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REVIEW ARTICLE

Effect of fibre-reinforced composite as a post-obturation restorative material on fracture resistance of endodontically treated teeth: A systematic review

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KEYWORDS

Endodontically treated teeth;
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Ever X Posterior;
Glass fibres

Abstract *Background:* Fracture resistance of endodontically treated tooth is affected due to large cavity designs and access cavities and an appropriate material capable to resist fracture plays an important role. This review aims to evaluate the effect of fibre-reinforced composite (FRC) as a post-obturation material on fracture resistance of endodontically treated teeth.

Objectives: To systematically gather and evaluate the fracture resistance of fibre-reinforced composite as a post-obturation restorative material in endodontically treated teeth.

Data Sources: A systematic search was conducted using PubMed, Ebsco Host, Scopus, Google Scholar, Hinari and manual search library resources from 1st Jan 2000 to 30th November 2019 to identify appropriate studies.

Result: A total of 157 articles were examined out of which 55 articles were selected after reading the title. After removing the duplicates, 27 articles were screened for abstract and 1 article was eliminated as it did not meet the eligibility criteria. A thorough reading of the full text of the remaining 26 selected articles was assessed for eligibility. Amongst these, 1 article was then excluded from the study as the full text was not accessible. Lastly, 25 articles were included in the study.

Conclusion: FRC as a core material increases fracture resistance of endodontically treated teeth but they do not have the fracture resistance similar to the intact tooth. Both polyethylene and short fibre-reinforced composites showed greater fracture resistance when compared to glass FRC and

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restoration without reinforcement. Also, the fracture resistance increases if restored with FRC along with retention slots and are placed on the occlusal third surfaces of cavities. Also, favourable fractures were most commonly seen and it usually occurred at the level of enamel and dentin and adhesive fractures were seen.

Contents

1. Introduction

Root canal treatment leads to a substantial lowering of the tooth's strength (Ozsevik et al., 2015). The tooth then has to receive a post-endodontic restoration to bolster its strength. The post-endodontic restoration is done in two phases. Internally with a core and externally with a full coverage/ partial coverage laboratory-generated restoration. This systematic review was done to evaluate the various in vitro studies that have been undertaken to evaluate the increase/decrease in the strength of an endodontically treated tooth.

Teeth are subjected to occlusal loading due to natural functions of the oral cavity such as chewing, biting and certain parafunctional habits (Ozsevik et al., 2015). So, to avoid tooth fractures, it is necessary to provide them with adequate and appropriate restorative material post endodontic treatment (Garlapati et al., 2017). Core build-up for root canal treated teeth can be done using amalgam, composite, inlays, crowns and cast restorations (Ozsevik et al., 2015). But recent techniques involve the use of composites reinforced with different fibres.

Fibres have the property of modifying the stress by creating a monoblock effect. This in turn helps to dissipate the stress along the long axis of the tooth (Ayna et al., 2009). They also can prevent crack formation which is due to the distribution of stress from the polymer matrix to the fibres (Garoushi et al., 2007a,b). Fibres such as polyethylene fibres, glass fibres and short fibre-reinforced composites have been used as core materials. Composites reinforced with polyethylene fibres help to change the stress pattern and distribute and transfer the stresses (Tekçe et al., 2016). Glass fibres have a reinforcing capacity and provide adequate aesthetics (Tekçe et al., 2016). EverX posterior is a new material having multidirectional and discontinuous fibres which help to increase the load-bearing capacity, act as a dentin substitute, prevent the crack formation and increase its strength (Vallittu, 2015; Tekçe et al., 2016).

Various studies have been done to evaluate the fracture resistance of fibre-reinforced composites (FRCs) as core material. Some studies suggest they increase the fracture resistance (Shivanna and Gopeshetti, 2013; Rahman et al., 2015) whereas some suggest there is no difference in fracture resistance (Cobankara et al., 2008; Rodrigues et al., 2010; Luthria et al., 2012). These conflicting results may be attributed to the different characteristics of FRCs. Thus, considering the available literature, the main aim of the systematic review was to evaluate the effect of FRCs as core material on fracture resistance of endodontically treated teeth.

2. Materials and method

2.1. Eligibility criteria

2.1.1. Inclusion criteria

(1) Articles in the English language or those having a summary in English.
(2) Studies published in 1st Jan 2000 to 30th Nov 2019.
(3) In vitro studies done in human extracted teeth.

(4) Studies evaluating the fracture resistance of fibre-reinforced composite on endodontically treated tooth.

2.1.2. Exclusion criteria

(1) Review, Abstract, Case reports, Letter to editorials and in vivo studies were excluded.
(2) Any studies are done before 1st Jan 2000.

2.1.3. The PICOS guidelines that were selected are:

P (PRODUCT) – Endodontically treated tooth
I (INTERVENTION) – Fibre-reinforced composite as a post-obturation restorative material
O (OUTCOME) - Fracture resistance

2.2. Information sources

Five internet sources of evidence were used in the search of appropriate papers satisfying the study purpose: The National Library of Medicine (MEDLINE PubMed), EBSCO host, SCOPUS, Hinari and Google Scholar. All cross-reference lists of the selected studies were screened for additional papers that could meet the eligibility criteria of the study.

2.3. Search

The following databases were searched using keywords in several combinations.

2.4. Study selection process

In vitro studies were selected. However, only articles where fibre-reinforced composite was used as a core material for endodontically treated tooth, which was assessed for fracture resistance using a universal testing machine were included.

3. Results

Total 143 articles were identified through the database search and 14 articles were identified through other sources. Total records obtained were 157. These articles were then screened for titles. After a thorough reading of titles, 102 articles were excluded as they did not match the motive of the study. The remaining 55 articles were further assessed for any duplicates and 28 articles were removed. These 27 articles were screened for abstracts and 1 article was excluded after screening abstracts as this article did not meet the eligibility criteria of the study. A fibre-reinforced composite as core material was not used in this study. A thorough reading of the full text of the remaining 26 selected articles was assessed for eligibility.

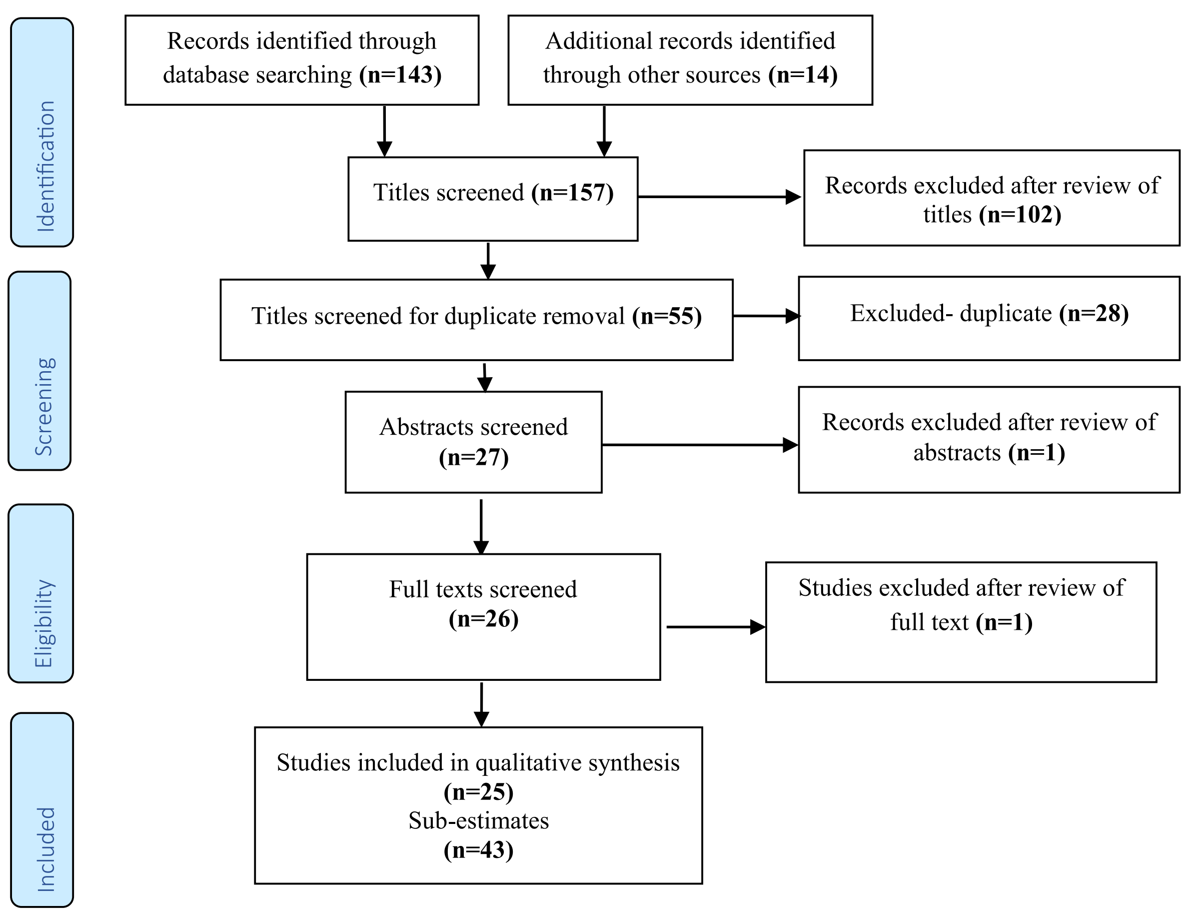

Fig. 1 PRISMA Flow chart of search results and study selection.

Amongst these, 1 article was then excluded from the study, due to eligibility criteria, the full text was not accessible. Finally, 25 articles were included in the study. Fig. 1 demonstrates the flow diagram of search results and study selection according to PRISMA recommendations.

4. Discussion

Restoration of a non-vital tooth post endodontic treatment requires the need to understand the reduced elasticity of the tooth and morphology of the lost tooth structure and should be addressed when selecting material for a restoration of the tooth. Using composites that are reinforced with micro inserts by the manufacturer or macro inserts by the clinicians is a wise way to go about thereby avoiding cuspal and vertical fractures which are undesired sequelae of root canal treatment. Remaining dental tissue is an important factor as disturbed marginal integrity or large cavities affect the fracture resistance.

This systematic review was undertaken to verify the hypothesis that the use of fibre-reinforced composite when used alone as a core material or in combination with a composite layer above it would increase the fracture resistance of endodontically treated teeth.

Belli et al. (2005) evaluated the fracture resistance of root canal treated teeth when restored with and without fibre-reinforced composite. They compared unrestored teeth, restored with composite resin, with flowable composite and polyethylene fibres placed in a buccolingual direction. The researchers concluded that when the polyethylene fibres were used in endodontically treated teeth having mesio-occlusal-distal (MOD) cavities increased the fracture resistance significantly.

Belli et al. (2006) evaluated the effect of two different fibre placement techniques on fracture resistance of endodontically treated molars. In this study, polyethylene woven fibre was placed on the occlusal third in the buccolingual direction and the bed of the resin. They concluded that fibre was placed on the occlusal surface increased the fracture resistance. Also, when fracture mode was evaluated, cohesive fracture on composite and flowable composite was observed when fibre was placed on the occlusal surface whereas cohesive fracture inside the fibre-flowable composite was observed when placed into the bed of the resin.

Sengun et al. (2008) also investigated the effect of composite reinforced with fibre on fracture resistance of endodontically treated premolars. They evaluated unrestored teeth, restored with composite restoration and with polyethylene fibres placed on the occlusal surface in the buccolingual direction. They concluded composite reinforced with fibres did not show any difference in fracture resistance. However, reinforced teeth showed enamel fracture whereas other groups showed dentin fracture.

Cobankara et al. (2008) studied the fracture resistance of endodontically treated mandibular molars with different restoration techniques such as restoration with amalgam, composite resin, hybrid incremental ceramic inlay material and polyethylene fibres in a buccolingual direction. They concluded that all the restoration groups were stronger than the unrestored group but could not restore the fracture resistance lost from MOD cavity preparation. Also, while evaluating the fracture mode, the FRC group showed restoration fractures involving a portion of the tooth.

Oskoee et al. (2009) evaluated the effect on fracture resistance of endodontically treated maxillary premolars by different fibre insertion placements such as no fibre, fibres placed in the gingival, middle and occlusal third of the tooth followed by composite resin. They concluded that the best fibre position is close to the force exertion point which provides higher fracture resistance. This was similar to the study by Singh et al (2013) stating that fibre placed on the occlusal surface increased the fracture resistance. Similarly, a study by Rahman et al. (2015) stated that the dual fibre technique (occlusal and base group) showed the highest fracture resistance. On contrary, a study by Ozsevik et al. (2015) evaluated the placement of polyethylene fibres and EverX Posterior at the base and stated that using Ever X posterior under composite restorations resulted in fracture resistance similar to that of intact teeth.

Rodrigues et al. (2010) evaluated the effect of unidirectional or woven glass fibre on the fracture resistance of endodontically treated molars. They concluded that the use of woven or unidirectional glass fibres did not increase the fracture resistance as the cuspal strength depends on the adhesive system and composite resin and not on glass fibre.

Some studies carried out later by Rocca et al. (2015) which evaluated EverX Posterior, E-glass fibres and bidirectional fibres and Atalay et al. (2016) which evaluated EverX Posterior, both of which stated that it did not increase the fracture resistance which was like the study conducted by Rodrigues et al. (2010). Also, the study by Göktürk et al. (2018) evaluated teeth restored with Interlig Angelus placed in a buccolingual direction stating that different restoration methods did not influence the fracture resistance.

Moezizadeh and Shokripour (2011) studied the effect of fibre and its placement on the fracture resistance of endodontically treated premolars by evaluating unrestored teeth, restored with Filtek Z250, restored with a piece of fibre i.e. Angelus in a U-shape pattern and restored with fibres placed in a cross-shape pattern. They stated that buccopalatal and mesiodistal placement of fibres in the occlusal area increased fracture resistance and provided more restorable fractures.

Luthria et al. (2012) evaluated the fracture resistance of endodontically treated maxillary premolars with wide MOD cavities restored with either composite resin or composite resin reinforced with different types of fibres such as impregnated glass fibre and polyethylene fibre. The researchers concluded that the fracture resistance of the composite impregnated glass fibre reinforced group was much higher.

Shivanna and Gopeshetti (2013) evaluated the effect on fracture resistance of endodontically treated maxillary premolars when not treated, left unrestored, restored with composite and restored with polyethylene fibres in buccolingual direction. The researchers concluded that fibre-reinforced composite improved the fracture resistance of the teeth compared to other groups. Also, it prevented unfavourable fracture of root canal treated teeth under occlusal loading.

Yasa et al. (2016) evaluated the effect of different composites with and without retention slots on fracture resistance of root canal treated mandibular molars. Also, they were left unrestored, restored with nano-hybrid composite, bulk-fill flowable and short FRC (Ever X Posterior). They concluded that retentive slots significantly increased the fracture resistance. Also, short FRC with retentive slot cavities had significantly higher fracture resistance.

Tekçe et al. (2016) investigated the effect of direct or indirect polymerisation of ribbon fibre on fracture resistance and compared polyethylene ribbon fibre with SFRC and its effectiveness. The researchers concluded that direct or indirect polymerization did not change the fracture strength. Also, polyethylene fibre-reinforced groups and SFRC showed similar fracture strength and different Ribbond-reinforced composites showed similar fracture resistance.

Scotti et al. (2016) evaluated the effect of composite reinforced with fibres on fracture resistance of root-filled mandibular first molars when teeth were unrestored, restored with flowable and packable composite, with fibre post supported direct composite, with pre-impregnated fibres in mesiodistal direction and with fibres placed Bucco-palatally. They concluded that FRC i.e. Ever X Posterior increased the fracture resistance and partially deviated the fracture pattern.

Forster et al. (2016) evaluated the fracture resistance of endodontically treated teeth restored with a direct layered FRC post and core. They evaluated teeth restored with FRC post, with direct layered short fibre-reinforced composite (SFRC) post and core, with SFRC in an oblique direction, with micro-hybrid composite, with FRC box using Everstick in buccolingual and mesiodistal direction. They concluded that natural teeth showed higher fracture resistance and FRC posts exhibited more favourable fracture patterns and are a promising alternative.

Garlapati et al. (2017) tested the effect of SFRC on fracture resistance of root canal when used as a core material where teeth were left unrestored, restored with hybrid composite, with polyethylene fibres in buccolingual direction and with Ever X Posterior. The results showed that Ever X posterior showed superior fracture resistance showing adhesive failure but all samples showed favourable fractures coronal to the cementoenamel junction (CEJ).

Eapen et al. (2017) evaluated the effect of different conventional and FRC on fracture resistance of endodontically treated premolars when restored with dual-cure composite, with posterior composite, with glass fibres pre-impregnated composite (Interlig Angelus), with SFRC (Ever X Posterior). It was seen that SFRC significantly increased the fracture resistance and showed a fracture at the enamel level whereas glass FRC showed fractures at the level of enamel and dentin.

Kumar and Sarthaj (2018) evaluated fracture resistance of endodontically treated mandibular premolars when left unrestored, restored with condensable bulk-fill composite, with flowable bulk-fill, with FRC (Ever X Posterior) and with conventional composite. They concluded that fracture resistance of teeth with fibre-reinforced bulk-fill composite was the highest and showed mode II fracture i.e. fracture of one cusp with intact restoration.

Dalkılıç et al. (2019) investigated whether composite reinforced with fibres had any effect on the fracture strength of endodontically treated premolars. In this study, teeth were subjected to thermomechanical ageing and were restored with bulk-fill composite, with RIBBOND embedded in composite, with two pieces of RIBBOND placed buccolingually. They concluded that fibre insertion did not increase the fracture strength but it increased the favourable fracture modes. Also, thermomechanical ageing did not have any additional effect on fracture resistance.

Fráter et al. (2020) evaluated the fracture behaviour of root canal treated premolars restored with different fibre-reinforced post-core composites (FRCs). In this study, the teeth were restored with prefabricated unidirectional FRC-post with G-Aenial posterior, prefabricated unidirectional FRC-post with SFRC (Everstick Posterior), unidirectional FRC-post with conventional composite core, SFRC 1 mm below the occlusal cavity with composite, uncured post (Everstick post) on the buccal and lingual walls with SFRC and conventional composite. They concluded that restoration of endodontically treated premolars with the use of SFRC showed better results in a matter of micro gap and load-bearing capacity.

Basaran and Gokce (2019) evaluated fracture resistance of endodontically treated teeth with different cavity wall thicknesses such as 2 mm, 1.5 mm and 1 mm and restored with direct composite, with polyethylene fibre i.e. RIBBOND in buccolingual direction, with fibre placed on the occlusal level, with fibre post and composite, with inlay, with fibre on cavity floor and inlay, with inlay and fibre on the occlusal level. They concluded that when the wall thickness was 1.5 mm and restored with FRC on the occlusal level increased the fracture resistance.

According to the studies, fracture resistance of various fibres was evaluated which showed that it does not reinforce the fracture resistance as that of the intact tooth but it is superior when compared to other restorations. Both polyethylene and short FRC showed greater fracture resistance. But the least fracture resistance was seen when reinforced with glass fibres and no effect was seen when teeth were restored unidirectional or bidirectional FRC.

Fracture patterns were evaluated by determining favourable and unfavourable fracture modes. Fractures 1 mm coronal to the CEJ are easily restored by restorative techniques so they are considered favourable. However, fractures deeper than this are unfavourable because they cannot be easily restored and might need further therapeutic interventions such as crown lengthening and orthodontic forced eruption, and in some cases, the tooth might even be a candidate for extraction (Bahari et al., 2019).

A study by Oskoee et al. (2009) suggested that the majority of fractures were found to be unfavourable. However, Fennis et al. (2005) showed that in cusp-covering and cusp-replacing procedures, composite with glass fibre had a better effect on the failure mode. Garlapati et al. (2017) categorized failure modes into Cohesive, Adhesive & Mixed Failure Modes. Short fibre composite substructure has the function to support the surface particulate filler composite layer and prevent crack propagation by dispersing the stresses. The transfer of stresses from the polymer matrix to the fibres is vital for the optimal reinforcement of the polymers which is a function of the critical fibre length.

It was seen that the E-glass has a fibre length between 0.5 and 1.6 mm and short fibres in Ever X posterior have length equal to or greater than this which enables uniform stress distribution. The failure of these samples was adhesive showing tooth restoration interface as the weakest phase. Regarding the fracture patterns, the studies by Oskoee et al. (2009) classified fractures as favourable or unfavourable, considering the CEJ as the limit for being restorable. The results showed that teeth restored with fibreglass tape on the occlusal surface show a high percentage of fractures where more than half tooth is fractured but allows restoration, which is similar to the study by Piccioli (2019). One reason for more favourable fractures in groups reinforced with fibres was adequate cuspal coverage with composite resin during the placement of fibres in the occlusal area (Bahari et al., 2019).

Piccioli (2019) evaluated the fracture resistance and pattern of root canal treated premolars restored with FRC. The fracture pattern was classified as Type I: isolated fracture of the restoration. Type II: Restoration fracture involving a small portion of the tooth. Type III: fracture of the restoration involving more than half of the tooth, without periodontal involvement. Type IV: fracture of the restoration involving more than half of the tooth, with periodontal involvement.

Fracture type of non-endodontically treated teeth restored with composites was evaluated according to the following criteria: Cohesive fractures, Adhesive fractures and Mixed fractures (Patnana et al.,2020).

A study by Patnana et al. (2020) on fracture type in glass FRC showed more mixed fractures, but the percentage of adhesive fractures increased when compared with particulate filler composites. These findings are contrary to Garoushi et al. (2007a,b) who observed that glass FRC showed cohesive fractures within the tooth structure which is due to the variation in fibre type and load applied.

The polyethylene FRC showed a maximum of cohesive fractures for incisal and mesioincisal restorations, which states that it increases fracture resistance of tooth and restoration (Patnana et al.,2020). However, the percentage of cohesive fractures within the tooth structure increased in the mesioincisal restoration group (Goguţă et al., 2012).

Ilday and Seven (2011) suggested that fibres used in areas of high stress, such as the tooth restorative material interface, play an internal stapling role that prevents fractures from arising and spreading by successfully distributing stresses. Fibres may therefore be recommended to clinicians as an alternative solution for bonding failures.

Endodontic treatment and extensive restorative procedures combined with high occlusal loads and lateral excursive contacts lead to higher susceptibility to fracture (Sakaguchi et al., 1991). It has been reported that the magnitude and duration of the load, tooth type and cuspal inclines is important in fracture resistance (Pantvisai and Messer, 1995). Depending on the tooth type, endodontically treated maxillary premolars are considered especially at risk of fracture (Robbins et al., 2006). Garlapati et al. (2017) used mandibular molars because they have a high incidence of developing dental caries that necessitate restorative intervention and are subjected to heavy occlusal forces and more prone to fracture.

Garoushi et al. (2018) reviewed the literature on SFRC and concluded that they exhibit unique fibre and polymer variety in their composition having enhanced mechanical and physical properties. Also, the biomimetic restorative technique, using SFRC as a substructure with particulate filler composite (PFC) overlying it, is recommended and can be used for the coronal restorations with large cavities in high stress-bearing areas.

5. Limitations

The limitations of this review are that amongst the various research studies selected, there was a lack in the standardization of evaluation procedures. There is not enough documented literature regarding the evaluation of different fibre-reinforced composites as core material on fracture resistance of endodontically treated teeth. The scoring criteria were different in the studies.

6. Conclusion

Within the limitations of this study, the following conclusions can be drawn:

FRC as a core material increases fracture resistance of endodontically treated teeth but they do not have the fracture resistance similar to the intact tooth. Both polyethylene and SFRC showed greater fracture resistance when compared to glass FRC and restoration without reinforcement. Other factors increasing the fracture resistance are teeth restored with retention slots, placing fibres closer to the high occlusal load bearing points i.e. occlusal third surfaces. Another observation from the literature is favourable fractures were most commonly seen with fracture pattern usually occurring at the level of enamel and dentin and adhesive fractures were seen. Although it is difficult to draw a concrete conclusion from the articles selected as they cannot be compared directly due to the diversity of the eligibility criteria, assessment methods and outcomes, an honest attempt has been made to get a conclusion towards a clinical recommendation.

Ethical Statement

Ethical approval to carry out this review was obtained from Ethics Committee of Dr. D. Y. Patil Vidyapeeth, Pune.

CRediT authorship contribution statement

Eshani H. Shah: Writing-original draft, Data curation. **Pradeep Shetty:** Data curation, Writing - review & editing, Visualization, Supervision. **Shalini Aggarwal:** Data curation, Writing - review & editing, Visualization, Supervision. **Sanket Sawant:** Conceptualization, Methodology. **Ronit Shinde:** Project administration. **Reetubrita Bhol:** Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sdentj.2021.07.006.

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