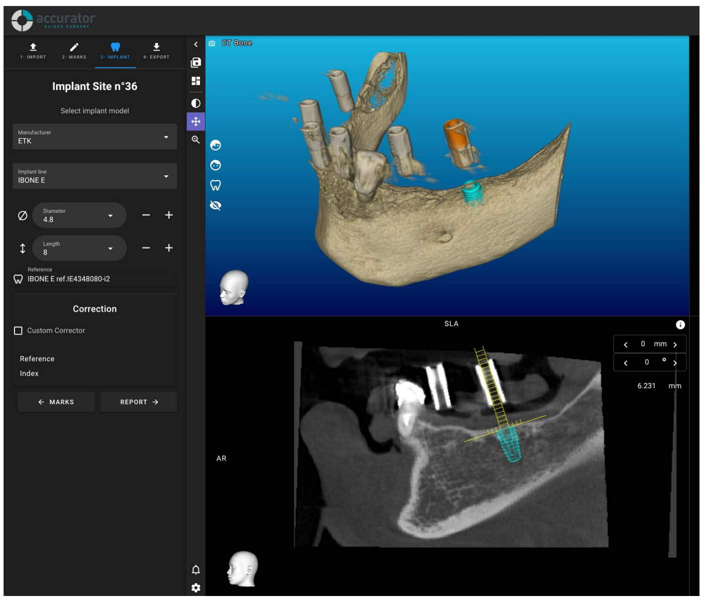

Figure 4: Figure 4: CBCT navigation planning interface showing multiplanar views (axial, sagittal, coronal) with superimposed 3D surface scan of teeth. Virtual implant crowns are positioned in proper occlusal relationship; with underlying virtual implant axes demonstrating prosthetically-driven planning that ensure ideal emergence profiles and biomechanical positioning.

- Import and export generic file formats (.dicom and .stl)
- Superimpose 3D files
- Perform dual scan .dicom superimposition
- Export images in a common coordinate system as individual or merged items

When clean .stl images are superimposed on CBCT data, the combined images allow the implant team to plan with osseous, dental, and soft tissue structures clearly visible along with the patient's occlusion[1].

Restoratively-Driven Planning

When starting to plan on the DN software, a panoramic curve for the arch requiring implants is developed on the axial plane of the patient's scan[1]. On the mandible, the inferior alveolar nerve also can be identified and marked[1].

Merger of the patient's scan and the IOS image or denture scan is performed, ensuring multiple areas of coordination between the images for accuracy of the merger[1].

Critical principle: The planning of implants should be restoratively driven. This starts with evaluating the occlusion and placing the restorative envelope of the virtual teeth in the proper occlusal position using virtual implant crowns available in the DN software[1]. Alternatively, a separate prosthetic software can be used to plan the restorations, which are then exported from the prosthetic software and imported as a .stl file into the DN software[1].

Once the implant crown is finalized, the virtual implants should be properly aligned below the virtual crowns for ideal emergence into the prosthetic space[1]. The DN software allows design of a generic implant or previously specified implant, with customization of implant platform diameter, apex diameter, length, and abutment height and angle[1].

Additional tools in the DN software allow mirroring to align implants across an arch and paralleling of adjacent implants[1].

Calibration

The instruments to be tracked by the system during surgery must be calibrated[1]. The geometry of the tracking arrays relative to the instrument being used must be determined by the tracking system. The assembled parts must be placed in front of the stereo cameras so the software can "learn" their geometry[1].

The instruments to be calibrated include:

1. Contra-angle handpiece
2. Straight handpiece
3. Probe tool

The calibration of instrumentation occurs approximately 60–80 cm from the camera[1]. The

contra-angle handpiece along with the handpiece tracker is assembled and calibrated by rotating the handpiece such that the camera can locate and identify the patterns on the handpiece tracker[1].
After calibration of the handpiece, a contra-angle handpiece chuck calibration is performed[1]. The handpiece is attached to the chuck and the drill motor is run at 10–20 revolutions per minute over the camera to calibrate the chuck plate to the handpiece[1]. A Go Plate (X-Nav Technologies, LLC, Lansdale, Pennsylvania) and probe are calibrated by placing the probe in the pivot hole of the Go Plate[1]. An implant drill bit is placed on the handpiece and the drill bit is placed on the Go Plate perpendicular to the center target[1]. The drill length is then verified by the DN system[1].

Registration:
The DN system must also be "taught" the geometry of the patient tracking array relative to the fiducials and thus the planned implants. This process is called registration[1].

Dentate Patient Registration:
For the dentate patient, the fiducial clip attached to a patient tracker arm and patient tracker is registered automatically by the system at the time of calibration[1].

Edentulous Patient Registration:
In the edentulous patient, an edentulous patient calibration probe is calibrated[1]. Then, the edentulous tracker plate is placed on the bone of the patient underneath a subperiosteal flap in an area of bone where there are no edentulous fiducial screws[1]. The tracker plate is attached to a patient tracker arm and patient tracker[1].
The patient tracker and the edentulous fiducial screws are then registered to the DN system by touching the screws (fiducials) with the probe as the system tracks them[1].

Verification of Calibration Accuracy:
The calibration accuracy is verified between the fiducials and the drill[1]. The drill bit is placed on three fiducial spheres on the fiducial clip for the dentate patient or the edentulous fiducial screws[1]. The doctor looks at the two-dimensional (2D) views for accuracy data in green colors[1]. If all three fiducials have green indicators, the system calibration is within 200 micrometers[1]. This step is not performed with edentulous patients[1].

Preoperative System Check:
Prior to the start of surgery and after every drill bit is changed, a "system check" is performed by the doctor[1]. This step ensures the instruments are calibrated and the system is properly registered to the patient[1].

Intraoperative Navigation Surgery:;
It is important to always confirm the accuracy of the tracking system by performing frequent system checks[1]. Anatomical landmarks on the patient are touched with the instruments. The doctor then visually confirms that the radiographic landmarks on the screen are exactly correlating[1].
Optimal landmarks are adjacent teeth or bony landmarks close to the planned implant site or fiducial markers on edentulous patients[1]. The operator looks at the screen as the drill is positioned over the surgical site[1]. The navigation system screen allows viewing of a virtual drill with demonstration of:

- Depth in tenths of a millimeter
- Angular deviation of the drill bit axis from the planned implant axis to the tenths of a degree
- The implant timing

The tip of the drill, indicated by a blue dot, is positioned over the target to indicate ideal planned platform position[1]. The top of the drill, a small circle, is then centered over the blue dot to indicate ideal planned angle[1]. Depth is indicated by color: yellow, green, and red[1]. The planned depth is always at the 45 degree position on the target[1].
The surgical assistant is in charge of suctioning and looking into the surgical field to notify the surgeon of any irregularities such as lack of irrigation or grossly off-positioned drill placement[1].
As implant drilling occurs, the depth indicator changes in color from green to yellow when the drill is 0.5 mm from the targeted depth[1]. The yellow turns to red, indicating when to stop the depth of the osteotomy[1].

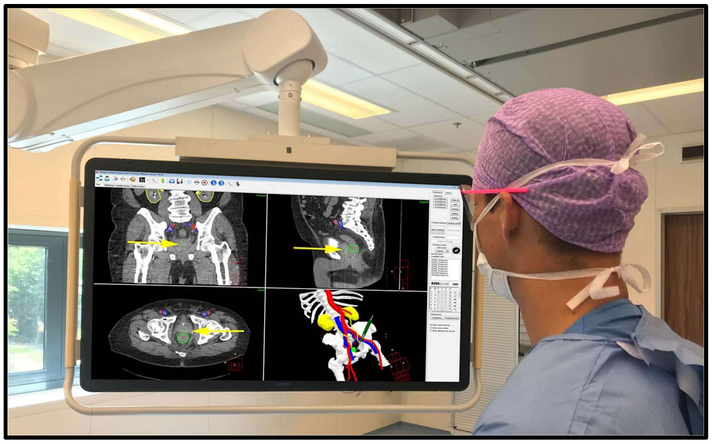

Figure 5: Figure 6: Intraoperative navigation monitor display showing real-time surgical guidance during implant osteotomy. The screen displays multiplanar CBCT views with virtual drill overlay, 3D reconstruction of planned implant position, angular deviation readout (in tenths of degrees), and color-coded depth indicator (green-yellow-red) showing proximity to target depth. This real-time feedback enables precise control and continuous accuracy verification throughout the procedure.

Intraoperative flexibility: During the implant surgery, the implant size, width, type, and location can be adjusted based on intraoperative factors deemed necessary for a stable and appropriately restorable implant[1]. This flexibility represents a significant advantage over static guided surgery[1].

Accuracy and Clinical Outcomes:
Multiple in vitro and clinical studies have evaluated the accuracy of DN compared with static guides and freehand placement[1,2,3].

Mean Deviation Measurements
A systematic review and meta-analysis of dynamic systems reported:

- Mean global platform deviation: approximately 1.0 mm
- Mean apical deviation: approximately 1.3 mm
- Mean angular deviation: 3.6–4.1 degrees
- No significant difference between model and clinical studies or between jaws

Prospective clinical data indicate that both DN and static guides achieve significantly lower platform, apical, and angular deviations than freehand placement[1,2,3]. Freehand placement shows a mean angular deviation of 6.50–9.92 degrees, whereas DN-placed implants demonstrate a mean angular deviation of 2.97–3.6 degrees[1,2].

Comparative Accuracy
Comparison of different implant placement methods:

Placement Method	Mean Angular Deviation (degrees)	Accuracy
Freehand (mucosal-borne guide)	9.92 ± 6.01	Lowest
Freehand (general)	6.50 ± 4.21	Low
Dynamic Navigation	2.97 ± 2.08	High
Static Guided Surgery	2.71 ± 1.36	High

Table 1: Comparison of mean angular deviations for different implant placement methods

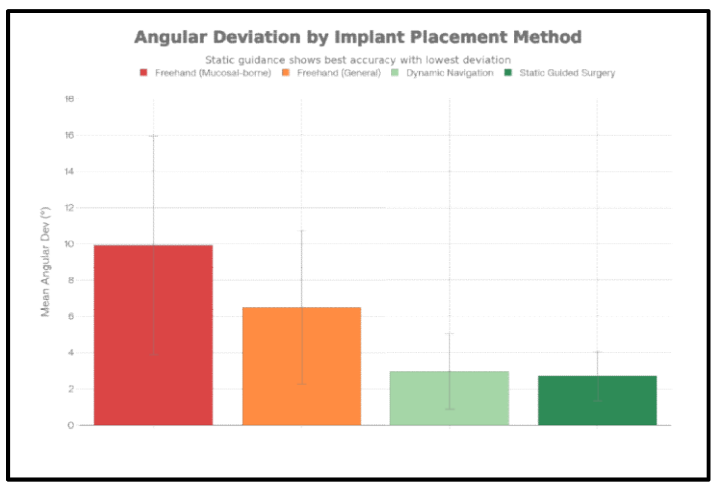

Figure 6: Figure 5: Bar chart comparing mean angular deviations (in degrees) across different implant placement methods. Freehand techniques demonstrate significantly higher deviations, with mucosal-borne guides showing 9.92±6.01° and

general freehand 6.50±4.21°, whereas both dynamic navigation (2.97±2.08°) and static guided surgery (2.71±1.36°) achieve substantially improved accuracy. Error bars represent standard deviation around each mean value.

Similar linear accuracy is achieved between DN and static guides, with slightly higher angular accuracy in some static systems[1,2]. Nevertheless, deviations obtained with DN remain well within clinically acceptable ranges and comparable to high-quality static guided surgery[1,2].

Clinical Applications

Implant survival rates with DN appear similar to those of conventional and static guided techniques[1,2,3]. DN has been successfully applied to complex situations including:

- Atrophic jaws with limited bone volume
- Immediate implant placement
- Pterygoid implants for extended cantilevers
- Full-arch rehabilitations and multiple implant cases
- Narrow interdental spaces with limited guide placement
- Patients with limited mouth opening

Advantages of Dynamic Navigation

Key advantages of DN over freehand and static guided surgery include:

Improved Accuracy and Safety

DN reduces angular and linear deviations relative to freehand placement, reducing the risk of:

- Nerve injury (inferior alveolar nerve, infraorbital nerve)
- Sinus perforation
- Cortical plate perforation
- Adjacent root damage
- Prosthetic misalignment and esthetic complications

Any form of computer-assisted surgery (CAS) is statistically more accurate and precise than freehand placement because it overcomes the inherent inaccuracy of human vision [1,2].

Real-Time Feedback and Verification

Real-time verification of drill trajectory and depth during every step of osteotomy preparation and implant insertion allows the surgeon to monitor position accuracy continuously[1,2]. Unlike static guides, where a mis-seated splint may result in significant gross error of the entire implant surgery, DN allows continuous verification of accuracy throughout the procedure[1].

Intraoperative Flexibility:

The ability to modify implant position, length, diameter, and even system during surgery without fabricating a new guide is a critical advantage over static templates[1]. This flexibility addresses the limitations of static guides, where changing implant position requires fabrication of a new guide or abandonment of the guided approach[1].

Minimally Invasive Approach:

DN facilitates flapless or minimally invasive approaches, potentially reducing:

- Intraoperative trauma
- Postoperative pain
- Healing time
- Tissue morbidity

DN allows surgeons the confidence to know implant placement is appropriately in bone without having to open a flap, thus minimizing trauma to the patient[1].

Ergonomic Benefits:

Ergonomically, DN allows the surgeon to look at the screen more so than inside the mouth, decreasing the need to bend the back or neck for a prolonged period[1]. This improved posture reduces surgeon fatigue and strain[1].

DN also allows the surgeon to perform the osteotomy and place the implant with limited direct visualization in the mouth in patients with:

- Limited mouth opening
- Difficult visualization in posterior regions
- Narrow interdental spaces that prohibit appropriate guidance tubes with static guides

Same-Day Treatment Protocol:

Implant surgeons are able to evaluate a patient, scan the patient, plan the implant position, and perform the implant surgery in the same day without the delay or cost of fabrication of a static surgical guide stent[1]. This streamlined workflow improves efficiency and patient satisfaction[1].

Patient-Reported Outcomes:

Patient-reported outcomes suggest that DN-assisted surgery may be perceived as more comfortable and less traumatic. Patients often appreciate being able to visualize the procedure on the screen and feel reassured by real-time monitoring[1].

Limitations and Disadvantages:

Despite its benefits, DN presents several challenges and limitations that clinicians should consider before implementation.

8.1 Financial Investment

The implementation of DN requires significant investment for the dental implant surgeon:

1. Capital costs: DN system hardware and software licenses
2. Imaging infrastructure: CBCT and intraoral scanning equipment
3. Per-case costs: Fiducial clips, markers, plates, and tracking components
4. Ongoing expenses: Software maintenance and system support

These costs may limit accessibility for smaller practices or those with limited capital budgets[1,2].

Learning Curve:

Those surgeons with limited experience with technology and virtual image processing may find it difficult to transition to a different modality of practice[1]. There is a learning curve with the application of a new technology for all levels of technological comfort[1].

The learning curve for DN systems was evaluated, showing that surgeons become statistically equivalent and proficient after 10–20 implants placed with the system[1]. During the learning phase, efficiency may be reduced and case selection limited[1].

In addition, restorative dentists will require training to be comfortable with the workflow implemented by the implant surgeon[1]. Interdisciplinary communication and coordination are essential for optimal outcomes[1].

Additional Surgical Steps for Edentulous Patients:

The current FDA-approved systems for edentulous patients require the additional surgery of the placement of fiducial screws and tracking plates[1]. This adds:

- Increased surgical time and cost
- Increased invasiveness for edentulous patients
- Additional patient morbidity from screw placement
- Need for coordinated scheduling of fiducial placement and implant placement

However, this obstacle will soon be replaced with a fiducial-free method, where the patient's anatomy will take the place of the screws[1].

Line-of-Sight Requirement:

Dependence on line-of-sight between the camera and tracking arrays represents a technical limitation[1,2]. Obstruction by hands, instruments, or soft tissues can temporarily interrupt tracking and require repositioning or re-registration[1]. In complex surgical cases or those with limited mouth opening, maintaining clear line-of-sight can be challenging[1].

Calibration and Registration Complexity:

Requirement for meticulous calibration and frequent system checks is essential; errors in these stages can compromise accuracy as much as mis-seated static guides[1,2]. The multi-step calibration and registration process requires:

- Careful attention to detail
- Understanding of system mechanics
- Systematic verification steps
- Knowledge of troubleshooting and error correction

Any deviation in calibration accuracy will propagate through the surgical procedure and compromise implant positioning[1].

Technological Dependence:

DN systems are complex technological devices that may experience hardware or software malfunctions[1,2]. Dependence on technology introduces the potential for system failures that may not be immediately apparent and could compromise accuracy[1]. Surgeons must have contingency plans and be prepared to revert to freehand or static guided techniques if system failure occurs[1].

Future Directions:

Integration of DN with emerging technologies represents an active and promising area of research and development[1,2,3].

Fiducial-Free Registration

Future developments include fiducial-free registration using anatomical landmarks [1]. Rather than requiring placement of fiducial screws in edentulous patients or thermoformed clips in dentate patients, the surgeon will select specific anatomical points on the CBCT during planning. After the patient tracker is placed, the patient will be registered by touching these points with the calibrated probe[1]. This approach will reduce invasiveness, operative time, and cost[1].

Robotic-Assisted Dynamic Navigation:

Robotic CAIS systems offer the potential for even higher positional stability and accuracy, particularly for long-span and extra-maxillary implants[1,3]. Integration of DN with robotic technology may allow autonomous or semi-autonomous execution of the surgical plan while maintaining real-time monitoring and intraoperative flexibility[1].

Artificial Intelligence and Machine Learning:

Integration of DN with artificial intelligence (AI) and machine learning offers several potential applications:

- Automated implant position optimization based on bone quality, anatomy, and occlusal considerations
- Predictive modeling of long-term outcomes based on implant position and angulation
- Real-time image guidance and augmented reality visualization
- Automated detection and correction of navigation system drift
- Personalized surgical planning based on individual anatomic variation

Augmented Reality Visualization

Augmented reality (AR) overlays of the virtual implant and surgical plan directly into the surgeon's field of view (using AR glasses or headsets) may eliminate the need to focus on a separate monitor and further improve ergonomics and surgical efficiency[3].

Cost Reduction and Technology Maturation:

As DN systems hardware and software mature, several disadvantages will diminish:

- Reduction in equipment costs through competition and economies of scale
- Simplified calibration and registration workflows
- Improved reliability and reduced downtime
- Wider accessibility across practice settings
- Standardization of techniques and better training resources

Clinical Research Needs

Further clinical research is needed to:

- Evaluate long-term survival rates, marginal bone behavior, and biological complications specific to DN workflows
- Assess patient-centered outcomes such as pain, satisfaction, quality of life, and return to function
- Perform cost-effectiveness analyses comparing DN with static guides and freehand protocols across different practice settings
- Develop evidence-based guidelines for case selection and patient counseling
- Establish standardized accuracy metrics and quality assurance protocols
- Compare DN with emerging robotic and AI-assisted systems

CONCLUSION:

The natural progression from analog 2D imaging and diagnostics to digital 3D imaging and diagnostics has led to increased understanding of the complex nature of implant surgery and prosthodontics[1]. The increased utilization of these digital 3D diagnostic and therapeutic modalities allows the surgical team to see the limitations of freehand surgery[1].

Computer-assisted surgery allows the implant team to overcome the limitations of human stereo vision and increase the accuracy and precision of implant placement [1]. DN allows the surgeon to implement digital implant treatment plans in an efficient fashion[1].

This efficiency and flexibility allow the team to utilize CAIS on every implant in every patient[1]. High-level statistical evidence clearly illustrates the improved accuracy and precision of computer-assisted surgery over freehand surgery[1,2,3].

Dynamic navigation represents a significant evolution in implant surgical technology, offering clinicians a powerful tool to enhance accuracy, minimize complications, and optimize patient outcomes. As technology matures, costs decrease, and evidence accumulates, DN is likely to become increasingly integrated into mainstream implant practice. Continued innovation and research will further refine these systems and expand their clinical applications.

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Nanotechnology in Orthodontics

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Abstract:
Nanotechnology has emerged as a transformative field in dentistry, particularly in orthodontics, due to its ability to manipulate materials at the molecular and atomic scale to enhance mechanical, biological, and functional properties. This review summarizes current advancements and potential applications of nanotechnology in orthodontics, focusing on nanomaterials, surface modifications, antimicrobial strategies, drug-delivery systems, and diagnostic innovations. Nanocoating's on orthodontic wires and brackets have shown improved frictional characteristics, increased corrosion resistance, and enhanced mechanical strength. Incorporation of nanoparticles into adhesives and elastomeric modules has demonstrated superior bond strength, reduced microbial colonization, and better colour stability. Despite significant promise, challenges remain regarding biocompatibility, long-term stability, cost-effectiveness, and regulatory approval. This review concludes that nanotechnology holds tremendous potential to revolutionize orthodontic practice, but further clinical studies are needed to ensure safety, optimize performance, and translate laboratory findings into routine clinical use.

Keywords: Nanotechnology, Orthodontics, Nanoparticle, Nanomaterial, Antimicrobial properties.

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INTRODUCTION

Nanotechnology is the study of modifying matter at the molecular and atomic levels. The word "Nano" is derived from "dwarf" in Greek. In 1959, American scientist and Nobel laureate Richard Feynman is credited with creating the concept and starting nanotechnology. He presented a paper titled "There is Plenty of Room at the Bottom" at the annual meeting of the American Physical Society at the California Institute of Technology on December 29, 1959.[1]
Eric Drexler's focus on the potential of molecular nanotechnology in the mid-1980s made this conceivable. The term "nano materials" was coined by N. Taniguchi, who defined them as substances with at least one dimension smaller than 100 nm.2 It is defined as an interdisciplinary field that concentrates on creating novel nano scale materials, devices, and systems. They stay below 100 nm because they obtain a better ratio of surface area to mass. These components may appear as nano holes, clusters, grains, or a combination of these. They are called quantum dots in three dimensions, sheets in one dimension, and nano wires and nano tubes in two.
The material's physical properties are significantly impacted by the fact that these new particles have a bigger surface area per unit mass than larger particles.3,4

Nanodentistry:
It is the science and technology of using nano materials, such as tissue engineering and nanorobots, to maintain almost perfect oral health.
Given that dentistry encompasses a wide range of interdisciplinary fields, all of which involve nanotechnology, including nanorobotics, nanoelectronics, and nanotechnology. Each of them has a distinct use in many dental specialties, such as biomechanics in orthodontics, local medication delivery and anesthetic in oral surgery and periodontal drug delivery, and enhanced diagnosis in oral medicine and diagnosis.[5,6]
Nanotechnology in Orthodontics:
Atomic force microscopy and nano indentation studies on orthodontic brackets and arch wires indicate that the surface characteristics of the brackets, including roughness and surface free energy (SFE), are crucial in reducing plaque development and friction. To examine An atomic force microscope (AFM) and a nanoindenter are used to examine the nano scale surface characteristics of biomaterials. Additionally, mechanical properties including as hardness, elastic modulus, yield strength, fracture toughness, and scratch resistance have been analyzed using nano indentation tests.7,8
Applications of Nanotechnology in Orthodontics
Nanoparticles in Elastomeric Ligatures:
Orthodontic elastomeric ligatures (OEM) are synthetic elastic polyurethane modules with characteristics like patient comfort and ease of application; they are often an affordable option in clinical practice.
Numerous studies have made an effort to highlight the correlations based on the chemical characteristics of various elastic ligatures and the need for modifications to lessen the negative effects of microbial biofilms on dental health. Fluoride-releasing ligatures have been the subject of some studies, but the findings have been conflicting and contradictory. Some highlight the long-term ineffectiveness associated with the ligatures' incapacity to ensure a prolonged release over time; they also seem to be ineffective even against decalcification.[9, 10]
It has been suggested that elastomeric ligatures could function as a support for the movement of nanoparticles, which could be compounds with antibacterial, anti-inflammatory, or anticariogenic qualities (like benzocaine) included into the matrix of elastomers.
Medicinal wax was also utilized. It has been shown that orthodontic brackets that release benzocaine gradually and constantly reduce the discomfort caused by mucosal irritation caused by the brackets. The most recent studies seem to evaluate the potential of ligature connection with silver nanoparticles, a material that appears to be able to combat dental biofilm and reduce the enamel demineralization caused by bacterial plaque formation without compromising the material's mechanical properties and, consequently, the effectiveness of orthodontic therapy.
The application of nanotechnology to dental materials is innovative in terms of improving results.Due to their anticariogenic qualities, silver particles may be produced by minimally invasive methods and have been incorporated into numerous products. It is commonly recognized that silver exhibits a cytotoxic effect on a range of microbes and is more antimicrobial than other metals:Although the precise mechanism is unknown, it most likely works by denaturing the enzymes involved in DNA synthesis and the respiratory cycle. Furthermore, Although the precise mechanism is unknown, it most likely works by denaturing the enzymes involved in DNA synthesis and the respiratory cycle. Furthermore,
Silver is safe and compatible with human cells. However, more investigation is now needed to determine whether they are truly biocompatible.[11, 12]
Application of Nanoparticles for Controlling Oral Biofilm in Orthodontics:
Brackets and fixed orthodontic appliances promote bacterial build up by providing retentive areas. Reports state that between 50 and 70 percent of individuals undergoing fixed orthodontic treatment. Enamel demineralization (white spot lesions or cavities) occurred around the brackets following appliance therapy.
Numerous strategies have been put out to reduce demineralization and the formation of white spots during therapy, many of which significantly rely on patient compliance. The cornerstones are the

elimination of mechanical plaque biofilm and the use of fluoride and/or antimicrobial treatments. To increase the resistance of enamel and dentine and stop the metabolism of the microorganisms that cause caries, fluoride is used in tooth paste, mouthwash, professional applications, and adhesives. Certain NPs have been introduced to orthodontic adhesives because of their biocidal or adhesion-resisting qualities to control the mouth biofilm. The main problem with adhesives and appliances when NPs are added to conventional orthodontic adhesives is that the failure to combine physical and chemical properties has a detrimental effect, leading to less-than-ideal clinical results. Additionally, the new product's security and antibacterial and sticky properties guaranteed nano-adhesives across a physiologically relevant surface pertinent time period.

Compounds containing NPs or covering the bracket surfaces NPs have been used to benefit from unique characteristics of specific NPs. 13. Additionally, by preventing the formation of biofilms, as should be shown in figure 4, nano-sized gold particles can be used on orthodontic devices like aligners to increase their antibacterial activity. Aligners cover the teeth and gingiva for almost the whole day, which increases the risk of plaque accumulation. Additionally, gold particles exhibit favorable biocompatibility in both in vitro and in vivo settings. [14]

Nanoparticles
1. Titania (Ti02)
2. Silver (Ag)
3. Gold (Au)
4. Silica (Si02)
5. Copper (Cu/Cu0)

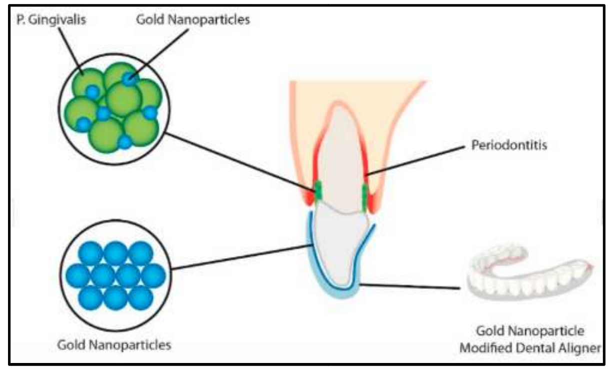


Figure 1: Aligners coated with modified gold nanoparticles causing enhanced antibacterial activity against Porphyromonas gingivalis. Due to presence of coated aligner, the number of bacterial cells was decreased, causing increased biofilm formation prevention.

Nanotechnology in Adhesives:

Nanomaterials can be used as adhesives in orthodontics to improve mechanical strength or reduce the possibility of enamel damage. The two adhesives that are most commonly used to affix bands and brackets to the surfaces of teeth are glass ionomer cements (GICs) and composites. Because of their superior mechanical properties and less potential for enamel damage, nanoparticles can be used as orthodontic adhesives. Two types of materials are nanomers (glass ionomers) and nanoclusters (composites).Furthermore, nanocomposites fall into two categories: Nanofills with nanometer-sized particles (1–100 nm) scattered throughout the resin matrix make up nanohybrids, which are composed of larger particles (400–500 nm) with additional nanometer-sized particles. [15, 16]

It is feasible to produce an increased filler load, which leads to less polymerization shrinkage and better mechanical properties, because the filler particles are smaller and can pass through the resin tags. Similar results can be obtained with a great peripheral seal to dentin and polish. The list of advantages is completed by excellent optical qualities, practical handling features, and polishability. Furthermore, adding nanofillers lessens surface roughness, which decreases the possibility of bacterial adhesion.

GIC is commonly used for band cementation in orthodontics due to its propensity to leak fluoride.The mechanical performance of traditional GIC was enhanced by the inclusion of fluorapatite polyacids, nano hydroxy, and N-vinyl pyrrolidone. Furthermore, it was shown that the biaxial flexural strength, diametral tensile strength, and compressive strength were greater than those of conventional GIC. A resin-modified GIC with high fluoride release and good mechanical properties was just released. Fluor aluminum glass and various nanofiller clusters are used to make it. [17, 18]

Orthodontic Power Chains:

Power chains have been used in every orthodontic office since their creation in the late 1960s. They are usually made of polymeric materials produced by the polymerization process, such as polyesters or polyether's. They provide light, continuous pressures, are inexpensive, easy to use, and facilitate patient adjustment, among other clinical advantages. They stand out for their exceptional adaptability and enhance the space closure of extraction scenarios. However, power chains offer drawbacks as well. Their mechanical performance has been demonstrated to be time-limited, requiring periodic replacement. However, power chains offer drawbacks as well. Their mechanical performance has been demonstrated to be time-limited, requiring periodic replacement. Both internal and external factors affect the strength of orthodontic power chains and decide whether permanent deformation takes place. The intrinsic factors are the material composition, production methods, and external morphology. External factors include the mouth cavity's temperature, pH, and moisture absorption. Because they absorb fluids from the oral cavity and have hydrophilic characteristics that allow them to discolor with time, they are less effective at maintaining oral health.[12]

In Orthodontic Archwires:

The frictional force that prevents the arch wires from moving presents several difficulties. It could also lead to tooth issues. By utilizing the right lubricants, these problems can be resolved. Nanotechnology has been applied to improve the properties of lubricants. Arch wires can be made to move more readily by lubricating them with materials based on nanotechnology. A self-lubricating coating with fullerene-like nanoparticles was used by Katz et al. The results showed that applying this lubricant decreased friction, which improved the arch wires' movement. The proper coating can reduce resistance to the movement of arch wires in addition to the use of lubricants.In one investigation, three wires composed of titanium molybdenum alloy, nickel-titanium, and stainless steel were coated with a uniform and smooth layer of nanoparticles (nanoceramics). Applying the coating was found to improve the surface topology, which lessens problems associated to friction. Orthodontic wires can be coated with a variety of nanoparticles to reduce friction force. Kachoei et al. coated stainless steel orthodontic wires with ZnO nanoparticles in the 40–45 nm size range. The addition of nanoparticles was shown to minimize friction between the wires and brackets by 51% when compared to reference wires. It was believed that the decreased friction was due to the nanoparticles' function as lubricants. [19, 20]

Shape Memory Polymers in Orthodontics:

The demand for beautiful orthodontic wires to complement tooth-colored brackets has increased significantly during the past ten years. It is possible to conduct research on shape memory attractive polymers. Shape memory polymers (SMPs) are materials that, after learning a macroscopic or equilibrium shape, can be changed and put to a transient or dormant shape under specific temperature and stress conditions. They can subsequently return to their initial, stress-free state under thermal, electrical, or environmental conditions. This relaxation is linked to the elastic deformation that was stored during previous manipulation. The SMP's return to its equilibrium shape may be accompanied by a macroscopic shape change that is helpful for ligation procedures or a sufficient and determined force that is advantageous for orthodontic tooth movement. Once in the mouth, these polymers may be activated by light-induced photoactive nanoparticles or body heat, which will move teeth. [21, 22]

Because SMP orthodontic wires will deliver lighter, more uniform forces than conventional orthodontic materials, patients may experience less discomfort.

Because the SMP materials are clear, colorable, and stain resistant, they also provide the patient with a more aesthetically pleasant appliance during treatment. Because of the SMP appliance's high percent elongation (up to about 300%), which allows for the continuous application of forces across a broad range of tooth movement, the patient requires fewer visits. [23, 24]

Nano Lipus Devices:

Low intensity pulse ultrasound, or LIPUS nanodevices, is a common therapeutic, surgical, and diagnostic technique in medicine. It is a form of mechanical energy that is transmitted as an acoustic pressure wave through and into biological tissues. It has been shown that low-intensity pulsed ultrasound (LIPUS) effectively improves angiogenesis during wound healing and releases preformed fibroblast growth factors from a macrophage-like cell line (U937).

Additionally, LIPUS has been demonstrated to enhance mandibular distraction osteogenesis, bone development into titanium porous-coated implants, and bone healing after fracture. It is still unclear how exactly US stimulation influences bone cell function. 25. El Bialy et al. applied LIPUS to the temporomandibular joint (TMJ) region of baboon monkeys and developing rabbits for a few minutes every day. 26, 27Their results showed that mandibular cartilaginous development had significantly increased. In a different study, Oyonartea et al. unilaterally stimulated experimental rats with LIPUS in the TMJ region for 10 or 20 minutes over the course of 20 days. The results showed that LIPUS treatment can affect rats' mandibular growth pattern by influencing the cartilage and bone levels. During orthodontic therapy, this strategy can also be employed to reduce root resorption. According to El-Bialy et al., LIPUS can improve the development of dental tissue in rabbits and may be used to cure root resorption. [28]

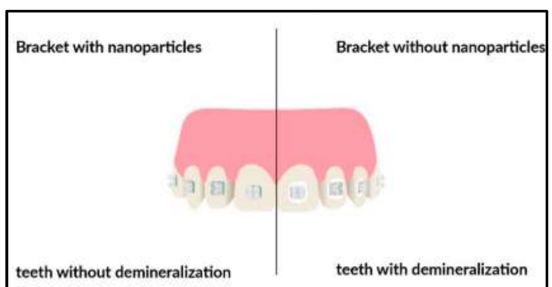
Biomems/Sems f or Orthodontic Teeth Movement

They are made up of silicon-based micromachined parts such gears, motors for biological systems, and rotary and linear motors. Nanoelectromechanical systems (NEMS) are nanoscale devices that combine mechanical and electrical functions. Evidence suggests that electrical pressures, in addition to mechanical ones, can enhance orthodontic tooth movement. It has been demonstrated that electric stimulation promotes tooth movement by raising cellular enzymatic phosphorylation activities and accelerating tooth movement in animal tests. Biomedical microelectromechanical systems (BioMEMS) are the science and technology of working at the microscale for biological and biomedical reasons, which may or may not include any electrical or mechanical functions. [29, 30]

When 15–20 microamperes of low direct current (dc) were applied to the alveolar bone by altering the bioelectric potential, it was discovered in animal experiments that osteoblasts and periodontal ligament cells had increased amounts of the second messengers cAMP and cGMP. These findings suggest that cellular enzymatic phosphorylation activities were elevated by electrical stimulation, leading to secretory and synthetic processes associated with accelerated bone remodeling. However, the intraoral source of energy is a major problem that needs to be fixed.[31,32]

Nano Remineralizing Agents:

White spot lesions and demineralization issues are common both during and after orthodontic treatment. Nanoparticles are being used to remineralize enamel that has lost calcium.Nanohydroxyapatite has been made into a paste. Because calcium nanophosphate crystals smaller than 100 nm increase the surface area and wettability of HA (hydroxyapatite) nanoparticles, the product has improved bioactivity and creates a protective layer that stops erosion on the enamel surface. [33]



Comparison of teeth demineralization development with and without nanoparticles' covered brackets.

Figure 2: Comparison of teeth demineralization development with and without nanoparticles covered brackets

Nanorobots:
By directly altering periodontal tissues, orthodontic nanorobots would enable quick tooth alignment. The idea of using such nanorobots in dentistry and orthodontics could be expanded in the far future. In these fields, nanorobots with specific motility mechanisms could move through periodontium and directly alter it, enabling faster orthodontic tooth movement. During orthodontic treatment, this strategy can also be employed to reduce root resorption. When it comes to solving issues like friction, which prevents teeth from aligning or retracting during treatment, nanotechnology has made significant progress. [34, 35]
Orthodontic nano robots enable quick tissue repair, painless tooth up righting, rotation, and vertical repositioning. A novel nanotechnology-based stainless-steel wire that combines exceptional strength with good deformability, corrosion resistance, and surface finish is being researched. In the future, periodontal tissues like gingival, periodontal ligament, cementum, and alveolar bone may be directly controlled by orthodontic nanorobots, enabling rapid and painless tooth alignment, rotation, and vertical repositioning in a matter of minutes to hours. Molar uprighting methods, on the other hand, require weeks or months to complete. [35]

Smart Brackets with Nanomechanical Sensors:
A idea for intelligent brackets with an integrated sensor system for measuring force and moment in three dimensions was recently released. Nanomechanical sensors can be included into the base of orthodontic brackets to provide the orthodontist with immediate feedback regarding the applied orthodontic forces. This will allow the orthodontist to successfully move teeth with the fewest possible negative effects by adjusting the applied force to be within a biological range.The primary advantages of smart brackets are the capacity to accurately manage teeth in all directions, move teeth more efficiently, spend less time at the chairside, and obtain treatment faster. 36, 37

Orthodontic Miniscrews
A tight proximity between the surface of the Mini screw and the bone is essential for greater stability and a stronger resistance to orthodontic forces. Additionally, the screw's primary stability may be harmed by inflammatory processes, which could lead to an early loss of strength. Two studies have evaluated the stability and osseointegration of nanotechnology-modified mini screw surfaces; arrays of TiO_2 (titanium dioxide) nanotubes were used to identify the surface. 38, 39The TiO_2 nanotube arrays were treated with ibuprofen and RhBMP-2 (recombinant human bone morphogenetic protein-2) before being compared to a control group of standard Mini screws. In order to evaluate the drugs' effects in vivo, the study looked at how drug-modified Mini screws enhanced tissue health. These modified Mini screws can also supply other drugs, like vitamin C, aspirin, and antibiotics, to reduce patient discomfort and edema at the insertion site. This modification to the materials has also proven essential in guaranteeing greater surface roughness of the aids and improved wettability as compared to standard products. [39]

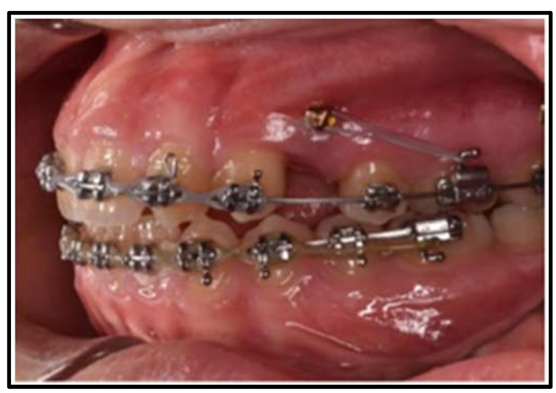


Figure 3

Nano silver Mouth Rinse

In order to prevent bacterial growth, the majority of mouthwashes often contain ethanol, which some patients with periodontal infections find uncomfortable. At incredibly low quantities, silver nanoparticles were added to an ethanol-free mouthwash and contrasted with reasonably priced mouthwashes. They noticed that there was no difference between the mouthwashes made with Silver Nano and other mouthwashes that were sold commercially.40

CONCLUSION

Nanotechnology now plays a larger and more constant role in the dentistry sector since it has the ability to bring about significant advances and benefits. Further research, especially in the field of orthodontics, must be sparked by the current positive results.

We have covered the several advantages that nanoparticles have provided to this sector, especially in relation to their mechanical and antimicrobial properties. The limitations of dental materials and technical techniques often refer to the fundamental objective of orthodontic treatment coordination and safety management; however, science and nanotechnology have helped to partially resolve some of these limitations, improving patient management in the clinical pathway

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Pit and Fissure Sealants in Children - Current Concepts and Emerging Innovations: A Narrative Review

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Abstract:
Pit and fissure sealants continue to play a key role in the prevention of dental caries in pediatric dentistry. In recent years, developments in material science—such as the incorporation of nano-fillers, amorphous calcium phosphate (ACP), and bioactive glass—together with refinements in adhesive techniques, advances in diagnostic imaging, and the expansion of school- and community-based preventive programs, have broadened their clinical use and potential benefits. This narrative review brings together current evidence on the clinical performance of sealants, emerging material innovations, and the role of diagnostic adjuncts in caries detection and management. Bioactive and ion-releasing sealants have demonstrated encouraging outcomes in laboratory investigations and short-term clinical studies, particularly with respect to enamel remineralization, reduction of microleakage, and arrest of early carious lesions. Nevertheless, there remains a need for well-designed, long-term randomized controlled trials to confirm the durability of these effects and to guide evidence-based clinical decision-making.

Keywords: Amorphous Calcium Phosphate, Bioactive Glasses, Nano-Hydroxyapatite, Narrative Review, Pediatric Dentistry, Pit and Fissure Sealants.

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INTRODUCTION:

Occlusal surfaces of posterior teeth are disproportionately affected by dental caries due to complex fissure morphology and plaque retention. Pit and fissure sealants create a physical barrier that prevents cariogenic biofilm ingress and have been shown to reduce occlusal caries incidence in children and adolescents when properly applied and maintained. Systematic reviews consistently report that sealants are effective for caries prevention on permanent and primary teeth under appropriate conditions[1,2].

Historically, resin-based sealants (unfilled or filled) have been the standard due to favourable retention and handling. However, concerns such as technique sensitivity, moisture contamination effects, marginal micro leakage, and material biocompatibility (e.g., BPA derivatives) have stimulated research into hydrophilic/resin-modified materials, ion-releasing fillers (ACP, nano-hydroxyapatite), bioactive glass-based formulations, and diagnostic tools to better identify lesions suited for sealing. Concurrently, advances in 3D and digital imaging, and minimally invasive approaches, enable more precise decision-making and patient selection.[3]

This review synthesizes contemporary evidence focused on clinical effectiveness, material innovations (nano- and bioactive approaches), surface conditioning and application strategies,diagnostic adjuncts, safety and regulatory concerns, andpublic-health and economic considerations.

MATERIALS AND METHODS:

This narrative review is based on a focused search of recent, high-quality literature published up to 2025, including systematic reviews, meta-analyses, clinical trials, and relevant in vitro studies related to pit and fissure sealants and associated technologies. Literature was identified through searches of PubMed/PMC, leading dental journals, and recently published systematic reviews. The review primarily concentrates on the clinical effectiveness of sealants, developments involving nano-hydroxyapatite (nHAp), amorphous calcium phosphate (ACP), bioactive glass and other ion-releasing materials, as well as advances in etching techniques such as laser and alternative surface conditioning methods. In addition, emerging diagnostic tools, including three-dimensional imaging, and considerations related to cost-effectiveness were also explored.

RESULTS:

1. Clinical effectiveness and evidence synthesis

Multiple systematic reviews and meta-analyses have reinforced the effectiveness of pit and fissure sealants in preventing occlusal caries in permanent teeth and, to a lesser extent, primary teeth; outcomes are strongly influenced by retention and follow-up duration. Systematic reviews through 2024 support sealant use as a non-inferior and often superior intervention compared with no treatment or fluoride varnish for occlusal caries prevention in school-aged children[1].

Comparative effectiveness between different sealant formulations (filled vs unfilled, hydrophobic vs hydrophilic) shows variable retention patterns; hydrophilic materials may offer advantages in less ideal isolation, while hydrophobic resins can offer better long-term retention in well-isolated conditions. A contemporary 2025 meta-analysis discussed these trade-offs and categorized sealants by retention and moisture-tolerance[4].

2. Nano-hydroxyapatite (nHAp)

nHAp has been extensively reviewed for remineralization potential in dentifrices and restorative materials. In vitro and in situ studies show nHAp can promote remineralization of early enamel lesions and increase surface microhardness. When incorporated into sealant formulations, nHAp and nACP improve mineral delivery to adjacent enamel and may reduce demineralization underneath sealants. These findings are supported by multiple scoping and systematic reviews on nHAp and by targeted in-vitro sealant studies[5].

3. Amorphous Calcium Phosphate (ACP) – ion-releasing sealants

ACP-containing sealants have been shown in laboratory studies and some clinical trials to release calcium and phosphate ions, aiding in remineralization and limiting subsurface demineralization adjacent to sealants. A number of controlled in-vitro studies and at least one clinical retention trial (trial registries and smaller RCTs) support ACP sealants' potential to protect enamel; however, the strength of long-term clinical evidence remains moderate and larger RCTs are warranted[6].

4. Bioactive glass and other bioactive materials

Bioactive glass (fluoride-containing 45S5 derivatives and others) incorporated into low-viscosity resins or as separate glaze materials has demonstrated ion-release, enamel protective effects, and potential to occlude micro-gaps at the tooth–material interface. Recent in-vitro and a few clinical evaluations indicate enhanced protective effects comparedwith conventional sealants; broader RCT evidence is emerging[7].

5. Antimicrobial additives (silver nanoparticles, chlorhexidine, etc.)

Antimicrobial-loaded sealants (e.g., silver nanoparticles) have shown in vitro reductions in cariogenic bacteria; clinical data are limited but suggest potential benefit in high-risk populations. The long-term effect on bacterial ecology, resistance, and staining needs careful assessment[8].

6. Surface conditioning and alternative etching (laser etching)

Er,Cr:YSGG and other laser etching techniques have shown comparable or improved marginal adaptation and microleakage profiles for sealants compared with conventional acid etching in several in-vitro studies, and can be useful in patients where traditional isolation is difficult. Clinical adoption is limited by equipment cost and training requirements; more clinical outcome data are needed[9].

7. Diagnostic adjuncts and digital imaging

3D scanned imaging and other optical/digital caries detection systems (including near-infrared transillumination and quantitative light-induced fluorescence) improve detection of early occlusal lesions and help clinicians avoid sealing over cavitated or established lesions. These technologies therefore support evidence-based selection for sealing vs restorative interventions[10].

8. Cost-effectiveness and public health programs

Economic evaluations indicate that sealants are cost-effective relative to untreated caries and often compare favourably to fluoride varnish programs when retention and re-seal strategies are considered. Community sealant programs remain an important component of school-based preventive care[11,12].

DISCUSSION:

Contemporary sealant research is increasingly focused on combining reliable mechanical retention with added therapeutic benefits, such as ion release and antimicrobial activity. The incorporation of nano-fillers, including nano-hydroxyapatite (nHAp) and nano-amorphous calcium phosphate (nACP), as well as bioactive glass formulations, has shifted sealants from being purely passive occlusal barriers to materials that actively interact with the tooth surface. These newer formulations have the potential to promote remineralization of adjacent enamel and may help arrest early carious lesions. However, while in-vitro findings are encouraging, their translation into consistent and sustained clinical caries reduction remains uncertain, underscoring the need for large, well-designed randomized controlled trials with follow-up periods of at least 2–5 years.

Careful case selection remains a critical determinant of long-term success when using pit and fissure sealants. Ideal candidates include sound fissures, particularly in newly erupting first permanent molars in children at increased risk of dental caries. During the eruption phase, these teeth are especially vulnerable due to partial eruption, difficulty in maintaining hygiene, and plaque accumulation, making sealant placement highly beneficial. The use of modern diagnostic adjuncts—such as three-dimensional surface scanning, near-infrared transillumination, and other advanced optical detection techniques—can further support clinical decision-making by allowing more accurate differentiation between non-cavitated early lesions suitable for sealing and lesions that have progressed and require preventive resin restorations or definitive treatment. In situations where moisture control is suboptimal, hydrophilic resin-based sealants and glass ionomer sealants provide practical alternatives. Although their retention may differ from conventional resin sealants, they offer distinct advantages in challenging clinical conditions and may function effectively as interim or, in selected cases, long-term preventive measures based on individual caries risk.

Despite extensive research, the current body of evidence on pit and fissure sealants has several important limitations. Many newer material innovations are supported largely by laboratory studies, with relatively few high-quality clinical trials available to validate their long-term effectiveness in routine practice. There is also marked heterogeneity among existing studies, including differences in outcome measures—such as an emphasis on sealant retention versus true caries prevention—as well as variations in follow-up periods and comparator materials. Moreover, although advanced diagnostic technologies show considerable promise in improving lesion detection and case selection, their uptake in everyday practice remains inconsistent due to factors such as cost, availability, and varying levels of clinician familiarity. Collectively, these issues limit the ability to draw standardized and universally applicable conclusions.

Future research should prioritize robust randomized controlled trials that compare bioactive and nano-enhanced sealants with contemporary resin-based materials over extended follow-up periods, with greater emphasis on clinically meaningful outcomes such as caries reduction rather than retention alone.

In addition, real-world studies conducted within school-based and community programs are needed to evaluate the performance of emerging materials and digital diagnostic tools under practical conditions. Ongoing assessment of biocompatibility and potential environmental implications will also be essential as newer additives and technologies continue to be introduced into clinical practice.

CONCLUSION:

Pit and fissure sealants remain a well-established and evidence-based approach for the prevention of occlusal caries in children, especially among those at higher caries risk. Recent advances in material science have gradually moved sealant development beyond reliance on mechanical retention alone, with increasing emphasis on multifunctional materials that offer additional therapeutic benefits, including ion release, remineralization potential, and antimicrobial properties. These developments are intended not only to improve protection of the enamel surface but also to enhance sealant durability and overall clinical performance. At the same time, improvements in diagnostic technologies—such as refined visual assessment methods, digital imaging, and optical caries-detection systems—have contributed to more accurate identification of early occlusal lesions and better-informed decisions regarding sealant placement. Evidence from public-health assessments and economic evaluations consistently supports the cost-effectiveness of sealant programs, underscoring their importance within community-based preventive dentistry. For pediatric clinicians, keeping pace with evolving material innovations, applying sealants based on appropriate caries-risk assessment, and adhering to sound clinical protocols for placement and follow-up remain critical for optimizing sealant success and achieving sustained caries prevention.

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Role of Self-Assembling Peptide P11-4 in Dentistry: Mechanism, Clinical Applications, and Recent Advances: A Review.

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Abstract:
Self-assembling peptides (SAPs) represent a novel class of biomimetic materials introduced in dentistry to facilitate non-invasive regeneration of early enamel carious lesions. Among these, self-assembling peptide P11-4 has gained significant attention due to its ability to mimic enamel matrix proteins and promote guided hydroxyapatite formation within subsurface enamel lesions. P11-4 is applied as a low-viscosity monomeric solution that penetrates early non-cavitated carious lesions and undergoes pH-triggered hierarchical self-assembly to form a three-dimensional fibrillar scaffold. This scaffold attracts calcium and phosphate ions from saliva, enabling de novo hydroxyapatite nucleation and true subsurface remineralization, in contrast to conventional fluoride-based therapies that primarily enhance surface mineralization. Increasing in vitro, in situ, and clinical evidence supports the use of P11-4 in the management of white spot lesions, early enamel caries, post-orthodontic demineralization, and enamel repair following bleaching procedures. Recent advances include combination therapies with fluoride, calcium–phosphate systems, and laser-assisted remineralization, as well as expanded applications in regenerative and restorative dentistry. This review summarizes the history, mechanism of action, clinical applications, advantages, limitations, and recent advances of self-assembling peptide P11-4, highlighting its potential role as a smart biomaterial in contemporary minimally invasive dentistry.

Keywords: Self assembling peptides, enamel remineralization, biomimetic dentistry, white spot lesions, minimally invasive dentistry.

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INTRODUCTION:

Dental caries remains one of the most prevalent chronic diseases worldwide and is currently understood as a dynamic and reversible process involving cycles of demineralization and remineralization of dental hard tissues [3,4]. Early enamel caries, clinically manifested as white spot lesions, represents a critical stage at which the disease can be arrested or reversed through non-invasive therapeutic interventions [3].

Self-assembling peptides (SAPs) are short protein fragments capable of spontaneously organizing into highly ordered nano- or microstructures such as fibers, ribbons, and hydrogels through non-covalent interactions including hydrogen bonding, electrostatic forces, and hydrophobic interactions [1]. Due to their tunable molecular architecture, biocompatibility, and responsiveness to environmental cues, SAPs have gained significant attention in biomedical applications including tissue engineering, drug delivery, and regenerative medicine [1]. Their ability to mimic natural extracellular matrices makes them particularly attractive for dental hard tissue regeneration.

Self-assembling peptide has been recently introduced to promote hard tissueregeneration for treating early non-cavitated carious lesions. These are rationally designed biomimetic peptides that can undergo spontaneous hierarchical self-assembly in response to specific environmental conditions, forming three-dimensional fibrillar scaffolds that promote enamel remineralization.

P11-4 is a self-assembling peptide that mimics the function of enamel matrix proteins, serving as a template for de novo hydroxyapatite formation within early carious lesions. P11-4 is a synthetically engineered, biomimetic peptide composed of naturally occurring amino acids that has the ability to self-assemble into a three-dimensional fibrillar scaffold within early carious enamel lesions. It mimics the function of amelogenin-derived enamel matrix proteins and promotes guided hydroxyapatite crystal nucleation and growth, leading to subsurface enamel remineralization rather than superficial mineral deposition.

Over the past decade, increasing in vitro, in situ, and clinical evidence has demonstrated the efficacy of P11-4 in the management of early non-cavitated enamel caries, post-orthodontic white spot lesions, and enamel demineralization following bleachingprocedures [2,3,5]. Recent advances have further expanded its potential applications through combination therapies, integration with calcium–phosphate systems, laser-assisted remineralization protocols, and investigation of its role as a pre-restorative enamel conditioning agent [4,8]. These developments position self-assembling peptides as “smart biomaterials” with significant relevance to regenerative and conservative dentistry.

Therefore, the aim of this review is to comprehensively discuss the mechanism of action, clinical applications, advantages, limitations, and recent advances of self-assembling peptide P11-4 in dentistry.

HISTORY AND DEVELOPMENT

Dental caries is now understood as a dynamic, reversible process characterized by cycles of demineralization and remineralization. Early clinical manifestations such as white spot lesions (WSLs) are reversible if remineralization is promoted. Increased understanding of the biological caries process and the philosophy of minimal intervention dentistry led to interest in non-invasive regenerative approaches. Natural enamel matrix proteins guide hydroxyapatite crystal growth duringtooth development, but these proteins are lost after enamel maturation, limiting natural repair. Conventional remineralizing agents (fluoride, CPP-ACP, tricalcium phosphate) primarily act by surface mineral deposition [4,6]. To overcome this limitation, biomimetic strategies were introduced. Self-assembling peptide P11-4 was developed as a synthetic analogue of enamel matrix proteins to enable guided enamel regeneration in post-eruptive teeth [3,4].

- **Early 2000s**: Advances in peptide chemistry and supramolecular biology led to the concept of **peptide self-assembly** for biomedical applications.
- **Mid-2000s**: Researchers developed **β-sheet-forming peptides** capable of nucleating hydroxyapatite, inspired by the role of **amelogenin** in enamel formation.
- **Development of P11-4**: P11-4 was rationally designed with alternating **hydrophilic and hydrophobic amino acids**, enabling hierarchical self-assembly. The peptide was later commercialized under CUROLOX® technology (e.g., Curodont Repair / Protect) for non-invasive management of early enamel caries.
- **Shift in caries philosophy**: The modern understanding of caries as a **dynamic, reversible process** encouraged development of **biomimetic remineralizing agents**, positioning SAPs as a new class beyond fluoride and calcium-phosphate systems.

Initial laboratory and in vitro investigations demonstrated that P11-4 could penetrate deeply into subsurface enamel porosities and promote mineral deposition from within the lesion rather than on the enamel surface alone [6]. These promising findings led to early clinical safety and feasibility trials, which confirmed that the material was biocompatible, non-invasive, and well tolerated when applied to early carious lesions [5]. The clinical translation of this technology culminated in the commercialization of P11-4-based products under CUROLOX® technology for the management of non-cavitated enamel caries [5].

Subsequent in vitro, in situ, and randomized clinical trials expanded the evidence base for P11-4, demonstrating its effectiveness in the management of white spot lesions, post-orthodontic demineralization, and earlyenamel caries, both as a standalone therapy and in combination with fluoride-based systems [2,3,7]. These studies reinforced the concept that self-assembling peptides function as biomimetic scaffolds rather than conventional remineralizing agents, offering enhanced subsurface remineralization and improved lesion aesthetics.

CLASSIFICATION AND THEIR MOLECULAR STRUCTURES

Self-assembling peptides can be classified based on their secondary structure and mode of molecular organization, which determine the type of supramolecular nanostructures they form and their functional applications in biomedical and dental sciences [1].

1. **β-sheet–forming peptides:**

B-sheet–forming peptides are short peptides, typically consisting of 12–16 amino acids, with an alternating arrangement of hydrophilic (charged) and hydrophobic residues. This molecular design promotes the formation of β-sheet secondary structures, which further self-assemble into higher-order nanostructures such as nanofibers, ribbons, tapes, or fibrils. These peptides generally exist initially as low-viscosity monomeric solutions, allowing deep penetration intosubsurface enamel porosities before undergoing self-assembly [1].

2. α-helix (Coiled-coil) peptides:

α-helix or coiled-coil peptides adopt an α-helical secondary structure and organize into coiled-coil motifs. Their molecular architecture is based on repeating heptad sequences (a–g), in which hydrophobic residues at specific positions stabilize the helical bundle,while charged residues contribute to intermolecular interactions and structural stability [1].

3. Collagen-like peptides (CLPs):

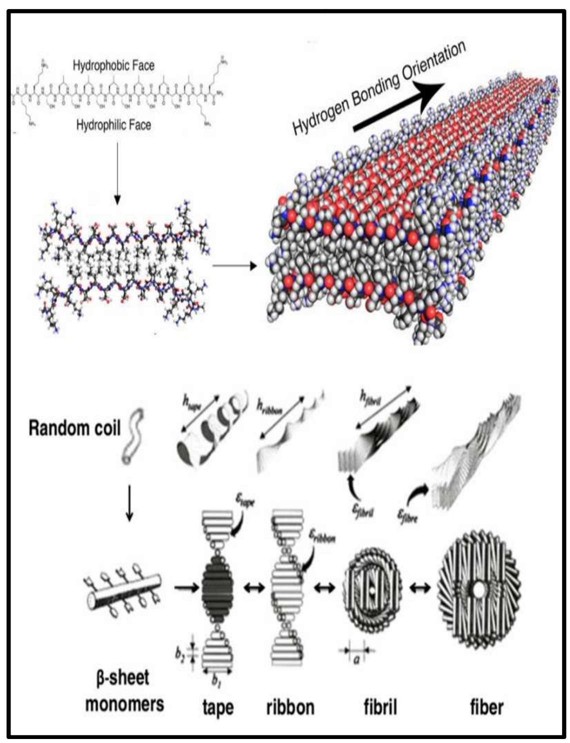
Collagen-like peptides (CLPs) are characterized by a repetitive Gly–X–Y tripeptide sequence, where X and Y are commonly proline and hydroxyproline. This unique sequence enables the formation of a triple-helical structure, closely mimicking the molecular architecture of natural collagen [1].

4. Elastin-like polypeptide es (ELPs):

Elastin-like polypeptides (ELPs) consist of repeating pentapeptide sequences (VPGXG), where X represents any amino acid except proline. These peptides exhibit unique conformational behavior and can undergoreversible structural transitions in response to environmental stimuli [1].

4. Peptide amphiphiles:

Peptide amphiphiles possess a distinct molecular design comprising a hydrophobic alkyl (lipid) tail linked to a peptide head group, which may include β-sheet-forming or bioactive sequences. This amphiphilic nature drives spontaneous self-assembly into organized nanostructures through hydrophobic interactions and hydrogen bonding [1].



(A) β-Sheet forming short peptides with alternating ionic complementary properties. [1]

(B) Short amphiphilic β-sheet peptides that self-assemble into anti-parallel nano tapes and further aggregate into ribbons and higher order structures. In a recent paper, shorter sequences (P9-6 and P7-6) with aliphatic hydrophobic resides (in green) were demonstrated to form fibrillar structures. [1]

MECHANISM OF ACTION

The demineralization action of self-assembling peptide P11-4 occurs through multiple sequential steps, they are as follows:

1. Diffusion into Early Carious Lesions:
Self-assembling peptide P11-4 is applied in a low-viscosity, monomeric solution, which enables it to diffuse effectively into the subsurface porosities of early, non-cavitated enamel carious lesions [6]. Owing to its small molecular size and fluid consistency, the peptide penetrates deeply into the lesion body rather than remaining on the enamel surface.

2.pH-TriggeredSelf-Assembly:
Within the acidic microenvironment of an initial carious lesion (pH < 7.4), P11-4 undergoes a conformational transformation. The peptide transitions from a soluble monomeric state into β-sheet secondary structures, which then hierarchically assemble into tapes, ribbons, fibrils, and ultimately fibers. This process leads to the formation of a three-dimensional scaffold within the lesion body [1,6].

3. Biomimetic Enamel Matrix Formation:
The three-dimensional fibrillar scaffold formed by P11-4 closely mimics the natural enamel extracellular protein matrix present during amelogenesis. The negatively charged glutamate residues distributed along the peptide fibrils exhibit a strong affinity for calcium ions, facilitating their localized concentration within the lesion [6].

4. Nucleation of Hydroxyapatite:
The peptide scaffold serves as a biomimetic nucleation template for de novo hydroxyapatite crystal formation. Calcium and phosphate ions derived from saliva are attracted and deposited along the scaffold, promoting guided and oriented crystal growth within the lesion body rather than superficial mineral precipitation [6,7].

5. Lesion Regeneration:
Progressive mineral deposition occurs from within the lesion toward the enamel surface, resulting in restoration of enamel density, microhardness, and structural integrity. This regenerative process fundamentally differs from fluoride-based remineralization, which predominantly enhances surfacemineralization without effectively rebuilding the subsurface lesion architecture [2,6].

CLINICAL APPLICATIONS

1. White Spot Lesions (WSLs): It has been proven to significantly increase surface microhardness and is particularly effective in the management of post-orthodontic and early enamel carious lesions. Additionally, it demonstrates superior remineralization potential when compared with CPP-ACP and nanohydroxyapatite.

2. Early Non-Cavitated Enamel Caries: It enables non-invasive management of dental caries by arresting lesion progression at the non-cavitated stage and is particularly useful in patients with a high risk of caries.

3. Post-Orthodontic Demineralization: It enhances enamel recovery around brackets and bands.

4. Post-Bleaching Enamel Repair: It improves the enamel microstructure following peroxide-induced demineralization and enhances the shear bond strength of composite resin to bleached enamel, although short-term studies have shown it to be inferior to nR5 technology.

5. Adjunct to Restorative Dentistry: It improves substrate quality prior to adhesive restorations and supports minimally invasive restorative protocols by facilitating biomimetic enamel repair through guided mineral deposition. When used as an adjunct to fluoride or CPP-ACPF, it enhances remineralization efficacy, promotes subsurface mineral deposition, and improves the aesthetic appearance of enamel lesions.

6. Adjunct to Laser-Assisted Remineralization:
Studies show enhanced uptake and remineralization

when combined with Er:YAG laser irradiation, due to increased enamel permeability.

7. Whitening and Surface Enhancement (Adjunct Use): When combined with hydroxyapatite suspensions, P11-4 improves particle adhesion, enhancing optical properties of enamel.

ADVANTAGES AND LIMITATIONS

Overall, the material is biomimetic and biologically inspired, providing a non-invasive and painless approach that promotes subsurface remineralization by mimicking natural enamel formation, with high biocompatibility and suitability for minimal intervention dentistry. However, its remineralization effect is time dependent and often requires repeated or long-term application, offers limited immediate benefitscompared with fluoride-based surface treatments, has insufficient evidence regarding long-term clinical durability, is less effective on cavitated lesions, and has shown no significant anti-erosive effect in some studies.

RECENT ADVANCES

1. Combination therapies:

Recent research has focused on combination approaches to enhance the remineralization potential of self-assembling peptides (SAPs). These include laser-assisted remineralization strategies such as the use of SAPs in conjunction with Er:YAG lasers, as well as their combination with hydroxyapatite or other calcium–phosphate–based systems to promote synergistic mineral deposition [8].

2. Improved delivery systems:

Efforts to optimize peptide delivery have led to the development of improved application protocols aimed at enhancing lesion penetration. Surface pre-treatments, such as the use of sodium hypochlorite (NaOCl), have been investigated to increase enamel permeability and facilitate deeper diffusion of SAPs into demineralized areas [4].

3. Expanded applications:

Beyond enamel remineralization, ongoing research is exploring the potential of SAPs in dentin remineralization and their integration with restorative materials. This expansion broadens their applicability in conservative and restorative dentistry.

4. Focus on regenerative dentistry:

Self-assembling peptides are increasingly classified as “smart biomaterials” due to their ability to respond to local oral environmental conditions, such as pH changes. This property positions them as key materials in the evolving field of regenerative dentistry [1,6].

5. Use as a pre-restorative enamel conditioning agent:

SAPs are being investigated for use as pre-restorative enamel conditioning agents to enhance enamel quality prior to adhesive or restorative procedures, potentially improving bonding and long-term restoration performance [6,7].

6. Integration with hydroxyapatite suspensions:

Another emerging approach involves the integration of SAPs with hydroxyapatite suspensions, aiming to combine the biomimetic scaffold-forming ability of peptides with readily available mineral sources for enhanced and guided remineralization.

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॥ पसायदान ॥

आतां विश्वात्मकें देवें । येणें वाग्यज्ञें तोषावें ।
तोषोनि मज द्यावें । पसायदान हें ॥१॥
जे खळांची व्यंकटी सांडो । तयां सत्कर्मी रिती वाढो ।
भूतां परस्परें पडो । मैत्र जीवाचें ॥२॥
दुरिताचें तिमिर जावो । विश्व स्वधर्मसूर्यें पाहो ।
जो जें वांछील तो तें लाहो । प्राणिजात ॥३॥
वर्षत सकळमंगळी । ईश्वरनिष्ठांची मांदियाळी ।
अनवरत भूमंडळी । भेटतु भूतां ॥४॥
चलां कल्पतरूंचे आरव । चेतना चिंतामणींचें गांव ।
बोलते जे अर्णव । पीयूषाचे ॥५॥
चंद्रमे जे अलांछन । मार्तंड जे तापहीन ।
ते सर्वांही सदा सज्जन । सोयरे होतु ॥६॥
किंबहुना सर्वसुखीं । पूर्ण होऊनि तिहीं लोकीं ।
भजिजो आदिपुरुखीं । अखंडित ॥७॥
आणि ग्रंथोपजीविये । विशेषीं लोकीं इयें ।
दृष्टादृष्ट विजयें । हो आवें जी ॥८॥
तेथ म्हणे श्रीविश्वेशरावो । हा होईल दानपसावो ।
येणें वरें ज्ञानदेवो । सुखिया झाला ॥९॥

॥ श्री संत ज्ञानेश्वर माऊली ॥