DOI: 10.7860/JCDR/2016/17996.8634

Review Article

Dentistry Section

Techniques to Evaluate Dental Erosion: A Systematic Review of Literature

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ABSTRACT

This article reviews different techniques for evaluating dental erosion, weighs the advantages and disadvantages of these techniques, and presents the latest trends in the study of dental erosion. In May 2014, an initial search was carried out in the PubMed/MEDLINE database of indexed journals from 1975 to 2013 using the following keywords: dental erosion; dental erosion In-vitro; and dental erosion in-vivo. Bibliographic citations from the papers found were then used to find other useful sources. The authors categorize the techniques into three classes: in-vitro, in-vivo and in-vitro/in-vivo. The article discusses the instrumentation required to use each of these techniques, as well as their rationale, merits and applications. The emergence of in-vitro/in-vivo techniques offers the potential to accurately quantify tooth wear in clinical situations. Cross-sectional as well as longitudinal studies show that these techniques will improve diagnosis, treatment planning and management of dental erosion.

Keywords: Indices, In-vitro techniques, Microscopy, Microradiography, Spectophotometry, Tomography, Tooth erosion, Wasting disease

INTRODUCTION

Dental erosion is a condition of increasing concern as it causes irreparable damage to the dentition in subjects of all ages [1]. In erosion, progressive and irreversible loss of hard dental tissues is seen due to a chemical process i.e., dissolution from acids not involving bacteria [2-4]. Very few prevalence studies have been conducted for dental erosion in national surveys [1,5]. In addition, it is often difficult to compare the outcomes of diverse epidemiological studies of dental erosion because they employ different examination standards and scoring systems and because the sampling methods and groups examined are not comparable [1]. Earlier studies of dental erosion have focused only on selected techniques-qualitative, quantitative, or In-vitro or in-vivo techniques [6-10]. Hence, in this article the authors endeavor to discuss comprehensively most of the techniques, regardless whether they are In-vitro, in-vivo, or a combination "In-vitro/in-vivo", thus bringing all the techniques "under one roof". The authors have attempted to evaluate these techniques in terms of specificity and sensitivity while identifying their advantages and disadvantages. This has been done to help the clinicians, specialists, community dentists, or researchers to select the particular technique most suitable for their particular needs.

The article reviews different techniques to evaluate dental erosion, weighs the advantages and disadvantages of these techniques, and present the latest trends in the study of dental erosion.

In May 2014, an initial search was carried out in the Pub Med/MEDLINE database of indexed journals from 1975 to 2013 using the following keywords: dental erosion; dental erosion In-vitro, dental erosion in-vivo. The search yielded 42 articles, of which 21 were relevant for our study. Bibliographic material from these papers was then used to find other useful sources.

The various techniques to evaluate erosion were classified under the following headings:

I. In-vitro techniques [Table/Fig-1].
II. In-vivo techniques [Table/Fig-2].
III. In-vitro/in-vivo techniques [Table/Fig-3].

To comprehend the complex nature of erosive mineral loss and dissolution, application of a single technique may not be adequate; rather, the application of different approaches is required for the full understanding of this phenomenon. In-vitro/in-vivo techniques are "combination techniques" wherein data is collected in-vivo and analyzed In-vitro. These techniques accurately reflect erosive changes in situ in addition to combining the precision of In-vitro techniques.

Sl. No.	Method	Quantitative/ Qualitative analysis
1	Scanning electron microscope	Qualitative
2	Surface profilometry	Quantitative
3	Non-contacting laser profilometer	Quantitative
4	Polarised light microscopy	Qualitative
5	Non-contact confocal laser scanning microscopy	Qualitative
6	Scanning acoustic microscope	Quantitative
7	Secondary ion mass spectroscopy	Semi-quantitative*
8	Iodide permeability test	Semi-quantitative*
9	Transverse microradiography	Quantitative
10	Contact X-ray microradiography	Quantitative
11	Ion chromatography	Quantitative
12	Microdensitometric scan	Semi-quantitative*

[Table/Fig-1]: In-vitro techniques.
*Semi-quantitative analysis: assigns approximate measurements of dental erosion rather than an exact measurement in cases where a direct measurement may not possible.

DISCUSSION

I. In-vitro Techniques

Traditionally, the evaluation of quantitative and qualitative tooth surface loss due to erosion has challenged researchers. The In-vitro studies present techniques that achieve greater sensitivity, specificity, and accuracy in measuring tooth loss compared to the in-vivo techniques. However, the In-vitro studies can mimic but cannot duplicate intra-oral conditions.

The Scanning Electron Microscope (SEM) Technique: Application of the SEM was one of the first technique used to determine In-vitro resorption of dental hard tissues. SEM micrographs yield a characteristic three-dimensional representation that is useful for understanding the surface structure of the sample

Sl. No.	Method	Quantitative/ Qualitative analysis
1	Clinical examination and using photograph	Qualitative
2	Indices	Qualitative
3	Colorimetric procedures	Quantitative

[Table/Fig-2]: In-vivo techniques.

Sl. No.	Method	Quantitative/ Qualitative analysis
1	Quantitative light-induced fluorescence	Semi-quantitative*
2	Optical coherence tomography	Semi-quantitative*
3	Atomic absorption spectroscopy	Quantitative
4	Digital pH meter	Quantitative
5	Microindentation and nanoindentation	Quantitative
6	Ultrasonication and chemical analysis	Quantitative

[Table/Fig-3]: In-vitro / In-vivo techniques.
*Semi-quantitative analysis: assigns approximate measurements of dental erosion rather than an exact measurement in cases where a direct measurement may not possible.

[8]. SEM investigations have been used to reveal the effects of superficially deposited precipitates resulting from mineral dissolution by various agents. These include differentially acting acids, the anti-erosive potential of fluoride and the re-mineralization and re-hardening potential of various agents in eroded enamel [11-17]. In Environmental SEM (ESEM), no sample preparation (sectioning, mounting, grinding and polishing) of the surface is required, thereby reducing the risk of artifacts to a minimum [6].

The SEM is one of the most frequently used devices for qualitatively assessing ultramicroscopic surface alterations associated with erosion on both enamel and dentine [18,19]. The efficacy of salivary pellicle and dental plaque in protecting underlying enamel surfaces from acidic dissolution can also be evaluated [20,21]. Very high-resolution images of less than 1nm in size of a sample surface can be visualized. SEM investigations can be performed on both polished and unpolished native surfaces after gold-sputtering, which mimics conditions at the tooth surface in-vivo and is highly reproducible. ESEM is preferred when wet substrates like dentin need to be evaluated. However, SEM and ESEM permit only subjective, qualitative assessment [6].

Surface Profilometry: Surface profilometry quantifies the loss of dental tissue in relation to a non-treated reference area. It also provides information on surface roughness [8]. In profilometry, the surface of a sample is scanned to produce a two-dimensional or three-dimensional profile, using either a contact or a non-contact measuring device [22]. In contact profilometry, the surface is scanned using a stylus with a diamond or steel tip [23,24]. Non-contact profilometry uses a laser light probe with its calibration based on the optical triangulation principle and the vertical array varies from 300µm to 10mm. This capacity provides the flexibility needed to analyze very deep erosion pits and even curved surfaces [25-28].

If flattened specimens can be obtained, contact profilometry may be used to quantify tooth loss. However, roughness measurements seem to be useful only for early stages of erosion in enamel and dentin [10,27,29]. In contact profilometry the stylus penetrates the eroded surface, which has undergone either partial or complete demineralization [30,31]. This can cause damage to the surface and lead to overestimation of early erosion depth [23,32,33]. Laser profilometry can overcome these drawbacks as this technique does not involve direct contact of a stylus with the surface being studied. However, one of the problem encountered is that the results can be affected by color and transparency [26]. Erosive lesions around 0.5µm deep can be consistently detected and measured with non-contact profilometry [34].

Polarized Light Microscopy: Polarized light consists of light waves in which the vibrations occur in a single plane. A polarizing microscope has two disk accessories made up of polarizing plastic. The disc which allows light vibrating in one plane to pass through is called a polarizer. An analyzer disc placed in the top part of the microscope, cuts off all the light vibrating in a perpendicular plane. The discs are aligned such that they allow light to vibrate in planes perpendicular to each other. Organic and inorganic substances with rigid yet repeatable structures can be observed using this technique [35]. Polarized light microscopy can be used to observe crystal birefringence changes in cross sections of dental erosion specimens, thus measuring lesion depth in thin slices [36,37].

In eroded dentine, polarized light microscopy discriminates between partly and fully demineralized tissues [37,38], qualitative information regarding mineral density, in the form of pore volume, is obtained with this method [36,37].

Non-Contact Confocal Laser Scanning Microscopy (CLSM): CLSM is a technique for obtaining high-resolution three dimensional optical images with depth selectivity from specimens. A laser beam passes through a light source aperture and focused by an objective lens into a small focal volume within or on the surface of a specimen. Only the in-focus light is recorded to acquire the images and all the out-of-focus light is suppressed by confocal apertures, resulting in sharper images. Topography is recorded by a series of consecutive images in both the x-y and x-z planes including depth measurement in the z-direction. CLSM allows for the study of un-sectioned, naturally moist teeth, hence, no sample preparation is required while visualizing the outermost surface or subsurface areas. It has the advantage of high resolution and fast recording of the surface topography [10,39]. Though it is mostly used to obtain qualitative information, it is also used for quantifying erosive tissue loss and softening depth [10,33].

Scanning Acoustic Microscope (SAM): The SAM uses focused sound to investigate, measure, or image an object based upon surface acoustic wave velocity measurements in a focused acoustic field generated by a piezoelectric transducer/lens system. This device can be used for tooth tissue study without processing, fixing, dehydrating, clearing, staining, or preparing or contrasting replicas, which is a substantial advantage when compared to other conventional devices. Acoustic impedance and sound velocity increase proportionally to the growth of a concentration of an inorganic component in simulated hard tissue, permitting the enamel thickness to be measured with high positional accuracy. It is a sensitive technique, but it cannot differentiate between different tooth wear phenomena such as erosion, abrasion, or abfraction (i.e., the technique is less specific) [40,41].

For diagnostic and research purposes, the SAM can be used for non-destructive evaluation of local physicomechanical properties of tooth microstructure elements in assessing mineralized tissue conditions like dental erosion [40,41].

Dynamic Secondary Ion Mass Spectrometry (DSIMS): It allows semi-quantitative analysis of elemental and molecular composition of specimen surfaces, although with some surface damage [6,9]. This technique employs an energized ion beam to remove or sputter atomic-charged and molecular-charged particles from a surface in a very controlled manner when they are bombarded by a primary beam of heavy particles. In-vitro trace element analysis of solid tooth, samples can be measured. It can also provide methods to visualize the two-dimensional and three-dimensional composition of solids at lateral resolutions approaching several hundred nanometers and depth resolutions of 1–10nm and exhibits excellent sensitivity [42]. This method has been shown to be a convenient, validated and very sensitive way to determine fluoride uptake and to map the fluoride distribution in incipient erosive enamel lesions. This is due to its rapid depth profiling capability, superior analytical sensitivity and sub-micron spatial resolution in imaging mode [43]. Secondary ion mass spectroscopy has been employed to study enamel erosion and fluoride uptake by early erosive lesions, although the depth of the erosive crater cannot, as yet, be accurately determined using this technique [9,42].

Iodide Permeability Test (IPT): In this method, defined areas of enamel samples are soaked for a few minutes with potassium iodide, which is then recovered from the enamel by Millipore pre-filter paper discs. The amount of iodide recovered from the discs is measured and information about the pore volume of the enamel is obtained [44]. Here, a linear relationship between iodide permeability and calcium loss is seen. Sensitive estimations of the early stages of demineralization and re-mineralization of enamel can be obtained and only In-vitro study of erosion is possible. This low-cost technique can be used for rapid screening of erosive potential on enamel, but not on dentine [44].

Microradiography: In microradiography, mineral loss can be directly quantified based on the attenuation of X-rays transmitted from the dental hard tissue. Transverse Microradiography (TMR) is one of the gold standards for measuring erosion. In this technique, the tooth sample is cut into thin enamel or dentin sections (50–200μm), which are then, oriented perpendicular to the sample surface. In contrast, using Longitudinal Microradiography (LMR) thicker specimens, (up to 4mm thick) comprising the natural enamel surface and some underlying dentin, are cut from the tooth, with the X-ray beam positioned approximately parallel to the direction of lesion progression [45].

A microradiographic image is then made on high-resolution X-ray sensitive photographic plates or film by X-ray exposure (nickel-filtered Cu Kα-line, i.e., at 20kV, 20 mA) perpendicular to the cut surface. Thereafter, the microradiogram is digitized by a video camera or photomultiplier. The mineral mass can be calculated from the photon counts or gray values of the photographic plates or film or by determining photographic density measurements calibrated by an aluminum step wedge [45]. Various parameters can be measured such as mineral loss (Delta Z in Vol% μm), lesion depth (Lesd in μm), ratio or average loss of mineral content in the lesion area (Delta Z / Lesd in Vol%), the mineral volume percentage, and the position of the sub-surface layer and lesion body [45-48].

TMR is one of the most practical and widely accepted method used to assess de-mineralization and re-mineralization in dental hard tissues and is used in both in-situ and in-vitro studies. It is also the most demanding and time-consuming method, with the exposure time of the X-rays being quite long (15 to 65 minutes). In some studies, TMR has been shown to have a high level of sensitivity even for early erosive lesions of less than one-hour duration [46]. LMR is less sensitive than TMR to minute changes in mineral content in erosive lesions, as the use of thinner specimens in TMR provides better information about the mineral changes within the specimen [6,47]. LMR also permits specimens to be reused to make longitudinal observations [6,47]

Contact X-Ray Microradiography: This is another method of directly evaluating changes in mineral densities of partially demineralized tooth specimens. In this technique, tooth tissue is cut into thin parallel slices and a geometric positioning marker is positioned parallel to the edge of interest and fixed with a small drop of epoxy, leaving a thin tooth edge exposed which is polished. Microradiographs of 100μm thick tooth sections, before and after acidic challenges are taken and converted into digital images from high-resolution holographic film with digital microscope camera and analyzed. The microradiographs showing mineral density changes before, during, and after acidic challenges are compared. This method demonstrates high specificity in distinguishing erosion. This method is commonly used for longitudinal studies [49].

Also, this method generally produces a high spatial resolution (better sensitivity) as compared to scanning a radiograph with a microdensitometer since it does not involve mechanically moving the densitometer [49].

Ion-Exchange Chromatography (Ion Chromatography): Ion-exchange chromatography relies on the reversible exchange of ions in solution with ions electrostatically bound to an insoluble support medium based on charge density [50]. It can be used for detecting almost any kind of charged molecule such as free sugars or fluoride content that have erosive potential in food [51,52]. Ion exchange chromatography provides high selectivity and efficiency. Selectivity depends not only on the nature and number of the ionic groups in the matrix but also on the experimental conditions, such as pH and ionic strength. The technique is easy and predictable. Further, the experimental conditions can be selectively manipulated and hence, ion-exchange chromatography achieves extremely high resolution [50].

Microdensitometric Scans: Microdensitometric scanning gives the relative measurement of light transmission through images on positive film transparencies. This measurement is termed "optical density". The scanner reads the optical density of the image using an optical scanning system and presents the computerized data graphically or digitally. This method can be used for detection and quantification of mineral loss and the minimum mineral content within the eroded area in thin tooth sections. These scans measure the percentage of mineral content versus the distance of a lesion and can be used to calculate the total amount of mineral loss, the minimum volume percentage of mineral value between two points in the lesion, and depth of the erosive lesion [46].

II. In-vivo Techniques

In-vivo studies are the gold standard for epidemiological purposes and have the advantage of assessing erosion directly in the patient's mouth. The results have greater validity compared to In-vitro study results. But one of the major disadvantages is that precise quantification and qualitative analysis cannot as yet be achieved using these methods. The techniques for in-vivo evaluation of erosion include photographs, indices and colorimetric procedures.

Clinical Examination and Use of Photographs: In epidemiology, photographs are valuable in measuring enamel defects and dental erosion. Photographs can be easily selected, arranged and rearranged and reassessed without re-examining the patient. They have potential in developing national and international comparisons in measuring erosion [53]. Photographs give results similar to those from visual examination of erosion but, may underestimate the extent of the condition [36,53]. The quality of the outcome depends on the dexterity of the photographer and ambient conditions such as light reflectivity. Though clinical photographs are useful for monitoring erosive wear, factors like proficiency of the operator or photographer and the general setting may affect the precision of erosion estimates, especially of early lesions [3].

Indices: Indices include morphological as well as quantitative criteria for recording erosive wear at individual and population levels. The earliest indices were based on work by Ten Bruggen [54] and Eccles and Jenkins. Eccles broadly classified dental erosion of nonindustrial origin into early, small and advanced, denoting the type of lesion, assigned to four surfaces, representing the surface where erosion was detected [55]. Based on Eccles work, Smith and Knight further developed the Tooth Wear Index (TWI), a comprehensive system whereby all four visible surfaces of all teeth present are scored for wear, irrespective of how it occurred which was more clinically relevant. This index has been widely used in various studies [55]. Most of the other indices which have been proposed are more or fewer modifications of the combination indices published by Eccles and Smith and Knight but fashioned to suit different research aims [56-59].

A new scoring system known as the Basic Erosive Wear Examination (BEWE) has been designed. It is a partial scoring system recording the most severely affected surface in a sextant and the cumulative score guides the management of the condition for the practitioner.

The four level score grades the appearance or severity of wear on the teeth from no surface loss (0), initial loss of enamel surface texture (1), distinct defect, hard tissue loss (dentine) less than 50% of the surface area (2) or hard tissue loss more than 50% of the surface area (3). This index not only measures the severity of the condition for scientific purposes but also establishes risk levels providing a possible guide towards erosion management including identification and elimination of the main aetiological factor(s), prevention and monitoring, as well as symptomatic and operative intervention where appropriate [59].

Although these indices have admirably served the purposes of the researchers who developed them, they lack universal acceptance. For an index to be internationally accepted and standardized, it must have the quality characteristics of validity (content, construct, and criterion), reliability, sensitivity and specificity. Such an index has yet to be developed.

Colorimetric Procedures: In colorimetric methods, the absorbance of light due to a formed colored complex is related to the quantity of the analyte [6]. Colorimetric assay is far superior as compared to diamond indentation and profilometry, in determining short time erosive effects occurring within 5second precisely and kinetically [60]. Arsenazo III and malachite green allow investigation of minimal erosive effects via direct determination of phosphorus and calcium dissolution respectively in different acidic solutions [61]. Malachite green has 10 times higher sensitivity for detection of minimal amounts of phosphate (7.3-29.1 micromol/L) in different acidic solutions compared to other methods [62].

III. In-vitro/In-vivo Techniques

In-vitro/in-vivo techniques to assess erosion have a high degree of sensitivity and specificity as they are quantitative or semi-quantitative, valid and reliable and may be used in-vivo. Moreover, these techniques can be used for assessing erosion in cross-sectional as well as longitudinal studies.

Quantitative Light-Induced Fluorescence (QLF): It is based upon the auto-fluorescence of enamel, which decreases with decreased mineral content. When tooth surface is irradiated with blue-green light, it emits fluorescence with a wavelength of 540 nm caused by chromophores, which are predominately located at the dentin–enamel junction and in the dentin. Demineralized areas appear darker permitting quantification of the erosion [63]. The amount of fluorescence radiance loss is related to the mineral loss in the lesion. The technique can be used In-vitro, in-situ and in-vivo to monitor mineral changes in lesions. This method can be used for the longitudinal assessment and detection of very early mineral changes in enamel [63- 65]. It can also be used to provide optical and quantitative feedback to patients [63]. The QLF device is currently a research tool and is expensive.

Optical Coherence Tomography (OCT): OCT is a high-resolution, Low Coherence Interferometric (LIC) technique that generates sub-surface images of enamel samples using near-infrared light (820nm). It is non-invasive and can potentially measure both surface characteristics and quantitative loss of tooth structure [66]. The method provides cross-sectional imaging by measuring the magnitude and echo time delay of backscattered light. The increased porosity of demineralized enamel as in case of erosion compared to sound enamel results in a change in optical properties, permitting the difference in intensity of the reflected light to be quantified and analyzed [66-68].

OCT can assess enamel thickness, reflectivity, and absorbance, which can then be related to the degree of mineral loss [8,66].

Atomic Absorption Spectrophotometry (AAS): AAS uses the adsorption of optical light by the analyte atoms or ions in gaseous state like calcium in solutions or directly in solid samples that is measured, to determine the concentration of gas-phase atoms [6]. It can be used to quantify erosion of both enamel and dentine. Pre-selected teeth are subjected to acidic challenge and this acid is collected after a predetermined time interval and chemically analyzed for calcium and/or phosphorus. This can be followed up repeatedly for longitudinal measurements [69].

It is reliable and sensitive for estimating calcium with little interference from other solutes such as phosphates [51]. It has been used to check for enamel dissolution by measuring calcium in acid etch solutions in-vivo or In-vitro after acidic challenge in early erosive lesions [69,70].

Digital pH meter: The qualitative determination of the pH value of foodstuffs is done by measuring the pH, which is perceived as acidic or alkaline depending on the hydrogen ion (H^+) concentration in the solution. A measuring electrode (pH electrode) is used with a reference electrode connected to an electronic meter that measures the activity of the hydrogen cations by producing a small voltage and displaying the resultant pH reading. The pH of beverages is considered a strong predictor of their erosive potential. The salivary pH before and after soft drink intake in children with erosive lesions or the pH of beverages with erosive potential can be measured using a digital pH meter [52,71].

Microindentation and Nanoindentation: Surface hardness softening, i.e., loss of hardness, is measured by the resistance of a substrate to the penetration of an indenter. Microhardness is measured with either a Knoop or a Vicker's diamond indenter, which are rhomboidal and tetra-pyramidal, respectively. The Knoop or Vicker's hardness numbers are calculated from the length of the indentation and the applied load [10]. For determining changes of surface hardness of dental hard tissues altered due to erosion including early stages of enamel and dentin dissolution microhardness and nanoindentation techniques are used [2,72,73].

Nanoindentation also uses the same principle as microhardness indentation but on a smaller scale. It uses a trigonal-pyramidal Berkovich diamond indenter that creates an indentation usually maximally 1µm in length under loads of 0.25mN–50mN. Nanoindentation can be used to measure Young's modulus (elastic deformation), which seems to be a relevant parameter for the characterization of very shallow erosive lesions [10].

Fosse described a technique for measuring microhardness in-vivo using an indenter that he developed. The method consisted of making indentations with a constant force on the natural outer enamel surface with a Vicker's diamond followed by making exact replicas of the indented enamel surfaces. The reproduced indentations were then measured in a light microscope to measure the diagonal of each indentation. The Vicker's Hardness Number (VHN) is calculated from the equation: VHN= 1854.4 X 600/D2 where D is one of the measured diagonals [73]. While surface hardness measurements are in principle applicable in-vivo as well as In-vitro and in-situ, this application requires further testing [10]

The main advantages of microhardness determinations are their relatively low cost, the long research experience with the system, and that they can be combined with measurements of abrasive surface loss [6]. A clear limitation is that in highly eroded dental substrates the indentation boundaries are not clearly defined, resulting in measurements that are inaccurate or impossible to make. The decrease in the surface of advanced erosive lesions cannot be quantified by hardness measurements of the remaining surface. Another limitation is that when material like fluoride is deposited, surface hardness measurements may not be representative [10].

Ultrasonication and Chemical Analysis: With ultrasonic pulse-echo measurements, the time interval between the transmission of an ultrasound pulse on the enamel surface and the echo produced by the amelodentinal junction is determined by a light stereomicroscope and the thickness of the enamel layer can

Sl. No.	Method	Advantages	Disadvantages
In-vitro techniques			
1.	Scanning electron microscope	ESEM preferred for wet samples (<1 nm) High resolution	Subjective assessment Requires sample preparation High cost
2.	Surface profilometry	Non destructive technique Can measure deep erosive pits and curved surfaces	Contact profilometry Could damage the surface Extremely technique sensitive Time-consuming
3.	Polarised light microscopy	High specificity	Only mineral density and pore volume
4.	Non-contact confocal laser scanning microscopy	Direct, rapid and noninvasive, High resolution	Only qualitative information
5.	Scanning acoustic microscope	Non-destructive No sample preparation High sensitivity	Less specificity
6.	Secondary ion mass spectroscopy	Excellent sensitivity High depth resolution	No estimation in dentine Some surface damage High costs
7.	Iodide permeability test	Low-cost Rapid screening High sensitivity	Cannot estimate in dentine Estimate only pore volume
8.	Microradiography	Most practical and direct technique Most informative High sensitivity in thinner sections [TMR] Longitudinal observations possible	Destructive technique
9.	Contact X-ray microradiography	Technically simple High specificity and sensitivity Longitudinal observations possible High spatial resolution	Technique sensitive
10.	Ion chromatography	High selectivity and efficiency Easy and predictable High resolution	No estimation in dentine No information about structural changes
11.	Microdensitometric scan	Low-cost	-
In-vivo techniques			
12.	Colourimetric procedures	Can measure very short term changes of erosive effects. Well established method	Presence of some agents or pH can interfere with the reactions. No information on structural changes
In-vitro / In-vivo techniques			
13.	Quantitative light-induced fluorescence	Non-destructive Longitudinal assessment possible Optical feedback to patients Not time consuming	Expensive Problematic probe positioning
14.	Optical coherence tomography	Non-destructive High resolution	Limited in-vivo accessibility Problematic probe positioning
15.	Atomic absorption spectroscopy	Non destructive Longitudinal measurements possible	Expensive
16.	Microindentation and nanoindentation	Nondestructive technique Relatively low cost	Flattened and polished surfaces required Inaccurate measurements in highly eroded areas
17.	Ultrasonication	Non-destructive technique Longitudinal measurement possible	Low resolution

[Table/Fig-4]: Advantages and disadvantages of some of the techniques.

be calculated [6]. This method is non-destructive and can be used for both early diagnosis of dental erosion and longitudinal measurement of progressive enamel loss [29,74,75]. However, its use in erosion studies is limited because of poor probe tip positioning and repeatability and poor reliability in measurement of enamel thickness changes of less than 300µm [76].

Some of the low cost techniques that can be used for evaluation of dental erosion are contact X-ray microradiography microdensitometer, microhardness determinations using microindentations, chemical analysis of minerals by iodide permeability test and ion exchange chromatography. These techniques give qualitative and quantitative information and have high levels of specificity, sensitivity and resolution which will allow researchers to continue further work in measurement of dental erosion depending on their objectives. Brief advantages and disadvantages of some of the techniques are summarized in [Table/Fig-4].

The presence of dental erosion in the general population is increasing steadily, especially among children and young adults, is well documented [77]. Many biological, behavioral and chemical factors interact with the tooth surface. Over time, they may wear away the tooth surface, or indeed protect it, depending upon a fine balance [1]. Since dental erosion is a complex process, it can be evaluated by a variety of methods including clinical examination, measurement of mineral loss i.e., calcium and phosphorus content, change in quality and quantity of dental hard tissue surface, and change in pH or salivary buffering capacity in-vivo and In-vitro in enamel or dentin [6,8,11].

CONCLUSION

A number of methods are available for quantitative and qualitative assessment of dental erosion. Based on the requirements of the researcher, a satisfactory technique can be selected. However, it is important to remember that each technique has advantages and disadvantages, so the technique to be used must be selected judiciously. For example, for epidemiological studies any of the in-vivo techniques may suffice; for exacting laboratory studies, the In-vitro studies are more appropriate. The In-vitro/in-vivo techniques present an exciting future for the study of dental erosion. The disadvantage of these methods presently is that they are technique sensitive and expensive. As some of these techniques are relatively new, further studies are needed to establish their accuracy, reliability, reproducibility and validity. They are well worth exploring in future research in the field of dental erosion diagnosis and assessment.

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FINANCIAL OR OTHER COMPETING INTERESTS: None.

Date of Submission: **Nov 26, 2015**
Date of Peer Review: **Apr 11, 2016**
Date of Acceptance: **May 10, 2016**
Date of Publishing: **Oct 01, 2016**