Assessment of Need of Prosthodontic Rehabilitation of Endodontically Treated Teeth in Patients Attending a Tertiary Care Center in Nepal

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ABSTRACT

Introduction: Endodontically treated teeth (ETT) are structurally weaker than vital teeth. Therefore, post endodontic restorations are needed to enhance structural integrity, to restore from, function and aesthetics, to prevent bacterial microleakage, to ensure periodontal health and to protect residual tooth structure from fracture, wear or abrasion. The type of post endodontic restoration chosen depends greatly on the amount of remaining tooth structure. The best current approach for restoring the root treated teeth (RTT) should be minimal tissue sacrifice, protection of remaining dentin especially the peri cervical dentine (PCD) and choice of best post endodontic restoration according to the amount of tooth structure loss.

Objectives: This study aimed to assess and determine the need and type of different types of prosthodontic rehabilitation or restoration of different endodontically treated teeth in patients attending TUTH, Nepal. We also aimed to investigate the need of different treatment options on the basis of remaining dentinal thickness (RDT) to recommend the various types of post endodontic restoration to the patients.

Materials and Methods: 360 patients (n =360) that underwent root canal treatment (RCT) in the Department of Dental Clinical Sciences I (Conservative Dentistry and Endodontics) were evaluated for RDT, Possibility of Chamber Retention, number of remaining walls and number of roots. Radiovisograph (RVGs), clinical pictures and impression were taken and casts were fabricated to determine the RDT, PCD, occlusion, tooth type and the type of force exerted on it. A group of 5 experts (2 endodontists and 3 prosthodontists) evaluated the case and the rehabilitation options were recommended.

Results: Out of 360 patients, 51.3% were male and 49.7% were female. The most frequently treated tooth was three rooted molars (35.8%) followed by two rooted molars (34.7%) followed by mandibular premolars (8.6%).8.3% of the patient were found to have compromised PCD. The condition of chamber retetion of the majority of the teeth (90.6%) that were treated and included in this study was adequate .Composite and reinforeced compsoite resin restoration were planned in 5.8% and 9.7% of the cases. Veneers, endocrwons, inlay and onlay were indicated in 2.8%, 3.9%, 8.9% and 21.9% of cases respectively. Similarly, Fiber post core crown, cast post core crown and full coverage crown were indicated in 2.8%, 7.2% and 36.9% respectively.

Conflict of Interest: None

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Conclusions: This study focus on the preservation of maximum amount of tooth structure and evaluation of remaining tooth structure for deciding post endodontic restoration and recommendation has been formulated on the basis of same.

Key words: Crown, Endodontic Treatment, Pericervical Dentine (PCD), Post and Core, Post Endodontic Restoration, Remaining Dentinal Thickness (RDT), Root Canal.

INTRODUCTION

A favorable outcome of endodontically treated teeth depends on adequate restorative treatment with proper coronal seal performed afterwards .[1] Although, well filled root canals provide a good seal, we still need a coronal restoration with well fitted margins to prevent bacterial penetration, percolation of fluids or both. Literature suggests a successful endodontic treatment outcome even in poorly filled root canals if the quality of the coronal restoration is favorable.[2] Moreover; endodontically treated teeth are structurally weaker than vital teeth. This loss of structural integrity is associated with the caries, existing restorations, access cavity preparation, loss of protective feedback mechanism, interaction of sodium hypochlorite with root dentin during root canal irrigation and loss of pericervical dentin (PCD) due to excessive coronal flaring.[3-5] Root filled teeth are thus more prone to fracture, with multifactorial etiology but dehydration of dentin in root filled teeth is not the cause anymore.[2,3] Therefore, post endodontic restorations are needed to enhance structural integrity, to restore form, function and aesthetics, to prevent bacterial microleakage, to ensure periodontal health and to protect residual tooth structure from fracture, wear or abrasion.[6,2]

Preservation of maximum amount of tooth structure and good final post endodontic restoration is mandatory for favorable outcome in root treated teeth (RTT). As root treated teeth often lose substantial amount of tooth structure, preparation of tooth for full coverage would further reduce the bulk of tooth structure and loss of sound dentin. Ironically, crown and post and core are still advocated in most of the root treated posterior teeth to strengthen it. However, root treated teeth might be restored with a wide range of treatment options of varying complexities. Most of the time, the posterior teeth don't even need post and core to retain a crown. Moreover, post and core do not strengthen the teeth but due to misconception of use of post to strengthen the teeth, it has been used widely in anterior as well as posterior teeth. Thus, the type of post endodontic restoration chosen depends greatly on the amount of remaining tooth structure and post, core and full crown might be indicated only in cases of severely broken, weakened or previously prepared teeth. Overlay, endocrown, inlay and adhesive restorations with/without reinforced ribbon fibers, are chosen in cases of teeth with adequate remaining dentin with no previously prepared tooth structure.[7] Hence, the best current approach for restoring the root treated teeth should be minimal tissue sacrifice, protection of remaining dentin especially the PCD and choice of best post endodontic restoration according to the amount of tooth structure loss.

This study assessed the need of prosthodontic rehabilitation of different root filled teeth and also impart significant knowledge for proper treatment option selection for the particular case.

MATERIALS AND METHODS

Proposal registration and sample size calculation. This is a quantitative observational, descriptive cross-sectional study that was performed on 360 patients (n=360) that underwent root

canal therapy in the Department of Dental Clinical Sciences I (Conservative Dentistry and Endodontics) Tribhuvan University Teaching Hospital (TUTH). Sample size was calculated based on sample size calculation for finite population using formula: $n=N/(1+Ne^2)$. Here, n= Sample size, N= population size (Average number of patients requiring root canal treatment in the Department of Dental Clinical Sciences I, TUTH as calculated from the register for the last six months= 3600); e= margin of error (0.05). Thus, the minimum sample size = 360 was included in the study.

Inclusion and exclusion criteria. The patients who underwent root canal treatment at Conservative Dentistry and Endodontics by endodontists only, were included in the study. Teeth with previous preparation, crowns, post core, onlay, inlay or any other prosthesis that needs endodontic treatment or retreatment, teeth with fracture or incomplete root formation, poor periodontal health are excluded from the study.

Data acquisition. Consent of the patients undergoing RCT at Conservative Dentistry and Endodontics, were taken. After competition of the treatment, 2 radiovisograph (RVGs) were taken from distal and mesial angulation to assess the quality of root canal filling, remaining dentinal thickness (RDT) and the status of the periapical tissues. Before restoring the access cavity with permanent filling material, alginate impression was taken to fabricate the study cast. This cast was studied for the remaining tooth structure (RDT), occlusion and the type of force exerted on it. The access cavity was then restored with resin modified glass ionomer cement (RMGIC) as an intermediate restoration. The cast and the radiographs were then assessed by the 3 prosthodontists and two endodontists to evaluate the need and type of restorative/prosthetic treatment for that particular case. After making preliminary treatment plan, the patients were recalled for the clinical evaluation and final restorative/ prosthetic treatment plan. The rehabilitation option was discussed and made on the basis of the remaining tooth structure (walls), possibility of chamber retention, pericervical dentine, and anatomy of the tooth and the longevity of the treatment. The planned treatment was based on the recommendation formulated for choosing post endodontic rehabilitations by the group of experts (Table 1).

Statistical Analysis

Performa sheets were filled with data collected from study participants. Variables such as age, gender, tooth number, number of walls present, possibility of chamber retention, no of roots, amount of PCD were taken into consideration while data was being entered in the sheet. Finally, the prosthetic rehabilitation option or restorative treatments planned in conciseness of 5 specialists (2 endodontists and 3 prosthodontists) and entered in the Performa sheet. If there were more than one opinion then the treatment options with majority was chosen. However, if there were multiple treatment options, that case was reevaluated and discussed until similar treatment plan was formulated. Then the data was entered in excel sheet and coded. SPSS (Statistical Package for Social Sciences) software version 20 was used to analyze the data. Descriptive statistics was used to assess mean, median, standard deviation (SD), frequency and percentage depending upon the nature of data. The need of prosthetic or restorative rehabilitation was assessed according to the tooth type; number of the root present, the amount of remaining tooth structure, pericervical dentine, possibility of chamber retention and the result will be formulated.

RESULTS

Out of 360 patients whose root canal treatment was performed at Department of Dental

Clinical Sciences I, Conservative Dentistry and Endodontics, IOM,TUTH 51.3% were male and 49.7% were female (Figure 1). The details of the teeth that needed root canal treatment are shown in the Table 2. The number of wall absent/present was evaluated in each tooth that underwent root canal treatment (Figure 2). The number of roots, amount of remaining pericervical dentine and the possibility of chamber retention to receive core filling after root canal treatment was then evaluated (Figure 4, 5 and 3 respectively). After assessing all these variables, 5 experts (2 endodontists and 3 prosthodontits) evaluated the data and according to the recommendations formulated beforehand (Table 1) the post endodontic restoration/ prosthetic rehabilitations options were planned and recommended to the patients (Figure 6).

Table 1: Recommendation for Choosing Post Endodontic Rehabilitations

Clinical Scenario	Upper Incisors/ Lower incisors	Canine	Upper premolars	Lower Premolars	1st and 2nd Molars	3rd Molars
1.If all walls are present, Chamber retention possible, PCD is not compromised and cusp/crown height not compromised and Optimal access cavity is present.	Composite restoration (CR)	Composite Restoration (CR)	Reinforced CR (RCR)	RCR	Inlay or RCR	RCR/ CR
2. If all walls are present, Chamber retention possible, PCD not compromised and cusp/crown height not compromised and optimal access cavity is present but tooth is:						
1.1 An abutment for FPD	Crown	Crown	Crown	Crown	Crown	Crown
1.2 Cracked tooth	Crown	Crown	Crown	Crown	Crown	Crown
Needs full mouth rehabilitation	Crown/onlay	Crown / onlay	Crown/onlay	Crown/ onlay	Crown/onlay	Crown/onlay
1.3 Severely discolored and bleaching is not effective	Veneer/ Crown	Veneer/ Crown	Crown	Crown	Crown	N/A
1.4 Disfigured (peg shaped 1.5 laterals/ Mulberry molars)	Veneers/ Crown	Veneers/ Crown	Onlay crown	Onlay / Crown	Onlay/ Crown	Onlay/Crown
1.6 Minor mal-alignment like 1.7 single rotation, buccoversion or lingoversion	Crown	Crown	Crown	Crown	Crown	N/A
1.8 Needs diaestema Closure/ 1.9 space closure	Veneers/ Crown	Veneers/ Crown	Crown	Crown	Crown	crown
1.10 Supraerupted and lower arch 1.11 needs replacement	Incisal Lapping veneers/ Crown	Incisal Lapping veneers / crown	Crown	Crown	Crown	Crown

1.12 Severe hypoplasia/ 1.13 hypocalcification of enamel, or dentine)	Crown	Crown	Crown	Crown	Crown	Crown
1.14 Chronic bruxers or clenchers	Crown	Crown	Crown	Crown	Crown	Crown (if in occlusion)
3. If all walls are present, Chamber retention possible, PCD not compromised and crown height not compromised and optimal access cavity is present but cusp undermined due to large carious lesion	RCR	RCR	Onlay	Onlay	Onlay	RCR
4. If 1 wall is missing, and the margin is supragingival with sufficient PCD and chamber retention	FRC	FRC	Crown	Crown	Onlay	FRC
5. If 1 wall is missing, but the margin is subgingival with sufficient PCD and chamber retention	FRC/ Crown	FRC/ Crown	Crown	Crown	Crown	Crown
6. If 2 walls are present, Chamber retention possible and PCD not compromised	Reinforced Composite restoration	RCR/ crown	crown	crown	Crown	Crown
7. If only 1 wall is present with compromised chamber retention and supragingival margin with sufficient PCD	Fiber-post andcore (FPCC)	FPCC	FPCC	FPCC	FPCC	N/A
8. If 1 or 2 or 3 walls present but chamber retention not possible in case of both palatal/buccal/ lingual cusp fracture, subgingival margin, chamber retention and PCD compromised	CPCC	CPCC	CPCC	CPCC	CPCC	N/A
9. If only 1 wall is present with compromised chamber retention, PCD and subgingival margin	Cast post and core and crown (CPCR)	CPCC	CPCC	CPCC	CPCC	N/A
10. If no walls are present with no chamber retention but PCD is not compromised	CPCC	CPCC	CPCC	CPCC	CPCC	N/A
11.Deep cervical caries with compromised PCD but chamber retention possible	Crown	Crown	Crown	Crown	Crown	Cervical caries: resin modified GIC or GIC or amalgam restoration

12. Deep cervical caries with compromised PCD and chamber retention not possible	CPCC	CPCC	CPCC	CPCC	CPCC	N/A
13. All or 3 or 2 walls present with sufficient chamber retention and PCD but the clinical crown height compromised and retention of the crown is a problem	CR/RCR	CR/RCR	Endocrown	Endocrown	Endocrown	Endocrown (recommended only if we need this tooth on occlusion and functional)
14. If all wall or 3 or 2 walls present, sufficient PCD and possible chamber retention but periodontally compromised with mobility.	CR/RCR	CR/RCR	CR/RCR	CR/RCR	CR/RCR	CR/RCR
15. If non caries lesions like severe attrition, abrasion, erosion or abfraction present with sufficient chamber retention and PCD	Crown	Crown	Crown	Crown	Crown	RMGIC or Microfilled composite
16. Complicated crown or crown root fractured resulting in loss of all walls or 3 walls or 2 walls with compromised chamber Retention and sufficient PCD.	CPCC/ FPCC	CPCC/ FPCC	CPCC/ FPCC	CPCC/ FPCC	CPCC/ FPCC	N/A

Table 2: Involvement of tooth considered for prosthetic rehabilitation.

Tooth involved	No. of participants	Percentage
Upper incisors	27	7.5
Lower incisors	30	8.3
Canine	18	5.0
Upper premolar	28	7.8
Lower premolar	31	8.6
First / second Molar	219	60.8
Third molar	7	1.9
Total	360	100.0

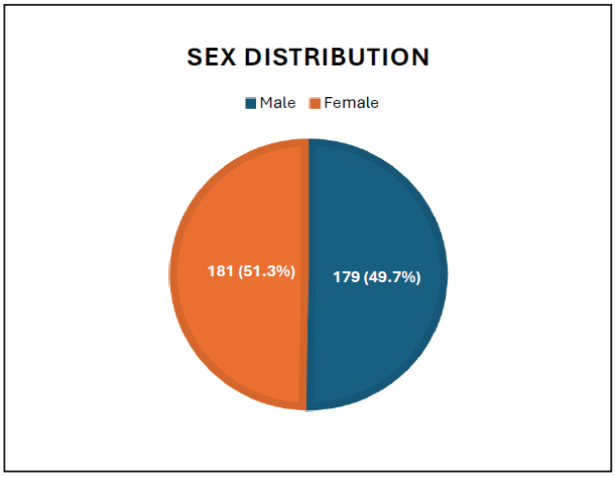

Figure 1: *Sex distribution of study participants*

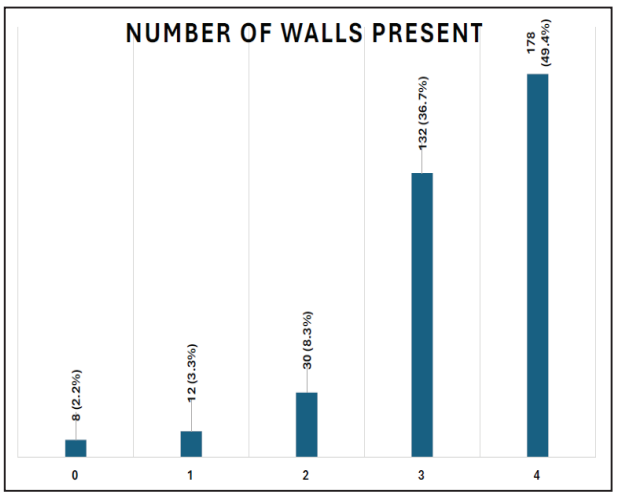

Figure 2: Number of walls absent on involved tooth.

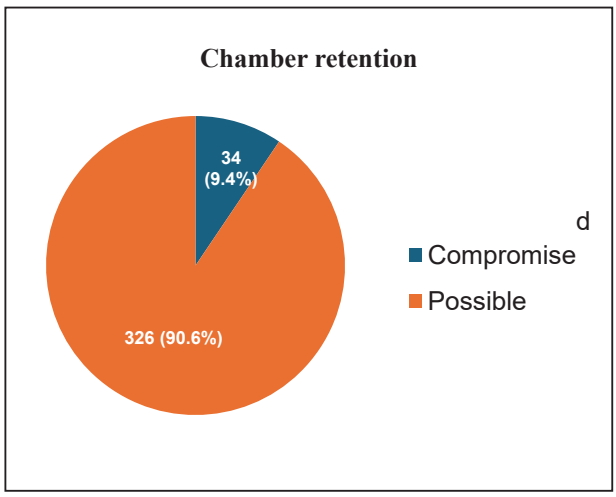

Figure 3: Condition of chamber retention after completion of root canal treatment

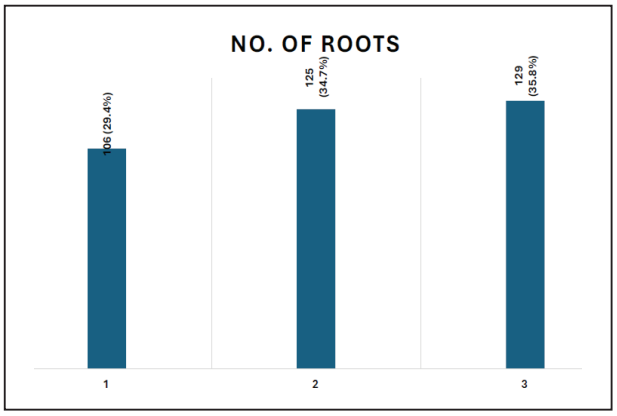

Figure 4: Number of roots present in the involved tooth.

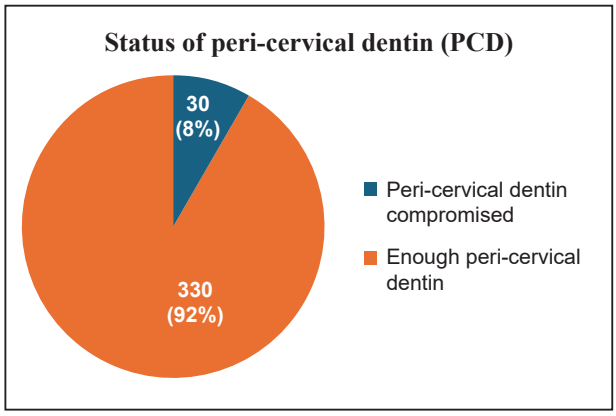

Figure 5: Status of Pericervical Dentine (PCD) of the involved tooth

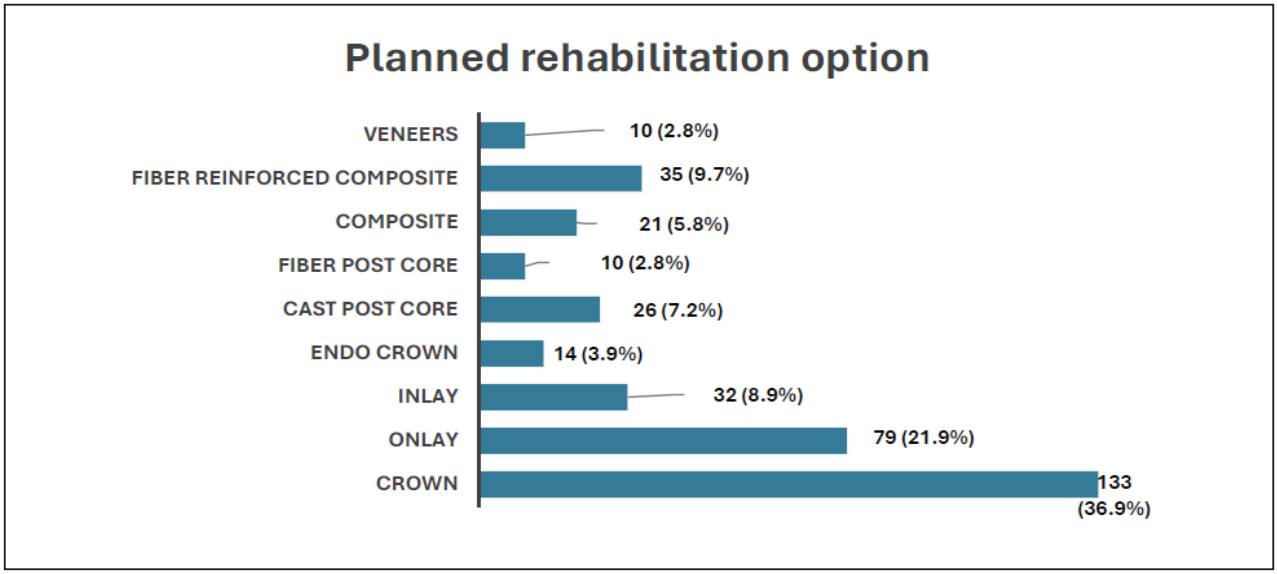

Figure 6: Recommendation post endodontic/ prosthetic rehabilitation option planned

DISCUSSION

The restoration or prosthetic rehabilitation of root treated teeth comprises of difficult decision-making process without clear guidelines or criteria in literature. When the single tooth undergoes root canal treatment we need to assess and apply various requirements before deciding the definitive restorative treatment. Moreover, when multiple teeth are treated as abutment teeth for prosthetic restorations, the treatment options might be different. Hence, this study was conducted to compile the important aspects, recommendations and clinical scenario for the restoration and prosthetic rehabilitation of endodontically treated teeth.

To avoid coronal leakage, reinfection of root canals and fractures under functional load resulting in mechanical failures, endodontically treated teeth should be restored as soon as possible in manner that can recreate function, aesthetics and harmony with adjacent soft and hard tissue[8-11]. In this study we have categorized the endodntically treated teeth on the basis of missing tooth structure and tooth type. This is in accordance with the study done by Kolpin et al[12] where they have classified the root treated teeth in five types according to tooth types and size of defect / missing walls. The cavity wall with remaining dentinal thickness less than 1mm is considered as missing walls as mechanical failures are most likely to occur in such scenarios[13].

Class I: Access cavity with 4 intact walls can be restored with hybrid composite resin

Class II: Access cavity with 3 remaining walls can also be restored with adhesive restoration

Class III: Access cavity with two remaining walls can be restored with adhesive restoration (direct or indirect)

Class IV: Access cavity with one remaining wall needs supporting retention for core either by fiber or cast post and core build up with crown. For anterior teeth, direct composite core build up is an option and crown can be indicated for aesthetic reasons.

Class V: Acess with 4 missing walls/decoronated tooth , fiber post core and adhesive restoration or cast post core with crown.[12]

Majority of the patients who visited our hospital for root canal treatment were males (51.3%) which is in contrast with our previous study[14]. However these studies were done in two different centers which might be the reason for the differences in frequency. The most frequently treated tooth was three rooted molars (35.8%) followed by two rooted molars (34.7%) followed by mandibular premolars (8.6%). We have encountered mandibular molars with three roots while we were performing this study and these cases were also included in the study. Hence, mostly molars were the one that needed endodontic treatment. This finding is similar with the study done by Scavo R et al[15].

Pericervical Dentine (PCD)

Pericervical dentine (PCD) is the dentine that is located approximately 4mm above and 4mm below the alveolar crestal bone and is critical with respect to force concentration and fracture resistant of endodontically treated teeth. Peri Cingulum Dentine (PCD) is a term that is used specifically for anterior teeth. This dentine plays a major role in reinforcing the tooth and strengthening it[5, 16-17]. PCD remaining after coronal enlargement of root canals is important for ferrule, fracture resistance and proximity of dentinal tubule orifices and plays an important role in deciding the post endodontic restoration/ prosthetic rehabilitation. In this study we tried to evaluate whether the PCD of the involved tooth after root canal treatment was enough or compromised. Most of the teeth with compromised PCD, before the treatments were indicated for extraction. The tooth that went RCT and had compromised PCD had poor prognosis and prosthesis were recommended accordingly.

8.3% of the patient with compromised PCD that was found in this study was recommended for cast post and core with full crown in order to increase the strength and survivability of them.

Chamber Retention

Chamber retention is anothe important aspect for deciding the post endodontic restoration especially the need for post . Literature states that molar tooth can be restored with composite if enough chamber retention is there and do not require posts. For premolars, glass fiber post and core is adviced[18-19].In this study also, we evaluated the possibility of chamber retention of the involved teeth after root canal treatment. The condition of chamber retetion of the majority of the teeth (90.6%) that were treated and included in this study was adequate.

The post endodontic restoration or prosthetic rehabilitation after root canal treatement were adviced to the patiant according to the number of remaining walls[12], Pericervical dentine , possibility of chamber retention and the type of tooth and force exerted on it. The endodontic-endorestorative-prosthodontic continuum (EERP) is a term coined by Clark and Khadami stating that endodontics is simply a foundation to serve the restoration and preservation of the tooth. EERP is a restoratively focused view of endodontics where endodontic designs are fully integrated as a part of interconnecting sequence of components. Hence, each component of root canal treatment and post endodontic restoration should strengthen the other components and should stronghold the tooth from crown to apex against fracture or failure. Another important factor one should consider while planning the post endodontic restorations is the bite force of each tooth which is unique to each other. The attachment position of elevator muscle to the mandible creates and generates the occlusal forces that are different throughout the dentition, according to the position of hinged axis (Temporomandibular Joint; TMD) which acts as a moment arm. The teeth which are closer to the hinge, the greater is the moment or the force applied; thus making anterior teeth with light biting force with much heavier bite forces at the posterior teeth. Incisors teeth splay forward on occlusal loading, bears oblique and shearing forces and molars absorbs greater vertical forces and has more compressive force. The net compressive force on molar (moment and splay) produces a state that needs different criteria for designing ferrule, post core, fracture resistance and pattern of endodontic access and shaping[16]. In this study also, we focused our recommendation of post endodontic restorations on the basis of above-mentioned components. Tooth type (incisors, canine, premolars and molars) were taken into consideration for the same reasons (Table 2). PCD is the neck of the tooth that cannot be replaced by any restorative material and plays a major role in transferring the masticatory forces to the root and the alveolar bone. PCD that is not compromised and enough can fortress the tooth against the fracture and helps in long term survivability of the tooth[20-22]. However, if PCD is compromised then reinforcement should be done for efficient transmission of masticatory forces and prevention of fracture under such loads. The use of intracoronal restorations and intraorifice barriers by using materials like resin modified glass inomer cements, nano-inomers, silorane composite resins has also been suggested for the reinforcement of compromised PCD[23-25].

Dimensional ferrules (3DF)

Another important aspect we considered while recommending the full coverage restorations like crowns is the 3-Dimensional ferrules (3DF) that buttresses the crown. It is the axial wall dentine in all 3 dimensions (height, thickness and total draw of the opposing buccal-lingual and mesial-distal walls; TOC), enclosed by the axial wall of the crown or bridge abutment. The minimal vertical amount required should range

from 3-5mm (absolute minimal thickness 1.5-2.5mm). The thickness of remaining dentine at the finish line externally is the important parameter and axially deep finish lines on root structure can be very detrimental to 3DF. The more the net taper or TOC more should be the vertical ferrule (TOC of 10 degree requires 3mm and 20 degree requires 4mm of vertical ferrule height[26-29]. Hence, the amount of remaining dentine and the volume of dentine removal in axial direction during crown preparation become very crucial and should be considered and questioned before planning for it. Instead, casted inlays or onlays with enough pulp chamber retention can be a simple, affordable, minimally invasive and effective method of restoring extensively damaged crowns of molars[30].

In case of anterior teeth, cingulum and marginal ridges features thick enamel and it should be preserved during endodontic treatment to compensate the area of stress concentration (palatal concavity). As heavy occlusal forces are concentrated at the cingulum when they are in function, structural breakdown of the root treated teeth can occur in long run. Hence anterior teeth with worn out enamel or loss of facial surface should be restored with materials whose properties are similar to that of enamel in order to restore the unique biomechanical properties of the tooth[29].

Composite and Reinforced Composite resin (RCR)

Literature supports the use bonded restorations like composite resin in root treated anterior teeth with minimal loss of tooth structure[31-32], similar to our recommendation in this study. In minimal o moderate cavity, direct composite resin restoration either with a glass inomer or dual cure resin base is advised. Placement of the composite resin below cementoenamel junction (CEJ) provides good seal and enhances the fracture resistance due to its good physical properties and ability to bond with tooth structure[33].

Recently fiber reinforced resin composites (FRC) are being used to reinforce endodontically treated teeth or structurally weaker teeth. FRC has better physical and mechanical properties and thus increases fracture resistance of teeth due to increased mechanical retention, decrease fracture propagation and good chemical bonding of glass fibers and resin matrix. Ribbond is a reinforced fiber with ultra-high molecular weight polyethylene fiber, high modulus of elasticity that is treated with cold glass plasma to increase its adherence with adherent. These fibers and their networks transfer the occlusal forces and when is used with composite resins, together acting as a stress reliever[34-38]. In our study we have recommended FRC to 9.7% of the patient who had intact teeth with the presence of all walls (for posterior) or 3 or 2 walls (for anterior), intact cusps or incisal edge and cingulum, with intact chamber retention and PCD. Root canals were either intentional or due to non-carious cause. We strongly recommended use of FRC in cases of canine tooth.

Veneers are either ceramic or composite, that covers entire labial surface with or without involving the incisal edge and upto the proximal contacts.Anteriorly, malformed, malposed, discolored teeth or diastemas with no loss of tooth structure can be restored conservatively to highly aesthetic and desirable form by using porcelain veneers [38-39]. We recommended veneers in severely discolored teeth that will not significantly improve even after multiple non vital bleaching sessions or when incisal edge or length, shape or size of the tooth needs correction.

Inlay and Onlays

Current research and restorative trends also show that crack initiates in root treated teeth during stress test and endodontic monoblaock concept or intracoronal splinting using adhesive

cement are not valid[40-43]. Meanwhile partial coverage restorations for posterior teeth have resurged for prevention of remaining dentine and the chamber retention for retaining core instead of post in molar teeth have been recognized[44]. Cobankara FK et did a randomized controlled trial to compare the fracture resistance of root treated mandibular molars with mesio-occluso-distal (MOD) cavities restored with amalgam, resin composite, hybrid ceramic inlay and polyethylene ribbon fiber with composite (RRC). They found promising result with hybrid inlay restoration with greater fracture strength and favorable modes of fractures which can be repaired if needed[45]. Casted inlay can be recommended for post endodontic restorations in molars if chamber retention is possible although case should be selected wisely and preparation should be precise to avoid gingivitis, secondary caries or food impaction[30]. Hence, in this study also we have recommended casted inlays in 8.9% of the cases. The inlays were recommended in molars or premolars with intact cusps, supragingival margins, presences of all or 3 walls with enough chamber retention and non-compromised PCD.

In some clinical scenarios, only buccal and palatal/lingual tooth structure is left and cusps are severely undermined and tooth is weakened. Indirect restorations that are conservative as well as capable of resisting occlusal functional or para-functional loading can be an ideal indication in such cases. Indirect onlays can provide cuspal coverage, conservative and increases the fracture resistance of endodontically treated teeth compared to full crown[47]. In a study by Shi R et al teeth restored with FRC and onlay showed significant fracture resistant and favorable modes of fracture compared to crown[48]. Keçeci AD et al reported that root treated premolars with large cavities can be significantly reinforced against fracture when ceramic inlays were indicated as partial coverage restorations[47]. Indirect onlays provide cuspal coverage and protect weakened cusps and hence can be used as an alternative to full coverage crown in teeth that have minimal to moderate amount of tooth structure loss after root canal treatment[49].

In this study we recommended ceramic or resin indirect onlays in 21.9% of cases with 1 or 2 walls missing, cusps undermined, premolars with intact walls but cusp undermined, enough chamber retention and PCD but margins were supragingival as it is generally accepted that there should be an adequate circumferential supramarginal collar of dentine for retention of extracoronal restorations[50].

Endocrowns

Another post endodontic restoration we recommended to our patients in this study was endocrowns. Endocrowns are intracoronal as well as extracoronal restoration that uses pulp chamber and the remaining tooth structure for retention and provides minimally invasive option with acceptable long term survivality of root treated teeth especially in cases of short clinical crown height[51]. A circular butt joint margin is made and central retention is obtained from access cavity and pulp chamber. Composite resins are used to fill the undercuts and provide substantial amount of tissue preservation. Endocrowns do not interfere with periodontal tissue as its margins are placed supragingivally and provides adequate function and aesthetics by using the surface available in the pulp chamber[52].Thus endocrown provides a postless alternative to treat root treated teeth by combining crown and core build up in a single unit and require minimally invasive preparation[53]. Biacchi GR et al reported that endocrown has several advantages in endodontically treated molar teeth with adequate function, esthetics and can maintain biomechanical integrity of the compromised root treated posterior teeth. Moreover, the need of post and core, number of adhesive bonds are also reduced and long-

term survival of the teeth is increased[54]. Bindl A et al treated root treated posterior teeth with complete loss of coronal structure with Cerec endocrowns and concluded that the overall clinical quality was excellent[55].

In a study by Bindl et al, feldspathic ceramic Endocrowns showed 87.1% of survival rates in four-year time[56]. Otto and Mormann however found 90.5% of survival rates after 10 years which was similar to the survival rates of control tooth or the tooth with full coverage crowns[57]. In both the studies the survival rates for premolars were significantly less with endocrowns compared to full coverage restorations, the main reason for failure being the debonding. Molars have greater surface area for adhesion compared to premolars. The unfavorable crown basis and height ratio in premolars makes it a tooth with greater leverage, lowering its success with endocrown type of restorations[56-57]. Therefore; in this study we recommended mostly full coverage crowns to premolar teeth.

Post and Core

The sole purpose of a post is to retain the core and should not be indicated when enough chamber retention is there. Mostly molars do not require posts due to possibility of chamber and canal retention[19]. Premolars have transitional internal morphology and hence remaining PCD should be evaluated before indicating for post. As tooth and pulp chamber are smaller, post are often indicated to retain a core in premolars. However, due to thin mesio-distal roots, taper, curvature, proximal concavities and invaginations in upper premolars and lingual inclination of clinical crown in lower premolars, these teeth are at risk of procedural mishaps like root perforation during post space preparation[38]. Studies show that anterior teeth with minimal loss of tooth structure after root treatment does not require post or crown and can be conservatively restored[31,58]. But anterior teeth, they are subjected to lateral and shearing forces under occlusal load and teeth with extensive loss of tooth structure need post to retain a core.

If sound PCD is removed during preparation for post and core, mishaps like crack formation, apical, lateral or strip perforation can occur the risk of root fracture increases[59]. Thus whenever a post is indicated, it should be placed in the largest and straightest canal such as distal canal of mandibular and palatal canals of maxillary molars, with minimal preparation to avoid above mentioned mishaps[38]. V Arora et al gave few recommendations when considering post in endodontically treated teeth; such as placement of the post in prepared root canal space with minimal removal of additional dentine, choosing the post with similar modulus of elasticity of PCD, extending the post apical to the crestal bone as far as possible and use of reinforcing adhesives to retain the post in post space[29]. Another important aspect while choosing for post and core is type of post and core. Fiber post or cast post is always a dilemma for the clinician. Literature shows the longevity and success of post and core restoration was not relevant to the type of post but was greatly dependent upon the amount of remaining dentine after preparation[60]. Although fiber post has shown similar survival rates in clinical studies compared to cast post, presence of minimum 1.5-2mm ferrule in dentine is mandatory for safe indication and success of fiber post[61-63]. In badly broken-down teeth with compromised core retention and absence of coronal ferrule clinician can opt for cast post and core[62]. The cervical portion of the tooth is more resistant to lateral forces than shoulder preparation. Hence, Ferrule is necessary primarily for resistance form and longevity of the root treated teeth for post, core and full coverage restoration like crown[64-66]. Other commonly indicated post is metallic post which also shows good clinical survival rate but the related failures are unfavorable and irreversible compared to glass fiber

posts[61]. In this study we adhered to the above-mentioned principles and cast post and core was recommended to only those cases (7.2%) whose ferrule and PCD was compromised with no chamber retention. Whereas other cases with compromised chamber retention but adequate ferrule was advised for fiber post and core (2.8%). Metallic posts were not indicated in any of our case in this study.

Number and percentage of remaining walls and thickness and height of ferrule, are the criteria used in literature to assess the influence of ferrule and the survival of different post endodontic restorations[60,67-70].

Hence in premolars, usually glass fiber posts are indicated due to lower failure risks as it protects against root fractures. In decoronated premolars quartz fiber post is better alternative as it significantly prolongs the survival time of the teeth[71].

Full Coverage Crowns

Generally, for endodontically treated teeth with less than 30% residual tooth volume, teeth with one or less remaining walls, teeth with no proximal contacts are at higher risk of fracture[50]. Moreover, the survival of root treated posterior teeth increases if cuspal coverage is provided[32]. Literature also suggest that root filled posterior teeth restored with crowns shows superior survival rates and those without may have 6 times more likely failure rates[50,72].

A systematic review by Stavropoulou and Koidis showed that the posterior teeth restored with crown had more than 10-year survival rates than teeth restored with direct restorations[73]. Similarly, Ng et al also recommended full coverage crown for long term survival of root filled posterior teeth[74]. Tikku AP et al reported that root treated posterior teeth not supported by full cast crown will fracture in due course of time and risk of losing the tooth is too high to take. Thus, crown should be indicated for reinforcement of cusps to withstand occlusal forces irrespective of amount of tooth structure loss[3]. Cracked teeth before or after endodontic treatment is also an important parameter to consider before deciding post endodontic restorations. A systemic review of cracked teeth after root canal treatment reported significant survival rate that have been restored with cuspal coverage restoration or orthodontic molar band. Mandibular second molars showed the highest incidence of cracks[75]. In Contrast Sequeira B P et al did a systematic review on single crown versus conventional fillings in endodontically treated teeth and concluded that present evidence was not sufficient enough to compare crown and conventional restorations of root treated teeth. They recommended clinicians own experience and consideration of individual circumstances and patient's preferences when choosing post endodontic restoration until evidences are clear[76].Moreover, in a systematic review by Suksaphar et al., reported that the survival rate of root treated posterior teeth restored with crown or composite resin was not significantly different in teeth with moderate or minimal loss of tooth structure. Thus, sacrificing the sound tooth structure to prepare crowns in such teeth is not suitable in this era of adhesive dentistry[77].

In clinical scenarios like three surface class two such as Mesio-Occlusal-Dital (MOD) preparation, there is loss of both marginal ridges and tooth loses its stiffness by 63%. Crown is indicated in such cases in order to maintain the stability of the tooth. Post is also indicated if chamber retention is compromised[71].

Endodontically treated teeth when prepared appropriately can serves as an abutment for crowns or fixed or removable partial denture but in some complex edentulous span and some fixed partial denture designs using it as an abutment should be avoided[78].

In our study we have indicated full coverage crowns (different materials) mostly in premolars

and molars that needs cuspal coverage, have subgingival margins, teeth with extensive loss of tooth structure restored with or without post (fiber or cast) , in bruxers, in cracked tooth, malformed tooth with anamolies, fractured tooth and so on (table 1).

CONCLUSION

With emergence of less invasive endodontic and restorative trends and techniques direct or indirect restoration both can be recommended after root canal treatment. Due to new adhesive techniques most of the anterior teeth with minimal or moderate amount of tooth loss can be restored back to function and aesthetics with maximum amount of dentine preservation. Resin composites, reinforced resin composite, minimal preparation veneers are usually indicated in anterior teeth. If case of extensive amount of tooth loss with sufficient ferrule, fiber post core and crown is an optimal treatment. However, if ferrule is compromised then, one should choose cast post and core. Indirect restorations like onlay, endocrowns or crown are usually indicated when cuspal coverage is needed. Inlay can be a very good choice of restoration with minimal to moderate amount of tooth loss where cups are not undermined. Endocrowns are a good choice of restoration in cases where crown height is compromised and crown retention would be a problem. Moreover, contemporary restorative techniques like ceramic crowns, onlays, endocrowns, are found as comparable to metal crowns in terms of durability.

In summary, the general consensus in root treated teeth is the preservation of maximum amount of tooth structure that is critical for long term survival of teeth. Although many choices and materials are available there are definitive indications for choosing and using them. Future research should be indicated towards Randomized Clinical Trial to evaluate long term survival of endodontically treated teeth restored with different restorative options.

LIMITATIONS

We only recommended the planned post endodontic restorations, but the execution of the planned treatment, its long term follow up and evaluation was not done in this study. Moreover, the types of materials used to fabricate indirect restoration in different clinical scenarios were not evaluated. Besides, selection of post endodontic treatment might depend on individual choices and feasibility of the clinician. Hence, the type of treatment chosen might have some biases. However, we had tried to minimize this bias by including a group of experts (three prosthodontists and two endodontists) for evaluation of root canal treated teeth for the recommendation of need and type of treatment.

This is an observational study. Randomized Control Trial (RCT) would have been better indicator of the success or the failure of the particular rehabilitation option and could have given us the exact and better results to prove the recommended treatment option at that particular clinical situation with predictable success in the survival of root treated teeth. Hence authors recommend further clinical research.

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