

Oral health in India: Researchers' Perspective Part I

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Abstract

Oral health disorders are major public health problems globally. There is a vast disparity in access to oral health care between developed and developing world as evident in reports of World Health Organisation (WHO) and Federation Dentaire Internationale (FDI). The oral health goals of WHO, FDI and International Association of Dental Research (IADR) for the year 2020 have brought forth the critical issues prevalent worldwide. India with huge population of 1.21 billion (2011 census) is faced with certain unique issues due to low level of awareness, varied terrain, strained infrastructure, limited access to oral health care and indigenous cultural practices. Research institutes and centrally funded agencies have been working at par with world standards, however, the oral health research has been lacking in terms of quality and addressing of community issues. It was deeply felt that this area requires appropriate summarization and future directions. This has been done in three parts with present paper attempting to address global vision, research orientations and specific burden, past research and future directions related to dental caries in India.

Keywords: Dental Caries, Minimal Invasive Dentistry, Oral Health, Research

1. Prelude

Oral health disorders such as periodontal diseases, dental caries, dentofacial deformities, oro-dental trauma and oral cancers are major public health concern due to their high incidence and prevalence in all regions of the world, especially the developing nations. The distribution and severity of oral diseases vary among different parts of the world, within the same country or region and also amongst people from varied socioeconomic and educational backgrounds^[1].

While the oral health has shown a trend towards significant improvement amongst the educated and the rich around the globe, majority of the populations in poor and developing countries, including the under-privileged and the urban poor, continue to suffer from the ill effects of dental and oral diseases^[1-3]. It goes without saying

that oral health has a significant impact on the general health and that no society can have a high level of health standards without addressing the oral health needs of its population.

The treatment of oral diseases, which essentially requires restoration and rehabilitation of mutilated dentition, is an expensive proposition. The Global Burden of untreated caries (GBD 2010) was reported to be high with caries in permanent dentition as most prevalent condition worldwide, affecting 2.4 billion adults^[4]. The untreated dental caries in deciduous teeth was found to be 10th-most prevalent condition, with 621 million children. The GBD surveys of 1990 and 2010 could not find major change in prevalence and incidence of dental caries in terms of age^[4]. The awareness and system of health insurance in developed nations enables the people to undergo periodic oral health check-ups, preventive

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procedures and treatments^[2,3]. However, the same does not hold true for the majority of the population of the developing countries. The high incidence of poverty, low level of education and awareness, over loading of existing oral health infrastructure and inequity of access to available services all add to the existing inadequacies in oral health standards. It must also be realized that many of the oral health afflictions cause a cumulative burden of disease, which leads to an increased cost of treatment with increasing time, making the prevention or treatment at an early stage very important, time saving and efficacious^[3].

India is a vast country with a population of over 1.21 billion people (2011 census). Current trends indicate that the population is about to cross the 1.3 billion mark (<http://www.indiaonlinepages.com/population/india-current-population.html>). Traditionally, India has a poor oral health record. The situation has been compounded by the rapid urbanization and fast changing food habits, further complicated by aggressive media campaigns for fast foods and bottled sweet drinks. This has adversely affected oral health of both rural and urban people; with the worst affected section being the uneducated and the people lacking access to oral health care^[1,3-6].

World Health Organization (WHO), in order to sensitize and emphasize oral health among public, health care workers and policy makers, assigned the theme “Oral Health for A Healthy Life” for the World Health Day in 1994. The then WHO Director General, Dr. Hiroshi Nakajima, emphasized the importance of traditional methods of oral hygiene maintenance for oral health care at community level. The lesser cost and cultural acceptability were cited as the reason for it^[2].

In 2003, Federation Dentaire Internationale (FDI), WHO and International Association for Dental Research (IADR) prepared the goals and targets for the new millennium and the year 2020^[2]. These issues were re-evaluated in 2015 and laid in the form of goals for 2020^[7]. They are:

1. To promote sustainable policies based on highest evidence derived from systematic reviews of best practices.
2. To develop accessible and cost effective oral health systems, integrating oral health promotion with other health sectors.
3. Strengthening systems and methods for oral health surveillance.
4. To reduce the oral health disparities among socioeconomic groups within the country and the inequalities persisting globally.
5. To increase the number of trained health care workers for imparting oral health surveillance and care.

The selected sixteen target areas for formulating and achieving the eventual 2020 resolutions were:^[2]

1. Pain
2. Functional disorders
3. Infectious diseases
4. Oropharyngeal cancer
5. Oral manifestation of HIV infection
6. Noma
7. Trauma
8. Craniofacial Anomalies
9. Dental Caries
10. Developmental Anomalies of the teeth
11. Periodontal Diseases
12. Oral mucosal diseases
13. Salivary gland disorders
14. Tooth loss
15. Health care services
16. Health care information systems

In the recent past, the FDI also brought to the fore a list of new goals as a part of FDI's vision 2020^[7]. The key issues included the followings:

- Poor oral health and its major inequalities both within a country and between various countries, despite the fact that prevention of most oral diseases is simple and effective.
- Lack of optimum effort towards research for effective prevention of oral diseases at community level. This should incorporate social and cultural variables and target at reducing the global burden of non communicable diseases.
- Prevalent isolation of dentistry from mainstream medical care secondary to lesser awareness of wider environmental and political issues effecting oral health care and its practice.
- A lacuna in translation of oral health research including basic cellular and molecular mechanism of oral disease and development of advanced innovative treatment modalities into day to day patient care.

- Need for scientific evidence based approach to oral health care with standardised methods of data collection and analysis.
- Monitoring and regulation of oral health needs for benefitting the patients, especially in terms of recent advances in the field.

The 2015 FDI oral health atlas has further illustrated the significant developments happening in terms of the key global challenges^[7].

The International Academy of Dental Research has also recently taken the initiative to promote Oral health globally by promoting initiatives that vary from grass root work by dental professionals to advanced scientific research for creating products that could be used in community services^[8]. IADR has identified key areas and has formed 'Scientific Groups' to promote the initiatives. (<http://www.iadr.org/i4a/pages/index.cfm?pageid=4473#Groups>)^[8].

Taking the precedence from the WHO policy of "Think globally and act locally, the researchers in India must address oral health related issues in India. This paper attempts to elaborate on scope of oral health research in India and discuss the burden of dental caries in our country. The future avenues for research in dental caries have also been presented with a special emphasis on the unique challenges faced by developing nations as India.

2. Research Orientations

India has extensive and well laid down network of facilities for Biological, Medical and Engineering related research with facilities funded by the Government of India, which are equipped with sophisticated, state-of-the-art advanced research facilities, infrastructure and equipments. These facilities remain unexplored for research by the dental professionals^[9,10].

3. Scope of Oral Health Research in the Country (Box 1)

India has more than 300 dental colleges of which about 170 colleges are also running the Postgraduate (MDS) programs. This encompasses more than 12000 teaching faculty, a yearly intake of around 4000 postgraduate students and producing over 24000 dental graduates per year to meet the dental care needs of enormous population.

Key areas for oral health research
<ul style="list-style-type: none"> • Dental Caries • Diseases of dental hard tissues specially those that effect several teeth such as Amelogenesis and Dentinogenesis imperfecta • Periodontal Diseases • Malocclusion • Oro-facial trauma • Dentofacial Anomalies • Congenital Defects of face like Cleft lip and Palate • Geriatric Oral Health • Stem cell applications • Regeneration • Oral and Systematic health • Infection control in dental office • Smart biomaterials • Dental care of medically compromised persons • Innovative oral hygiene products • Evidence based dentistry

Box 1: The key areas for oral health research.

Despite these encouraging numbers among the academics and learners, our representation in international dental research committees and peer reviewed indexed dental literature is negligible^[9]. Poor documentation and record maintenance has been felt as a major barrier for quality research publications in India. Most of the research in India is limited to the Master of Dental Surgery (MDS) degree thesis, which is essentially conducted to fulfil mandatory requirements of MDS course. Many of these researches only add to the cost of training and increase the book load of department libraries without a significant contribution to quality research and probably result in imperfect use of resources^[9].

It is saddening to know that only a few dedicated research projects of significant importance have been conducted in India. Periodic training and workshop sessions being conducted by various institutions and agencies help to increase awareness and motivation for planning and executing quality researches, especially among younger and middle level faculty in Dental Colleges^[9,10].

It is deeply felt that the research facilities in dental institutions should be strengthened and oral health research methodology related training programs should be encouraged. Self motivation and inculcation of a broad

globally based vision is important amongst both the institutional faculty and trainee students. Longitudinal research is considered to be the effective clinical research studies. There is a dire need of longitudinal and evidenced based clinical research in Indian population. Deficiency of descent and stable job opportunities in dental research field result in subsequent diminishing of valuable and worthy manpower in research thereby resulting in lack of longitudinal research. Easy availability of relevant scientific literature should also be facilitated at Dental Colleges' libraries along-with the online subscriptions of various journals in form of digital or e-library^[6,10]. Additionally, it is important to give equal stature to the Research Staff at par with the other Academic Staff members of every Dental Institution in the Country.

4. Dental Caries

According to WHO^[1], dental caries still remains a major oral disease, even in the most developed countries, with a prevalence of 60-90% in school children and affecting vast majority of adults. It is a major oral health problem in several Asian and Latin American countries, though it appears to be less common with reduced severity in North America, China and some of the African nations^[1,7]. The literature survey by Lukacs, analyzing data from 32 independent clinical studies in South Asians found caries being prevalent among all age groups ranging from 20% to 87% in both the sexes^[11].

The estimated prevalence in the 1940s was about 55.5 per cent which rose to 68 per cent with a DMFT of 2 in 1960. In the 1980s it had further increased to an over 80 per cent with a DMFT of 4^[12]. In general, in India, the point prevalence of dental caries has been on increase.

The most recent National Oral Health Survey in India was conducted in 20 states in 2003-2004. According to the survey, the prevalence of dental caries was 51.9% in 5 year-old children, 53.8% in 12 year-old children and 63.1% in 15 year-old teenagers.^[13] The prevalence of dental caries in geriatric age group (65 years and above) was observed to be 85%^[13]. Another multicentric survey conducted by Ministry of health and family welfare in collaboration with WHO, conducted in eight states, reported a prevalence of 67.8%^[5].

Currently, most of the available studies focus on particular regions in the country. Moses *et al.*, observed that dental caries was present in about 64% of the 2362 students (5-15 years of age) from Chidambaram district

in Tamil Nadu.¹² Kotecha *et al.*, conducted a survey of 266 villages in Gujarat (6093 subjects) and found that prevalence of dental caries was 39.53% in high fluoride zones and 48.21% in normal fluoride areas^[14]. In a study conducted among 1031 pre-school children aged 3-5 years in Greater Noida, U.P., the overall prevalence of dental caries was found to be 30.06% with a mean deft score of 1.68^[15]. Grewal *et al.*, conducted a study on 520 school going children between 9-12 years in Delhi and found the prevalence of dental caries to be 52.3% with mean deft and DMFT scores of 0.5038 ± 1.0859 and 0.8250 ± 1.3437 , respectively, having restorative treatment need of 49.7%^[16]. In a study in Mangalore in 858 school-going children, the prevalence of dental caries was found to be 59.4%^[17]. More alarming is the region specific data among geriatric age group, with Goel *et al.*, observing dental caries prevalence of 100% in their survey^[18].

In a recent survey conducted by Centre for Dental Education and Research (CDER), All Institute of Medical Sciences (AIIMS), New Delhi, as a WHO collaborating centre, at Ballabgarh block in Faridabad district, Haryana, the caries prevalence was 43.3%. Among the various age groups, the prevalence rate was 33.2% in 5-7 years, 31.3% in 12-15 years, 64.9% in 35-44 years and 50.1% in 65-74 years^[19].

Considering the massive effect caries and periodontal disease have on dental and general health, the IADR has formed the Cariology Research Group (CRG) to look into the various aspects of "etiology, epidemiology, risk assessment, pathogenesis, diagnosis, prevention and management of dental caries." (<http://www.iadr.org/i4a/pages/index.cfm?pageid=4473#Groups>). The initiatives of IADR encompass awards for excellence in the field and provide a forum for pooling of ideas and initiatives which could be used to control the global menace by innovative means^[8].

4.1. Research Done in Past

Efforts in the past have been made for identification of risk factors in Indian population, which may provide effective insight into possible solutions^[20]. Recent study by Sheiham and James has reemphasized the pivotal role of dietary sugars in etiology of dental caries with control of sugars being the single most effective measure in caries prevention^[21]. Traditionally, the recommended prevention strategies include provision of fluoridated water supply, use of topical fluorides, promotion of better oral hygiene

habits and effective tooth brushing. Investigators have also explored the effectiveness of oral health education to nursing mothers in preventing caries risk in pre eruptive and eruptive stages of infants^[17]. The association of dental caries in individuals with chronic systemic illness and infections as HIV have also been investigated in past^[3].

Fluoridation of drinking water and topical application of fluoride have been documented to be effective in prevention of dental caries^[22,23]. ICMR Task Force project “*Feasibility module for the primary prevention of dental caries and gingival diseases in children in community within the existing health infrastructure*” was undertaken to test the use of topical fluorides in prevention of dental caries and study the logistics for implementing such a preventive programme in India. The results showed an appreciable reduction in the incidence of caries and DMFT in children. This study has also demonstrated that it is possible to educate the population for better self oral health care and that the existing health care personnel can be trained and equipped to do so effectively^[6]. Mass education based on exposure to visual media (television) can be an effective means of imparting awareness regarding dental health to the masses especially in the remote and rural areas. We urge the government to take steps in this regard and create dedicated TV based campaigns for promoting better oral health habits and consequences of neglecting oral health, in line with the campaigns used for increasing awareness against tobacco related oral cancer.

The currently popular fluoride varnishes available in the market are mostly imported, and though effective, are quite expensive and also suffer from limited availability in the market. Thus, their use in community programmes becomes quite costly and limited in reach. Consequently, there is a need for indigenous fluoride releasing compounds, which could be used for reduction of dental caries incidence^[10]. For example, bark and leaves of a commonly found tree, *Salvadora persica* miswak, has been shown to contain significant amounts of fluoride^[24]. The parts of the tree can be used by local population for getting daily exposure to topical fluoride. In the Indian setup it is important to focus research on products, which are cost effective, easily portable, provide long-term protection, are minimally invasive and require minimal armamentarium. The recent Cochrane review by Iheozor-Ejiofor concluded that the level of evidence to indicate the effectiveness of community water fluoridation is low and depends upon the oral health habits as use of fluoride tooth

pastes or mouth rinses^[25]. Future research in this field is needed to assess the results of discontinuing fluoridation programs or highlighting the factors affecting community water fluoridation strategies.

Another situation endemic to several parts of our country is problem of dental, skeletal and non skeletal fluorosis. India falls in geographical belt of high fluoride content in water^[26]. Fluoride levels in water in India range from 2-29 ppm, whereas the WHO recommended permissible level in drinking water is 1.0-1.5 ppm^[26,27]. Water fluoride is beneficial in small amounts but toxic in high amounts.²² Excessive consumption of fluorides for longer periods in various forms results in deleterious effects on teeth (dental fluorosis), bone (skeletal fluorosis) and soft tissues (non-skeletal fluorosis)^[26]. Regions such as Andhra Pradesh, Madhya Pradesh, Telangana, Punjab, Haryana, Rajasthan, Maharashtra and Chhatisgarh have high natural fluoride content in ground water sources, leading to adverse effects in people consuming them^[26].

High fluoride zones have been identified and steps are being taken to promote the use of safe drinking water with optimum fluoride levels for maximum benefit. The techniques of defluoridation based on adsorption, ion-exchange, precipitation, electrochemical defluoridation and reverse osmosis are currently being developed and tested at community level^[27]. The key area in defluoridation research is to develop indigenous, cost effective and accessible technique which can be implemented in the toughest of terrains with minimal infrastructure^[27]. The dental professionals especially public health dentists can educate people residing in high fluoride belts and make them aware about hazards of fluorosis, emphasizing on the importance of drinking safe water^[26]. Traditionally, many indigenous methods of defluoridation are known, however, their efficacy and applicability is limited due to technical or practical reasons. Roots of Vetiver grass and seeds of Tamarind have been shown to have good defluoridation potential; further research needs to be done to make their practical use applicable in rural Indian setups where community drinking water provisions are not available^[28].

4.2. Suggested Areas of Future Research (Box 2)

4.2.1. Gender Preponderance of Females in Caries Prevalence

The data from south Asia has revealed a gender bias in prevalence of dental caries in adolescence age group^[11].

Dental caries research directions

- Gender preponderance of females in caries prevalence
- Innovative cost effective technology for early detection of the invisible carious lesions
- Innovative technology for painless caries removal without cutting instruments & Minimally Invasive Dentistry
- Remineralization of incipient caries
- Caries prevention without fluorides
- Caries preventive strategies through alternate foods
- Bacteriological basis of dental caries
- Caries preventive strategies
- Genetic aspects of dental caries
- Immunology of dental caries

Box 2: Dental caries research directions.

The equal incidence of caries in childhood is replaced by greater number of girls being affected in adolescence. This consistent trend of age-based reversal in gender bias in dental caries has not been previously appreciated in oral health research. A surge in female sex hormones (estrogen and estradiol) at the onset of puberty has been attributed to this variation.^[11] Nevertheless, contribution of the other affiliations such as race, origin, socioeconomic factors, and genetic preponderance may also be vital. Significant knowledge in this field is yet to be deciphered and research into the causation and its clinical implication should be a priority.

4.2.2. Early Identification of the Incipient Lesions

Diagnosis of caries at its initial stage and its appropriate management through newer paradigms of preventive strategies can lead to reversal of the underlying demineralization process^[29]. This not only prevents the advancement of caries into frank cavitations and further pulpal pathologies, but the disease can also be easily managed in a minimally invasive manner. Newer tools like polarized light, magnification and trans-illumination are being increasingly used to identify difficult proximal lesions hidden from sight^[29]. Technologies like Optical Coherence Tomography (OCT) and Polarized Raman Spectroscopy (PRS) are being tested for applicability in early caries detection and monitoring^[30]. The pressing need in Indian scenario is to develop a tool, which is simple to use, and portable^[10]. These may be in the form

of lasers, impedance based devices, photo illumination devices, staining gels or enzyme markers.

4.2.3. Caries Prevention Through Education Programs

Many children may grow up under less than the optimal parental care and guidance with respect to feeding, nutrition and oral hygiene maintenance not just in underprivileged sections of the populace but even in the educated sections of the society. Such children are particularly prone to Early Childhood Caries (ECC)^[31]. Parental counselling through mechanisms for improvement of individual awareness and efficacy along with other psychological approaches as performance feedback may instil confidence in parents for maintaining oral health in children^[16,17]. It is hoped that community level programs towards education and training of dental hygienists and health workers at the Anganwadi and village level like Village Health Workers (VHW) or Accredited Social Health Activist (ASHA) can significantly reduce the prevalence of ECC and its related morbidity.

4.2.4. Caries Management Through Minimally Invasive Dentistry (MID)

Minimally Invasive Dentistry (MID) is based on the ideology that restoration of a cavity is not the ultimate treatment of dental caries^[32]. Use of novel approaches for identification of dental caries in the incipient (pre cavitation) stage itself along with the development of remineralising agents and newer adhesive dental materials have paved way for MID^[31,32]. Walsh *et al.*, in 2013 summarised MID in four core principles- (1) Recognition- for identification and early assessment of caries risk factors, (2) Reduction- for elimination or minimizing risk factors, (3) Regeneration- by using topical fluorides, remineralising agents and other materials for arresting the active caries and reversing the incipient lesions and (4) Repair- when cavitations are present that too with a conservative approach^[32].

World Health Organisation pioneered the atraumatic restorative treatment (ART) in the 1980's in Tanzania, Africa which utilized the concept of minimal intervention for treatment of carious teeth^[33,34]. It involves removal of carious tissues solely by using hand instruments and restoring it with fluoride releasing and pulp biocompatible adhesive restorative materials such as glass ionomer cement^[34]. This approach has yielded beneficial results

at community level programmes through use of dental auxiliaries and health care workers^[34].

Research should focus on the development of indigenous re-mineralizing agents, non/minimal cutting alternatives for removal of dental caries and surface adhering-biocompatible restorative cements^[29]. This would significantly reduce the cost and armamentarium required for restorative treatment. The utilisation of health care professionals for implementation of MID principles can also be evaluated for benefitting a large section of the population with limited access to oral and dental care^[33]. Marinho *et al.*, in a recent Cochrane review have stated that role of fluoride gels need to be supported by high level of evidence^[35]. Future researches in this field must be directed towards placebo controlled trials and long term toxic effects of the topical fluoride gels^[35].

4.2.5. Recognition of the Immunological and Bacteriological Basis of Dental Caries - The Development of Caries Vaccine

Streptococcus mutans is a major etiological agent of dental caries. Current research has enabled immunologically mediated prevention of cariogenic bacterium, reducing the caries risk^[31]. Caries defence through mucosally delivered vaccines have also been explored in past. By understanding the immunological and bacteriological basis of dental caries and the kinetics of DNA vaccine mechanisms, the research can lead to development of effective caries vaccine. The metagenomic study of oral microbiome is another highly researched novel avenue in identifying dental caries causing bacterial species^[36]. Future research in caries vaccine might be based on the results of caries' meta-genomics results^[36].

4.2.6. Alternative Strategies for Minimizing Caries Risk

Strategies to curb and prevent caries such as water fluoridation and topical fluorides, with widely documented success, were all started as alternative management approaches^[22]. On similar lines, research needs to focus on other alternate systems of making enamel resistant to acid attacks or increasing the salivary buffering capacity^[7,10]. An expert panel was constituted by American Dental Association to evaluate the efficacy of non-fluoride caries preventive agents^[37]. Based on the review of available scientific evidence, they recommended that the role of agents as polyols for coronal caries and

Chlorhexidine for occlusal and root caries as an adjunct to contemporary fluoride therapy^[37]. Use of pit and fissure sealants has also been emphasized by ADA which recommends periodic re-evaluation of caries risk and application of sealants at an early stage to prevent the progression of any lesion^[38].

Additionally, components of plants like Neem (*Azadirachta Indica*), Hop plant, Green and Black Tea, *Prunus mume*, Tulsi, Cacao bean husk and Cranberry all have been shown to have significant anticariogenic action^[39-41]. The caries management process and research may explore the role of dental hygiene in this change in the paradigm^[31]. Research should be focused on strategies to reduce *Streptococcus mutans* load even in absence of post treatment compliance^[23]. Products like enzymatic mouthwashes, non toxic bactericidal products (especially herbal based), immune mediation, surface enamel treatment agents, need to be researched and developed^[40]. Agents that can reduce *Streptococcus mutans* load in the oral cavity and technology to create genetic alteration of bacteria to make them protective and such strategies are the relevant area of research development, which need immediate focus.

4.2.7. Role of Genetic Factors in Etiopathogenesis of Dental Caries

There have been numerous studies, which tried to elucidate the genetic factors associated with dental caries^[42]. Although its multi-factorial causation has been widely accepted, a strong genetic predisposition can never be ruled out. Shuler, on the backdrop of animal studies, twin studies and heredity chartings, concluded that genetics in etiopathogenesis of dental caries must be explored^[42]. Studies by Slayton *et al.*, on Tuftelin gene and Yildiz *et al.*, on Amelx gene have revealed polymorphisms resulting in high susceptibility to caries in various populations^[43,44].

Perhaps the earliest significant breakthrough in this field was achieved by Wendell *et al.*, who used Single Nucleotide Polymorphism (SNP) techniques to show possible and statistically significant associations in TAS2R38 and TAS1R2 for caries risk and/or protection^[45]. Shaffer *et al.*, were the first to study Genome Wide Association (GWA), and suggested the possible loci associated with the increased risk of dental caries, namely, ACTN2, MTR, and EDARADD, MPPED2, and LPO^[46]. Current research is underway to further link the association of genes with caries susceptibility^[44].

5. Conclusion

India, with its vast population, strained resources and infrastructure, and traditionally poor oral health records, merits special attention as far as dental caries and oral health research is concerned. Due to peculiar situation in India, mere global findings and studies on caries prevalence, prevention and treatment, cannot be applied to the Indian set-up. Due to high morbidity caused by dental caries and the overall health burden imposed by it, it becomes imperative that necessary corrective steps be positioned so as to reduce the burden of caries. The best step for India will be prevention of caries by way of better oral hygiene awareness as well as promoting research to develop low-cost, indigenous products which can be made available in remote areas with limited access. Additionally, research should focus also on the current advances in caries detection and management so that India can be at par with the rest of the world.

6. References

- Petersen PE, Bourgeois D, Ogawa H, Estupinan-Day S, Ndiaye C. The global burden of oral diseases and risks to oral health. *Bull World Health Organ.* 2005;83:661–69. PMID:16211157 PMCID:PMC2626328
- Hobdell M, Petersen PE, Clarkson J, Johnson N. Global goals for oral health 2020. *Int Dent J.* 2003;53:285–288. <https://doi.org/10.1111/j.1875-595X.2003.tb00761.x>. PMID:14560802
- Jin LJ, Lamster I, Greenspan JS, Pitts N, Scully C, Warnakulasuriya S. Global burden of oral diseases: Emerging concepts, management and interplay with systemic health. *Oral Dis.* 2016 Oct;22(7):609–619. <https://doi.org/10.1111/odi.12428>. PMID:26704694
- Kassebaum NJ, Bernabé E, Dahiya M, Bhandari B, Murray CJ, Marcenes W. Global burden of untreated caries: A systematic review and metaregression. *J Dent Res.* 2015;94:650–658. <https://doi.org/10.1177/0022034515573272>. PMID:25740856
- Shah N, Pandey RM, Duggal R, Mathur VP, Parkash H, Sundaram KR. *Oral Health in India.* A report of Multi-centric study. Director General of Health Services, Ministry of Health and Family Welfare, Government of India and WHO collaborative programme; 2007.
- Oral Health: ICMR Bulletin, New Delhi. 1994 Apr;24.
- The Challenge of Oral Disease – A Call for Global Action.* The Oral Health Atlas. 2nd ed. Geneva: FDI World Dental Federation; 2015.
- Annual Report. International Association of Dental Research.* IADR/AADR-2014
- Bishen KA, Chhabra KG, Sagari S, Gupta P. Nationwide survey on barriers for dental research in India. *J Pharm Bioallied Sci.* 2015;7:201–206. <https://doi.org/10.4103/0975-7406.160017>. PMID:26229354. PMCID:PMC4517322
- Luthra UK, Tewari A, Shah B, Prabhakar AK. Perspectives of Research in Oral Health. *J Indian Dent Assoc.* 1986;38:289.
- Lukacs JR. Gender differences in oral health in South Asia: Metadata imply multifactorial biological and cultural causes. *Am J Hum Biol.* 2011;23(3):398. <https://doi.org/10.1002/ajhb.21164>. PMID:21448908
- Moses J, Rangeeth BN, Gurunathan D. Prevalence of dental caries, socio-economic status and treatment needs among 5 to 15 year old school going children of Chidambaram. *J Clin Diagn Res.* 2011;5:146–151.
- National Oral Health Survey and Fluoride Mapping. An Epidemiological Study of Oral Health Problems and Estimation of Fluoride Levels in Drinking Water. Dental Council of India, New Delhi, 2004;32; 67–78.
- Kotecha PV, Patel SV, Bhalani KD, Shah D, Shah VS, Mehta KG. Prevalence of dental fluorosis & dental caries in association with high levels of drinking water fluoride content in a district of Gujarat, India. *Indian J Med Res.* 2012;135:873–877. PMID:22825606. PMCID:PMC3410214
- Arora SA, Setia S, Ahuja P, Singh D, Chandna A. Prevalence of dental caries among pre-school children of Greater Noida city. *Indian J Dent Sci.* 2012;2:4–6.
- Grewal H, Verma M, Kumar A. Prevalence of dental caries and treatment needs amongst the school children of three educational zones of urban Delhi, India. *Indian J Dent Res.* 2011;22:517–579. <https://doi.org/10.4103/0970-9290.90283>. PMID:22124044
- Suprabha BS, Rao A, Shenoy R, Khanal S. Utility of knowledge, attitude, and practice survey, and prevalence of dental caries among 11- to 13-year-old children in an urban community in India. *Glob Health Action.* 2013;6:20750. <https://doi.org/10.3402/gha.v6i0.20750>. PMID:23639177. PMCID:PMC3643074
- Goel P, Singh K, Kaur A, Verma M. Oral health care for elderly: Identifying needs and feasible strategies for service provision. *Indian J Dent Res.* 2006;17:11–21. <https://doi.org/10.4103/0970-9290.29897>. PMID:16900890
- Shah N, Mathur VP, Pandey RN, Kant S, Haldar P, Garg R, Priya H, Monga VK, Gupta A, Mehta N. *Oral Health Survey of Ballabgarh Block in Faridabad District, Haryana.* A report by CDER, AIIMS as WHO Collaborating centre, September; 2015.
- Simratvir M, Moghe GA, Thomas AM, Singh N, Chopra S. Evaluation of caries experience in 3-6-year-old children,

- and dental attitudes amongst the caregivers in the Ludhiana city. *J Indian Soc Pedod Prev Dent*. 2009;27:164–169. <https://doi.org/10.4103/0970-4388.57097>. PMID:19841548
21. Sheiham A, James WP. Diet and Dental Caries: The pivotal role of free sugars reemphasized. *J Dent Res*. 2015;94:1341–1347. <https://doi.org/10.1177/0022034515590377>. PMID:26261186
 22. Armfield JM. Community effectiveness of public water fluoridation in reducing children's dental disease. *Public Health Rep*. 2010;125:655–664. <https://doi.org/10.1177/003335491012500507>. PMID:20873281. PMCid: PMC2925001
 23. Rogers HJ, Morgan AG, Batley H, Deery C. Why, what and how: caries control for erupting molars. *Dent Update*. 2015;42:154–156, 159. <https://doi.org/10.12968/denu.2015.42.2.154>. PMID:26058229
 24. Hassan Suliman Halawany. A review on miswak (*Salvadora persica*) and its effect on various aspects of oral health. *The Saudi Dental Journal*. 2012;24:63–69. <https://doi.org/10.1016/j.sdentj.2011.12.004>. PMID:23960531. PMCid:PMC3723367
 25. Iheozor-Ejiofor Z, Worthington HV, Walsh T, O'Malley L, Clarkson JE, Macey R, Alam R, Tugwell P, Welch V, Glenny AM. *Water fluoridation for the prevention of dental caries*. Cochrane Database of Systematic Reviews Cochrane Database Syst Rev.
 26. Khairnar MR, Dodamani AS, Jadhav HC, Naik RG, Deshmukh MA. Mitigation of fluorosis - A review. *J Clin Diagn Res*. 2015;9:ZE05–ZE09. <https://doi.org/10.7860/JCDR/2015/13261.6085>
 27. Ingle NA, Dubey HV, Kaur N, Nagpal A. Defluoridating water. *Br Dent J*. 2014;216:437. <https://doi.org/10.1038/sj.bdj.2014.305>. PMID:24762874
 28. Piddennavar Renuka, Krishnappa Pushpanjali. Review on defluoridation techniques of water. *The International Journal Of Engineering And Science*; 2013;2(3);86–94.
 29. Tuli A, Singh A. Early childhood caries and oral rehabilitation. A treatment quandary. *Eur J Paediatr Dent*. 2010;11:181–184. PMID:21250768
 30. Mohanty B, Dadlani D, Mahoney D, Mann AB. Characterizing and identifying incipient carious lesions in dental enamel using micro-Raman spectroscopy. *Caries Res*. 2013;47:27–33. <https://doi.org/10.1159/000342432>. PMID:23051625
 31. Policy on Early Childhood Caries (ECC): Classifications, consequences, and preventive strategies. American Academy of Pediatric Dentistry reference manual on oral health policies. 2014;37:50–52.
 32. Walsh LJ, Brostek AM. Minimum intervention dentistry principles and objectives. *Aust Dent J*. 2013;58:3–16. <https://doi.org/10.1111/adj.12045>. PMID:23721333
 33. Arrow P. Restorative outcomes of a minimally invasive restorative approach based on atraumatic restorative treatment to manage early childhood caries: A Randomised Controlled Trial. *Caries Res*. 2015;15:1–8.
 34. Frencken J, van Amerogen E, Phantumvanit P, Songpaisan Y, Pilot T. *Manual for the atraumatic restorative treatment approach to control dental caries*. 3rd ed. Groningen: WHO Collaborating Centre for Oral Health Research; 1997. PMID:9461988
 35. Marinho VCC, Worthington HV, Walsh T, Chong LY. Fluoride gels for preventing dental caries in children and adolescents. *Cochrane Database Syst Rev*. 2015 Jun 15;(6):CD002280. <https://doi.org/10.1002/14651858.CD002280.pub2>
 36. Xu P, Gunsolley J. Application of metagenomics in understanding oral health and disease. *Virulence*. 2014;5:424–432. <https://doi.org/10.4161/viru.28532>. PMID:24642489. PMCid:PMC3979870
 37. Rethman MP, Beltrán-Aguilar ED, Billings RJ, Hujoel PP, Katz BP, Milgrom P et al. Nonfluoride caries-preventive agents: executive summary of evidence-based clinical recommendations. *J Am Dent Assoc*. 2011;142:1065–1071. <https://doi.org/10.14219/jada.archive.2011.0329>. PMID:21987836
 38. Beauchamp J, Caufield PW, Crall JJ, Donly K, Feigal R, Gooch B et al. Evidence-based clinical recommendations for the use of pit-and-fissure sealants: a report of the American Dental Association Council on Scientific Affairs. *J Am Dent Assoc*. 2008;139:257–268. <https://doi.org/10.14219/jada.archive.2008.0155>. PMID:18310730
 39. Lakshmi T, Krishnan V, Rajendran R, Madhusudhanan N. *Azadirachta indica*: A herbal panacea in dentistry - An update. *Pharmacogn Rev*. 2015;9:41–44. <https://doi.org/10.4103/0973-7847.156337>. PMID:26009692. PMCid:PMC4441161
 40. Prabhakar J, Balagopal S, Priya MS, Selvi S, Senthilkumar M. Evaluation of antimicrobial efficacy of Triphala (an Indian Ayurvedic herbal formulation) and 0.2% chlorhexidine against *Streptococcus mutans* biofilm formed on tooth substrate: an in vitro study. *Indian J Dent Res*. 2014;25:475–479. <https://doi.org/10.4103/0970-9290.142539>. PMID:25307912
 41. Ravi Agarwal, Chanchal Singh, Ramakrishna Yeluri and Kalpna Chaudhry. Prevention of Dental Caries-Measures beyond Fluoride. *Oral Hyg Health*. 2014;2:1.
 42. Shuler CF. Inherited risks for susceptibility to dental caries. *J Dent Educ*. 2001;65:1038–1045. PMID:11699975
 43. Slayton RL, Cooper ME, Marazita ML. Tuffelin, mutans streptococci, and dental caries susceptibility. *J Dent Res*. 2005;84:711. <https://doi.org/10.1177/154405910508400805>. PMID:16040727

44. Yildiz G, Ermis RB, Calapoglu NS, Celik EU, Turel GY. Gene-environment Interactions in the Etiology of Dental Caries. *J Dent Res.* 2016;95:74–79. <https://doi.org/10.1177/0022034515605281>. PMID:26377569
45. Wendell S, Wang X, Brown M, Cooper ME, DeSensi RS, Weyant RJ, Crout R, McNeil DW, Marazita ML. Taste genes associated with dental caries. *J Dent Res.* 2010;89:1198. <https://doi.org/10.1177/0022034510381502>. PMID:20858777. PMCID:PMC2954250
46. Shaffer JR, Wang X, Feingold E, Lee M, Begum F, Weeks DE, Cuenco KT, Barmada MM, Wendell SK, Crosslin DR, Laurie CC. Genome-wide association scan for childhood caries implicates novel genes. *J Dent Res.* 2011;90:1457. <https://doi.org/10.1177/0022034511422910>. PMID:21940522. PMCID:PMC3215757