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# BIOMODIFICATION OF TOOTH DISCOLOURATION

***Lt Col Sonali Sharma + MDS, PhD**
## Lt Gen SM Londhe SM MDS
Corresponding author: Lt Col Sonali Sharma
Postal address : A 201 Winter Hills
Dwarka Morh 110059
Mobile number : 9717888513
Email address: sonaliendo@gmail.com
Affiliations of author(s) :
*Professor Conservative Dentistry & Endodontics
Army Dental Centre
Research & Referral
Delhi
## Director General Dental Services, Room number 11, L Block,
Adjutant General's branch, IHQ of MOD (Army) New Delhi :110001

## ABSTRACT

Many an attractive smile are marred by discolouration or staining, either of an individual tooth or of all teeth, which has a far-reaching psychological impact. Management of intrinsic stains have in the past relied on masking discolourations by full-coverage crowns. Today, the Minimal invasive concepts, methods and techniques have permeated in all disciplines of dentistry and esthetic dentistry is no exception. The minimally invasive approach in dentistry is based on safeguarding and shielding the tooth structure framework, especially enamel.

Biomodification is the rationale or a process by chemical, physical, genetic means oftransmogrifying aliving organism. In dentistry, biomodification is a non-invasive or a minimally invasive concept which by chemical or physical means bring about a revision in tooth architecture. This paper gives an insight to the current status and emerging minimal invasive and non-invasive trends like microabrasion, macroabrasion and bleaching or a combination of these in management of discoloured dentition.

Keywords: Discolouration, biomodification, bleaching, microabrasion, macro abrasion

## INTRODUCTION

Discolouration of teeth has a variegated aetiology and it may intrinsic or extrinsic in origin.Intrinsic discolouration is due to fusion of the chromogenic component during odontogenesis into enamel and dentin. Tooth discolouration of varying degree can result due to tetracycline ingestion during various stages of odontogenesis or as a result of excess fluoride levels in groundwater. The severity of tetracycline stains depends on the time duration and dosage of the drug and also on type of tetracycline. The Chlortetracycline (Aureomycin) gives a greyish-brown discolouration, Dimethylchlortetracycline (Ledermycin) and Oxytetracycline (Terramycin) gives yellowish discolouration, Doxycycline does not give rise to any discolouration or staining of the teeth. Developmental disorders can leave its mark on the dentition in the form of tooth discolouration depending on the stage of tooth development i.e amelogenesis or dentinogenesis and the chronologic stage of the onslaught.

 

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Post eruptive causes of tooth discolouration are due to pulpal necrosis, and regressive changes may be due to deposition of dentin which affect the transmission of light and thus give an appearance of tooth appearing darker. Extrinsic strains result due to ingestion of tea, coffees, red wine, and carotene-rich foods. Smoking or use of nicotine products are also an extrinsic cause of tooth discolouration.[1]

Biomodification is the rationale or a process by chemical, physical, genetic means of transmogrifying a living organism. Acid etching is an example of biomodification and has since 1960s been an accepted integral clinical protocol of adhesive dentistry. The chemical treatment with phosphoric acid of enamel and dentin catalyses the interdiffusion of resins into the tooth substrates. Tooth discolouration can also be clinically managed by altering or biomodification of dental substrate.Biomodification of tooth discolouration can be brought about primarily by three methods micro abrasion, macro abrasion and bleaching.

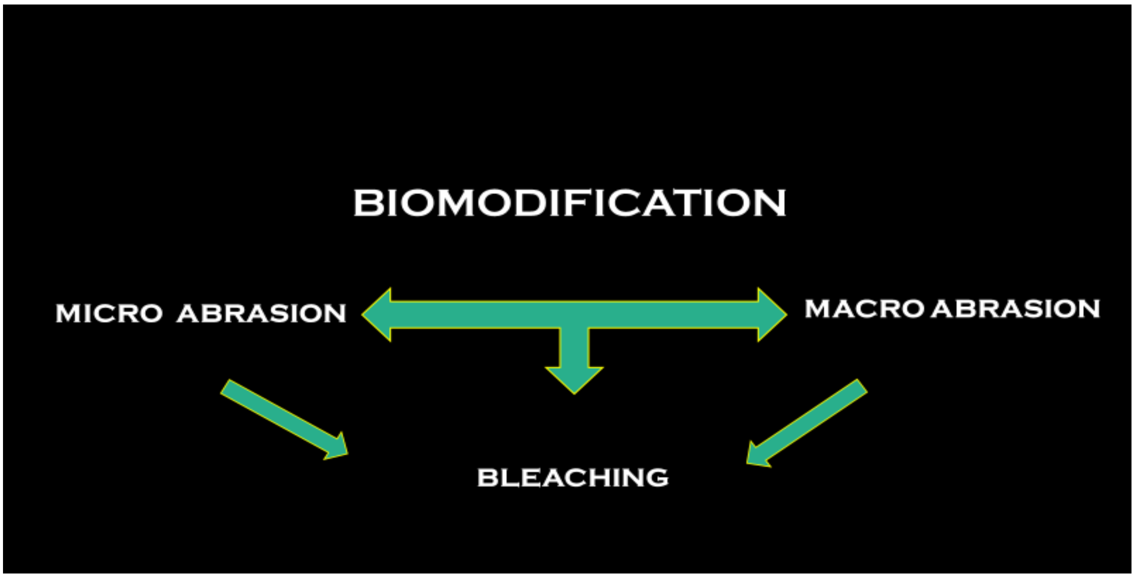


Fig 1: Biomodification of tooth discolouration

## BLEACHING

Bleaching isan effective and non-invasive method to whiten or lighten the discoloured teeth and is an accepted treatment modality. Over the years, evidence-based research has led to development of newer materials and innovative techniques which has resulted in predictable long-term tooth whitening.[1-5]

In mid-1800, chloride of lime was used for bleaching of discoloured non-vital teeth bleaching. Truman, according to Kirk introduced Labarraques solution containing chlorine, which in turn was a resultant of the reaction between acetic acid and calcium hypochlorite.[2]

In 1880s strong concentrations of hydrogen peroxide was used along with a lamp, the drawback was that relapse to original shade was a rule and duration of treatment was lengthy with multiple number of thevisits.[3] Various experimental bleaching techniques and reagents were tried like oxalic acid, chlorine and ammonia.For removing iron oxide caused intrinsic stains of pulpal necrosis and haemorrhagic discolouration, oxalic acid was used. With amalgam restoration,there is discolouration due tosilver or copper products which can be counteracted by use of chlorine.For iodine associated stains of root canal treatment, ammonia was used. For more stubborn, metallic ion origin stains, potassium cyanide extract was suggested but was never accepted owing to its fatal toxicity it heralded.[3-5]Early literature as in 1800, its focus revolved primarily on the whitening of non-vital teeth.[3] It was in 1868 that

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bleaching of vital dentition was first undertaken with oxalic acid. In 1884, Harlan reportedly demonstrated the use of what he called hydrogen dioxide, later it was rechristened as hydrogen peroxide.[4]Thereafter, many techniques were used for hastening the bleaching process by use of electric current, ultraviolet light and heating instruments. It was in early 1900s that bleaching products were commercially available.[4-6]

In 1961, Spasser introduced the concept of walking bleach, in which after root canal treatment, in the pulp chamber a mixture of water and sodium perborate was placed between visits.[6] This was further modified by Nutting & Poe in 1963 by replacement of water with 30 -35 percent hydrogen peroxide.[7,8] Haywood an orthodontist by profession, in 1991 used 10 percent carbamide peroxide to reduce post orthodontic gingival swelling.[9] He observed that with 10 percent carbamide peroxide not only was gingival health restored but it also brought about lightening of tooth shade, thus, paving the way of nightguard bleaching which came into being after two decades of being documented by Haywood and Heymann.[9-12]

The realization of whitening of the teeth depends heavily on accurate diagnosis on the initial cause of discolouration. Though broadly the aetiology is intrinsic or extrinsic but more often than not it is multifactorial. At times the external stains over a time get internalized as both enamel and dentin are permeable to substances leaching into the toothsinorganic and organic region.[13]

**The Mechanism of Action of Hydrogen Peroxide:**

The traditional hypothesis is the chromophore theory which is based on the interaction of hydrogen peroxide with the organic chromophore of the tooth substrate. According to this theory, reactive oxygen species like hydrogen peroxide convert chromophore chains into simpler units and modify the optical properties and the tooth appears whiter. This theory had certain glaring lacunae as the complete process and the reaction and fate of the by-products had not been elucidated. Thus, the complete whitening process according to Kwon, can be understood by studying the three different phases of bleaching mechanism.[5]

The Phase One: Diffusion[5]

Evidence-based studies by, Bowles, Ugwuneri, Hanks et al, Palo et al, Kwon et al evaluated the diffusion rate of hydrogen peroxide.[14-18] These studies observed that the concentration, time of application, temperature increase, size of dentinal tubules, modes of activation, associated local conditions like etching etc, type of formulation and means of dispensing, they had all a bearing on the final outcome. These studies were in consonance with Fick's second law of diffusion. This law states that that diffusion of a substance is inversely proportionate to the distance and directly proportionate to concentration of the substance, coefficient of diffusion of that particular molecule and the surface area of the molecule or that substance. Thus one has to determine the optimal concentration of the bleaching agent and the time to bring about whitening without affecting the integrity of the tooth structure.[11-15]

The Phase Two: Diffusion Interaction

Fourier transformation infrared spectroscopy studies have failed to locate the chromophore or record their breakdown into smaller molecules. Thus, studies by Fattibiene et al, Eimar et al and Darchuk have challenged the chromophore theory. [19-22] Hydrogen peroxide, when applied on the tooth surface, has an oxidising reaction. The particular oxygen species or free radical liberated depends on the concentration of ions of peroxide, temperature raised, the change in pH and existence of other molecules. [5]

The empirical formula for hydrogen peroxide is $H_2O_2$. The structural formula is HO–OH. The molecular weight of hydrogen peroxide is 34.0. The first pathway is a homolytic cleavage which is light and is heat dependent and in which there is a resultant shared electron due to splitting of boding shared electron. This pathway will generate free radicals.

$$HOOH \rightarrow H + OOH \text{ or } HO + OH$$

The Heterolytic cleavage is a pH-dependent deprotonation reaction and gives rise to electron pair. If the pH is high then perhydroxyl ions are liberated

$$HOOH \rightarrow H^+ + OOH^-$$

A third pathway is a coalitionof ,homolytic pathway and heterolytic cleavage pathway and results in formationof active oxygen that has both a free reactive radical and an anion. The electronic rich zones of the stain attract the active oxygen and thus the double bonds will be cleaved and result in lightening the shade.[18-19] The oxidizing potential of hydrogen peroxide leads changes in the organic portion of the enamel and dentin while the acidity of the product affects the mineral element. Current studies indicates that hydrogen peroxide interacts not only with the chromophore, in addition interacts with hard tissue of the dental substrate and this cumulative effect is responsible for whitening of discoloured teeth.[5]

According to Kwon, the next phase in bleaching is Phase Three: Surface change and colour-Multiple studies have proved that enamel properties play a pivotal role in the optical perception of the tooth shade. Thus, miniscule changes in density of enamel which lead to decrease in compactness of enamel crystal will cause increase in refractive index of the tooth. SEM and AFM studies have shown that surface irregularities and topography can impact the absorption pattern and spectrum leading to uneven whitening of the substrate. It has also been observed that rough surfaces of substrate lead to diffuse reflection and thus the surface in question appear more bright, whereas a smooth surface will result in a specular reflection pattern. Thus, the current literature review demonstrates that chromophore theory needs revisionism and whitening of tooth discolouration is a complex mechanism impacted by topographical alterations of tooth structure and the bleaching agent will have an effect on microstructures of the substrate.[5]

Currently, two most commonly used means of bleaching procedures are used, one is use of low concentration of hydrogen peroxide or a low concentration of hydrogen peroxide released from carbamide peroxide which is used for home bleaching. Other bleaching agents which are used for professional or in-office use has a high concentration of hydrogen peroxide. To reduce the time of bleaching procedure, various methods are advocated to catalyse the decomposition of hydrogen peroxide like photocatalytic, photochemical or photothermal i.e use of heat also called power bleaching. Various source of light like quartz tungsten halogen light, light-emitting diodes and laser's like diodes, erbium family, $CO_2$, Nd:YAG, and KTP have been experimented upon.

To enhance the laser absorption, the bleaching gel has particles increasing the absorption of the laser light. Not only do these particles absorb the laser light but also converts the lased energy into thermal energy and hence enhancing the effectuality of bleaching process.[23,24]

For laser-assisted bleaching there are two techniques, one is the use of photothermal energy, also called power bleaching, another method is photochemical. Photothermal techniques is when absorbed light energy is converted into thermal energy and it causes activation of bleaching gel in a controlled manner and hastens the peroxide reaction. Whereas photochemical bleaching reaction uses light to directly act on an oxygen molecule.[23]The lasers indicated for photothermal bleaching are Diode laser, Nd:YAG, Er:YAG, Alexandrite. According to studies done by Gutknecht et al, the erbium laser is absorbed fully by bleaching gel and hence does not increase the temperature of the tooth.[24] Whereas the wavelength of the diode laser is poorly absorbed by the bleaching gel and it is transmitted through to tooth and leads to increasing the temperature of the tooth.[24] On the other hand, the diode wavelength is relatively weakly absorbed in the gel, and the transmitted light directly heats up the whole

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tooth. The erbium family's chromophore is water and the bleaching gel is aqueous and thus, maximum absorption of the lased energy is in the gel, hence there is no requirement for specific particles to enhance absorption. Erbium and Alexandrite enhanced bleaching process leads to smoother enamel surface as compared to Nd: YAG.[23-25]

When selecting a laser for enhancing the bleaching potential, the wavelength and the target substrate must be considered. Each wavelength has a different chromophore where the absorption is maximum and which in turn will potentiate the desired outcome. In addition, the type of gel, as well as thickness and pH, will have a bearing on final outcome. The addition of additives to the bleaching gel will affect the final shade as well as the spectrum of absorption. The pH will determine the kind of and quantity of free radicalsliberated. [25] The buffering of peroxide to a pH range of 9.5 to 10.8 provides a greater amount of perhydroxyl free radicals

For stubborn tetracycline stains, the laser which isadvocated is the KTP laser (potassium-titanyl-phosphate) which is a Nd: YAG frequency-doubled laser. Initially, the laser effuses a 1064nm wavelength visible green light, which is passed through a KTP crystal and the resultant lased light is KTP laser in which the original wavelength of Nd: YAG is halved to 532nm. The advantage is that the green light will be preferentiallyabsorbed by the chromophore of discolouration and by melanin and haemoglobin and not by water or hydroxyapatite of tooth substrate. It is advocated to use a patented bleaching gel Smart Bleach gel (SBI: Herzele, Belgium) containingsulphorhodamine B, a photosensitizer, which is red in colour and acts as a complementary colour to green KTP laser light. In addition the gel has a high percentage of hydrogen peroxide. To activate the gel it is first mixed, which initiates the reaction and pH rises from 5.5 to 7 and when the gel is irradiated by KTP laser there is an increase in pH from 9.5 to 10 and thus leads to ionization of hydrogen peroxide, observed by increased formation of perhydroxyl radicals, this is known as the photocatlytic effect of laser. The photothermal effect of laser is due to the complementary colours of the bleaching gel -red and lasing KTP -green, this leads to maximum absorption of lased light and increase in thermal energy. The third mechanism is by photochemical reaction which leads to higher yield of the free radicals that would be brought about by photothermal effect. The heating up of the tooth is thus reduced. Hence a greater concentration of free radicals at a minimal time period are obtained without the deleterious effect of temperature build-up as seen in other lasers like diode. [26,27]


Fig 2: Inside Out laser-assisted bleaching for nonvital, root canal treated 21

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Diode laser can serve as an economical and portable means of laser-assisted bleaching. It can be used for non vital bleaching as demonstrated by the author in Fig 2. It can also be used for vital bleaching as observed in Fig 3. To reduce post-operative sensitivity, it is advocated to use a remineralizing paste or a desensitizing paste. In the case illustrated in Fig 3, the author has used a CPP ACP F based paste to prevent sensitivity.


Fig 3: Vital Bleaching

## MICROABRASION

During amelogenesis, if there is excessive intake of fluoride, it leads to a variant of enamel dysplasia manifested as dental fluorosis. The enamel dysplasia may range from fluorotic opaque areas to yellowish or brownish discolourations with or without pitting. To counteract this esthetic issue, various modalities like veneers and crowns were recommended but the disadvantage was loss of healthy tooth structure. Thus, there was a dire need of a more conservative, non-invasive modality. Enamel surface "dysmineralization" is defined as a developmental defect, during amelogenesis, affecting the inorganic part of enamel. For such specific cases of enamel dysmineralization the treatment modality advocated to improve the appearance of affected tooth substrate is Enamel microabrasion.[27,28]

Since nearly a century two conservative treatment strategies have been recommended to remove enamel dysmineralizationi.e enamel microabrasion and vital bleaching or a combination of both approaches. Enamel microabrasions objective is to remove hypermineralized or pitted superficial enamel layer, thereafter if required bleaching is advised for eradication of the extrinsic stains which may be enmeshed in subsurface enamel porosities. [27-29]

In 1926 Walter Kane treated the prominent fluorotic brownish discolouration of upper anterior of a 16-year-old teenage girl with the help of muriatic acid. Robert McCloskey

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followed up the case in1986 and found the results quite promising. In 1986 Croll used a combination of pumice and hydrochloric acid and observed that enamel staining and pitting can be removed to a depth of tenth of millimetre with a concerted effort of chemical erosion and mechanical abrasion, this approach was later called **abrosion** and it resulted in a glazed surface of enamel.This treatment modality was name enamel microabrasion by Croll and Cavanaugh as it mimicked dermabrasion for pitted acne-affected skin surface. [30] Today enamel microabrasion has become a clinical reality with the advent of commercially available preparationslike Opalustre by Ultradent and PREMA which contain abrasives like silicon carbide with very low concentration of Hydrochloric acid (6.6 % in Opalustre). Depending on the abrasive content and concentration of the HCL acid only 10-200micrometre outer enamel surface can be removed. Evidence-based studies have shown that the glazed appearance is due to compacted aprismatic enamel layer. [31-35]
In Fig 4 the author has used commercially available Opalustre containing 6.6 % HCL and carried out enamel microabrasion from maxillary premolar to premolar. Then the author has restored the fractured 21 with composite. In Fig 5 the author has in the case of pitted fluorotic discolouration used a abrasive disc along with opalusture gel. Thereafter, in next appointment laser-assisted bleaching was done with a diode laser. To counteract the postoperative sensitivity, a remineralizing paste of CPP-ACP F was applied.

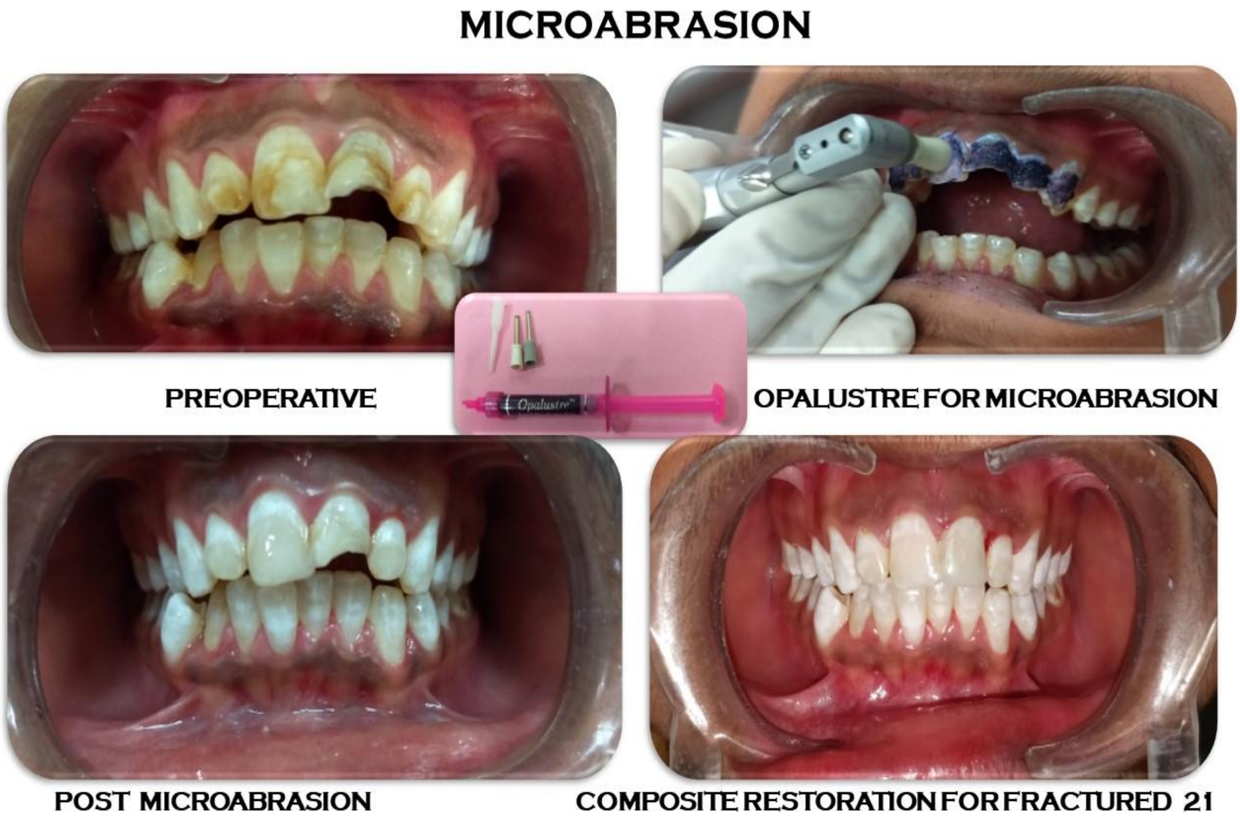


Fig 4: Microabrasion carried out from 14-24, thereafter fractured 21 is restored with composite.

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Fig 5: Microabrasion of maxillary arch 14-24 followed by bleaching of both arches and followed by application of Remineralizing paste to prevent sensitivity.

## MACROABRASION

Air abrasion was introduced for cavity preparation in 1940 by Robert Black. However, it did not register commercial success because at that time there was no method to evacuate the sand particles and further air turbine handpieces had just been introduced in early decades of $20^{th}$ century. Further adhesion was still in a rudimentary state. Today with routine use of high evacuation system evacuation of sand particles is no longer a concern. The emergence of the philosophy of minimal concepts of cavity preparation and advent of adhesive dentistry have paved the way for air abrasion to be revisited. Air abrasion uses a stream of aluminium oxide particles of size 27 micron or 50 micron with or without water. When water is used with air abrasion it is a form of hydro-air abrasion and due to venturi effect the water curtains the sand particles and hence site of work is not messy. The air abrasion is based on the principle of kinetic energy due to which the air abrasive particles strike the substrate and abrade the enamel surface. [36-43]

Thepressurerangeof air abrasión unitisof 40 -160 psi. Forstainremoval, a briefexposureof 27 micronswith machine settingof 40 psi target thesubstrate at 45 -60-degree angle. Thisbringsabout light abrasión oftoothsurface and removalofstain. Thereafter a direct composite veneerrestoration can be done as illustrated in Fig 6 bytheauthor.


Fig 6: Air abrasion for stain removal

## CONCLUSION

Discolouration of the teeth has a far-reaching psychological impact on an individual's psyche. The need of the hour is a non-invasive or minimally invasive approach in management of intrinsic stains. The treatment plan should be tailor-made, need-based and comprehensive in approach. Bleaching or whitening of dentition or tooth in question is one such method. It should be used judiciously and one should not give in to the bleachorexic demands of some patients. Bleachorexia, which is an obsession to whitening of the teeth is said to be abehavioral problem similar to the disorder anorexia. In today'sesthetic driven society ,one has to consider it a reality and hence be judicious in case selection. The second option, especially in cases of fluorotic pitting of enamel is to microabrade the tooth surface with hydrochloric acid gel and abrasives. Air abrasion is also another option to minimally abrade tooth surface and remove stains. All these techniques can be used alone or they can be combined, depending on the case. All these techniques are non-invasive or minimally invasive and can be integrated in our clinical practise as demonstrated in the cases.

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