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Knowledge of Libyan dentists about vertical root fractures (VRF): A survey study (Benghazi dentists as a case study).

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Highlights

- **Vertical root fracture is a complete or incomplete fracture initiated from the root mostly or can also initiate at any level above the CEJ.**
- **The signs, symptoms, and radiographic findings of VRF can be confused with those of advanced periodontal disease or endodontic treatment failure, thus complicating the diagnosis.**
- **Vertical root fractures have been reported to occur primarily in endodontically treated teeth due to compaction forces and/or with post placement.**
- **Vertical root fracture is one of the most frustrating conditions in dental office. In most cases, it leads to extraction—or at least root amputation.**

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ABSTRACT

The aim of the present study was to assess the knowledge of Libyan dentists about vertical root fractures (VRF), causes, clinical signs and symptoms, diagnosis and treatment and to find out the relationship between the knowledge and sociodemographic data of the dentists.

Materials and Methods: This was a descriptive cross-sectional study. The survey was carried out in Benghazi (Libya) in 2021. 375 dentists were invited. Data were collected using an electronic questionnaire. The questionnaire is designed to consist of two parts; the first part deals with the demographic characteristics of the participants and the second part is divided into four aspects to assess the knowledge of participants about VRF; (the definition and general information of VRF, the signs, symptoms, and diagnostic process of VRF, factors that contribute to VRFs and the preferred treatment of VRF in single-root and multi-rooted teeth). The survey data were statistically analyzed using Fisher's Exact test.

Results: The survey response rate was 375/225(60%). Almost half of respondents 112 (49.8%) had moderate Knowledge score about (definition and general information of VRF) and (the signs, symptoms and diagnostic process of VRF). The relationship between the knowledge score of the Libyan dentists regarding the signs, symptoms and diagnostic process of VRF and (gender, Specialization) was statistically significant difference p value < 0.05. The male participants in this study had higher knowledge score than female regarding this section. The endodontists had a higher knowledge for diagnosis of VRF than others did. More than half (63.1%) and Almost half (46.2%) of respondents had high knowledge scores about contributing factors to the susceptibility of root to fracture and the preferred treatment for VRF in single and multi-rooted teeth, respectively. The relationship between the knowledge score of the Libyan Dentists regarding the preferred treatment for VRF in single and multi-rooted teeth and gender was a statistically significant difference p value <0.05. The male participants in this study had higher knowledge score than female participants regarding the preferred treatment for VRF.

Conclusion: This study showed that around half of the participants had moderate to high knowledge regarding to different aspects of VRF.

1. Introduction

A vertical root fracture is one of the most frustrating conditions in the dental office. According to The American Dental Association of Endodontists "True vertical root fracture is defined as a complete or incomplete fracture initiated from the root mostly or can also initiate at any level above the CEJ" (Revera *et al.*, 2008). In general, tooth fracture is considered the third most common cause of tooth loss. In addition, VRF accounts for 2—5% of total tooth fracture cases (Torbjrner *et al.*, 1995). The incidence of VRF is more frequently associated with endodontically than non-endodontically treated teeth (Garcia-Guerrero., 2018). The etiology of vertical root fracture (VRF) in root canal-treated teeth is complex due to its multifactorial nature. There are both predisposing and contributing factors (Tamse, 2008). The predisposing factors are actually uncontrollable. These are biochemical changes in the dentin at the root of root canal treated teeth, pre-existing cracks in untreated teeth, and the specific anatomy of vulnerable teeth with VRF (Tang *et al.*, 2010). Contributing factors have been attributed to iatrogenic risk factors associated with various dental procedures performed on the teeth (Reeh *et al.*, 1989). VRF is considered a clinical condition in which multiple predisposing factors contribute to the development of root fractures. However, the associated pathology occurs only after an unknown period of time when the root canal and fracture area become infected. Thus, an uninfected VRF (defined as "histological VRF") is not clinically apparent until fracture infection develops, followed by clinical signs and symptoms. At this

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stage, VRF can be defined as "clinical VRF". The prevalence of 'histological VRF' in endodontically treated teeth may be significantly higher than the prevalence of clinically apparent 'clinical VRF' (Tamse, 2008).

The final diagnosis of VRF is at times complicated for lack of specific signs, symptoms, and/or radiographic features and because several etiologic factors might be involved. Signs and symptoms, for example, dull pain or pain on mastication, mobility, presence of a sinus tract, deep probing defects, a periodontal abscess, and periapical radiolucencies, are often similar to those found in failing root canal treatment or in periodontal disease. Thus, the differential diagnosis from other pathologic entities might be difficult (Walton *et al*., 2017). A timely mannered diagnosis and appropriate management are prudent to avoid excessive alveolar bone loss, which may affect future reconstructive procedures, should implant therapy be the treatment of choice (Tsesis *et al*., 2010).

VRF is a complicated condition that requires a clinician with wide vision and wise decisions. The combination of comprehensive clinical and radiographic examination is essential as the diagnosis of such cases is challenging. The aim of the present study was to assess the knowledge of the Libyan dentists (Benghazi dentists as a case study) about vertical root fractures, causes, clinical signs and symptoms, diagnosis and treatment and to find out the relationship between the knowledge and sociodemographic data of the dentists.

2. Materials and Methods

This was a descriptive cross-sectional study. The survey was carried out in Benghazi (Libya) during 2021. 375 dentists were invited among the dentists who registered successfully as members of the Libyan Dental Association. This sample was convenience sample included general practitioners, specialists and endodontists. The dentists included in this study were informed about the purposes of the questionnaire and the anonymous nature of the response. The study was conducted through an online survey were contacted directly or by mail. Among the 375 dentists requested for the survey, 225 dentists responded with a response rate of 60%. The questionnaire used in the present study was developed under the guidance of previous study on VRF (Tamse *et al*., 2015; Metzger *et al*., 2016). The questionnaire designed to consists of two parts; the first part (items 1-4) deals with the demographic characteristics of the participants including age, gender, years of experience in dentistry, and specialty, and the second part was divided into four different aspects to assess knowledge about vertical root fractures; first items (5-14) examined the definition and general information of VRF, second item (15) examined the signs, symptoms, and diagnostic process of VRF, third item (16) examined factors that contribute to VRF, fourth items (17) and (18) are related to the preferred treatment of VRF in single-root and multi-rooted teeth. All the questions in this questionnaire are closed-ended questions. The participants were asked to choose from the answers (yes, no or I do not know).

The questionnaire was first piloted on a few dentists in a local setting and minor modifications were made before it was utilized in this study. Approval from ethics committee of Faculty of Dentistry, Benghazi University, Libya was obtained (protocol no 0109). The survey data were statistically analyzed using statistical package for social science (SPSS). Fisher's Exact test was used to find out the relationship between the knowledge score and sociodemographic data of the participants with level of statistical significance set at $p<0.05$.

3. Results:

The survey response rate was 225/ 375 (60%). A total of 225 respondents, 51(22, 7%) male, and 174 (77.3%) female participated in the study. The majority 168(74.7%) of the study participants were general dental practitioners, 48(21.3%) were specialist (not endodontist) and 9(4.0%) were endodontists. Regarding years of experience in dentistry, the majority of respondents 101 (44.5%) had 1-6 years of experience as a dentist, while 57 (25.3%) had 6-10 years of experience. 33 (14.7%) had 11-15 years of experience. 14 (6.2%) had 16-20 years of experience. Descriptive statistics of the participants are shown in Table 1.

To assess the knowledge of Libyan dentists about VRFs, The questionnaire was designed into four different aspects the definition and general information of VRF, the signs, symptoms, and diagnostic process of VRF, the contributing factors to the susceptibility of root to fracture, and the preferred treatment for VRF in single and multi-rooted teeth. The knowledge was classified into three scores (low knowledge, moderate knowledge, and high knowledge) according to respondents' answers (Sezgin and Şirinoğlu Çapan, 2020).

Table 1

Descriptive statistics of the participants

Demographic data	Numbers	(%)
Gender		
Male	51	(22.7 %)
Female	174	(77.3 %)
Total	225	(100.0 %)
Specialization		
General dental practitioner	168	(74.7 %)
Specialist (not endodontist)	48	(21.3 %)
Endodontists	9	(4.0 %)
Total	225	(100.0 %)
Years of experience in dentistry		
1–5 years.	101	(44.9%)
6–10 years.	57	(25.3%)
11–15 years.	33	(14.7%)
16–20 years	14	(6.2%)
More than 20 years	20	(8.9%)

I. Dentist's knowledge regarding the definition and general information of VRF

Almost half of the respondents (49.8%) had a moderate Knowledge scores about the definition and general information of VRF, (27.1% high Knowledge score and 23.1% low knowledge score (Fig. 1). As shown in Table 2 the descriptive responses of the participants to the survey questions related to this section, (37%) of dentists knew that VRF was defined as a complete or incomplete fracture initiated from the root at any levels usually directed bucco-lingually. More than half of respondents 60% identified that the fractures probably begin internally (canal walls) and grow outward to the root surface. Almost half of the respondents (48%) were aware that the most susceptible roots to fracture are those in which the mesiodistal diameter is narrow compared to buccolingual dimension. (55.6%) of respondents knew that VRF is mostly associated with endodontically treated teeth. More than half of respondents (68%) were unaware that radiopaque metal post cause artifacts, making CBCT assessment of VRF difficult and reducing its specificity. (22.2%) of the dentists knew that neither cracked teeth nor trauma-related fractures are types of VRF. 36% of respondents identified the correct percentage (10-20%) of VRF.

The relationship between the knowledge score of the Libyan dentists regarding the definition and general information of VRF and demographic variables (gender, specialization, and years of experience in dentistry) was not significantly different, with p-value (0.125,0.496 and 0.947) respectively, Table 3.

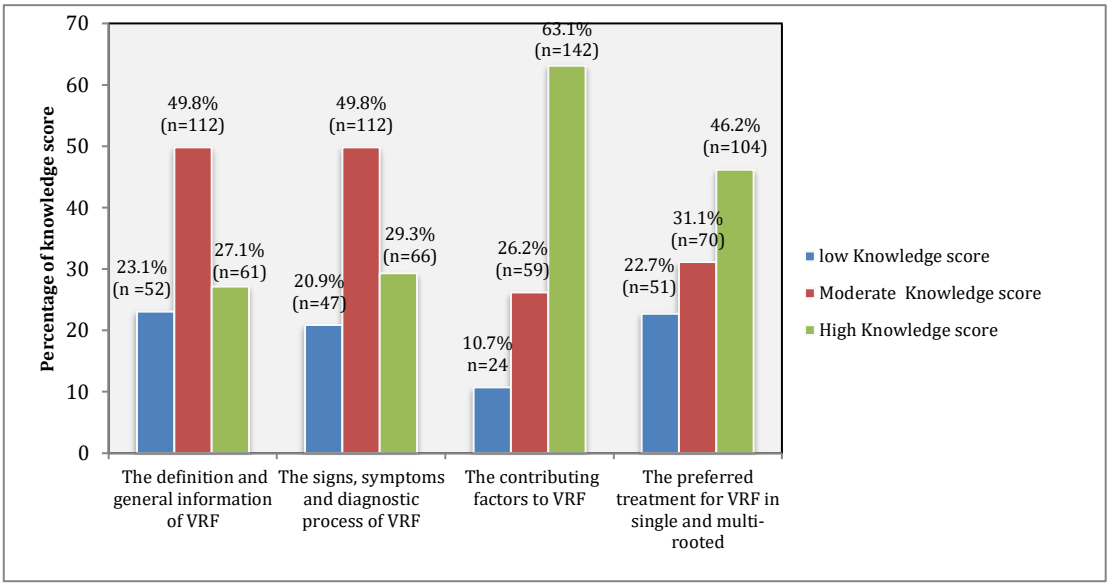

Fig. 1. Percentage of Knowledge score of the participants for the four aspects of VRF.

Table 2

The descriptive responses of the participants to the survey questions related to the definition and general information of VRF

I. The definition and general information of VRF	Answers, Number (%)			
	Yes	No	I don't know	Total
VRF complete or incomplete fracture initiated from the root at any levels usually directed bucco-lingually.	85(37.8%)	87(38.7%)	53 (23.6%)	225(100%)
The fractures probably begins internally (canal walls) and grows outward to the root surface.	135 (60.0%)	47(20.9%)	43 (19.1%)	225(100%)
The most susceptible roots to fracture are those in which the mesiodistal diameter is narrow compared to buccolingual dimension.	108 (48.0%)	49 (21.8%)	68 (30.3%)	225(100%)
VRFs are longitudinal (apico-coronal direction) fracture and may occur at any level in the root.	171 (76.0%)	23 (10.2%)	31(13.8%)	225(100%)
A vertical root fracture (VRF) is not an uncommon complication in root canal treated teeth	125 (55.6%)	76 (33.8%)	24 (10.7%)	225(100%)
Is it possible vertical root fracture to occur in nonendodontically treated teeth.	185 (82.2%)	25 (11.1%)	15 (6.7%)	225(100%)
VRF results in major damage to the periodontium	144 (64.0%)	57 (25.3%)	24 (10.7%)	225(100%)
Both cracked tooth and truma related fractures are types of VRF	143 (63.6%)	50 (22.2%)	32 (14.2%)	225(100%)
CBCT is superior to conventional radiographs to detect VRF, especially when metal posts are present.	153 (68.0%)	27 (12.0%)	45 (20.0%)	225(100%)

What is your information about the percentage of vertical root fracture	0-10%	11-20%	21-30%	31-40%	41-50%	Total
Answer, Number (%)	57 (25.3%)	81 (36.0%)	69 (30.7%)	16 (7.1%)	2 (0.9%)	225 (100%)

Table 3

The relationship between the knowledge score of the Libyan Dentists regarding the definition and general information of VRF and demographic variables

Knowledge score of The definition and general information of VRF	Gender, No. (%)		Specialization, No. (%)			Years of experience in dentistry, No. (%)				
	Male	Female	General	Specialist (not an endodontist)	Endodontist	1-5 years	6-10 years	11-15 years	16-20 years	More than 20 years
Low Knowledge score	7 (13.7 %)	45 (26%)	40 (23.8%)	12 (25 %)	0 (0.0%)	23 (22.8 %)	13 (22.8 %)	8 (24 %)	4 (28.6 %)	4 (20 %)
Moderate Knowledge score	26 (51%)	86 (49%)	84 (50 %)	23 (48 %)	5 (55.6 %)	48 (47.5 %)	32 (56.1 %)	17 (52%)	6 (42.8 %)	9 (45 %)
High Knowledge score	18 (35.3 %)	43 (25%)	44 (26.2 %)	13 (27 %)	4 (44.4 %)	30 (29.7%)	12 (21.1 %)	8 (24%)	4 (28.6 %)	7 (35 %)
Total	51 100%	174 100%	168 100%	48 100%	9 (100%)	101 100%	57 100%	33 100%	14 100%	20 100%
P value	0.125		0.496			0.947				

II. Dentist's knowledge regarding the signs, symptoms, and diagnostic process of VRF

Almost half of the respondents 112 (49.8%) had a moderate level of knowledge about the signs, symptoms, and diagnostic process of VRF. (29.3%) high knowledge and (20.9%) low knowledge, (Fig. 1). As shown in Table 4 the descriptive statistic responses of the participants to the survey questions related to signs, symptoms, and diagnostic process of VRF, Less than one-third of respondents (22.7%) knew that VRF does not elicit symptoms that bring the patient to the dentist, while 65.8% of respondents answered incorrectly. The majority (72.9%) are aware that mild pain on mastication is a common symptom and mild mobility is detectable, but not a common sign. More than half of the respondents (68.9%) knew that percussion and palpation usually elicit a mild response. (63.6%) of respondents knew that localized swelling or bad taste from the drainage of periodontal abscess.

Table 4

The descriptive responses of the participants to the survey questions related to the signs and symptoms and diagnostic process of VRF

II. Which of the following/s is/are correct about signs and symptoms and diagnostic process of VRF	Answers, Number (%)			
	Yes	No	I don't know	Total
VRF does not elicit symptoms that bring the patient to the dentist.	51(22.7%)	148 (65.8%)	26 (11.6%)	225(100%)
Pain on mastication is common but mild and mobility is detectable, but mild and not common.	164 (72.9%)	35 (15.6%)	26 (11.6%)	225(100%)
Percussion and palpation usually generate a mild response.	155 (68.9%)	47 (20.9%)	23 (10.2%)	225(100%)
Localized swelling or bad taste from the drainage of periodontal abscess	143 (63.6%)	39 (17.3%)	43 (19.1%)	225 (100%)
VRFs produce narrow and deep defects on facial and /or lingual surfaces representing the periodontal breakdown and inflammatory process facing the fracture	123(54.7%)	47 (20.9%)	55 (24.4%)	225(100%)
Draining sinus tract	107 (47.6%)	77 (34.2%)	41 (18.2%)	225(100%)
A combination of probing defects coupled with sinus tract in an endodontically treated tooth(with or without a post) is often pathognomonic for VRF	117 (52.0%)	31 (13.8%)	77 (34.2%)	225(100%)
A most frequent radiographic feature of VRF is the "halo" (J-shaped).	121 (53.8%)	16 (7.1%)	88 (39.1%)	225(100%)
Many of the VRF cases do not show any pathological bony changes and normal probing depths.	96 (42.7%)	78 (34.7%)	51(22.7%)	225(100%)
Flap reflection is the only reliable method of identification of VRF	60 (26.7%)	117 (52.0%)	48 (21.3%)	225(100%)

However, (54.7%) of respondents agreed that VRF produces narrow and deep defect on facial and /or lingual surfaces. Almost half of the respondents (47.6%) were aware that one of the signs of VRF is draining the sinus tract. (52%) of respondents identified that a combination of probing defects coupled with sinus tract in an endodontically treated tooth (with or without a post) is often pathognomonic for VRF. More than half of respondents (53.8%) knew that the most frequent radiographic feature of VRF is the "halo" (J-shaped). (26.7%) of respondents identified that a flap reflection is the only reliable way to identify VRF, while (52%) answered incorrectly. As shown in Table 5, the relationship between the knowledge score of the Libyan Dentists regarding the signs, symptoms, and diagnostic process of VRF and gender was significantly different at p-value <0.05. The male participants in this study showed a higher knowledge score than female participants regarding this section. More than half (62.7%) of males and (46%) of females had moderate knowledge scores, (31.3%) of males and (28.7%) of females had high knowledge scores and (6%) of males and (25.3%) of females had low knowledge scores. The relationship between the mentioned knowledge score and specialization (general, specialist, and endodontist) was statistically significant with a P value of <0.05. Endodontists have the highest level of knowledge for the diagnosis of VRF. A majority (88.9%) of endodontists had high knowledge scores while (41.7%) of Specialists (not an endodontist) and (54.2%) of general had moderate knowledge scores. There was no significant difference between the mentioned knowledge level and years of experience p=0.501.

III. Dentist's knowledge Regarding the Contributing factors to the susceptibility of root to fracture

More than half (63.1%) of respondents participants in this study had a high Knowledge score about contributing factors to the susceptibility of root to fracture Whereas the moderate Knowledge score (26.2%) and low knowledge score (10.7%), (Fig. 1). As shown in Table 6 the descriptive responses of the participants to the survey questions related to contributing factors to the susceptibility of root to fracture, the majority (78.7%) of respondents were aware that shape of root cross section is one of the natural predisposing factors for VRF. The majority (82.2%) (84.9%) and (85.3%) of respondents reported that excessive occlusal loads or high concentration of such loads at a specific point, Preexisting micro-cracks, and excessive root canal preparation respectively are the contributing factors to the susceptibility of root to fracture. Half (50.7%) of the respondents identified that the design of nickel-titanium rotary and reciprocation files is one of the contributing factors. More than half (61.3%) and (54.2%) of respondents were aware that uneven thickness of remaining dentin and obturation techniques-lateral compaction exert a lot of strain on radicular dentin respectively have an effect on the susceptibility of root to fracture. More than a third of respondents (38.7%) reported that type of spreader used is one of the influencing factors. (16.9%) of the respondents knew that the excessive use of various root canal irrigation solutions and medications can affect the susceptibility to root fractures. The majority (80.9%) of respondents reported that post selection; design and seating are the contributing factors.

Table 5

The relationship between the knowledge score of the Libyan Dentists regarding the signs and symptoms and diagnostic process of VRF and demographic variables

Knowledge score of The signs, symptoms and diagnostic process of VRF	Gender No. (%)		Specialization No. (%)			Years of experience in dentistry No. (%)				
	Male	Female	General	Specialist (not an endodontist)	Endodontis	1-5 years	6-10 years	11-15 years	16-20 years	More than 20 years
Low Knowledge score	3 6.0%	44 25.3%	33 19.6%	14 29.2%	0 0.0%	21 20.8%	9 15.8%	9 27.2%	4 28.6%	4 20%
Moderate Knowledge score	32 62.7 %	80 46.0%	91 54.2%	20 41.7%	1 11.1%	56 55.4%	29 50.9%	12 36.4%	7 50%	8 40%
High Knowledge score	16 31.3 %	50 28.7	44 26.2%	14 29.1%	8 88.9%	24 23.8%	19 33.3%	12 36.4%	3 21.4%	8 40%
Total	51 100%	174 100%	168 100%	48 100%	9 100%	101 100%	57 100%	33 100%	14 100%	20 100%
P value	0.005		0.002			0.501				

Table 6

The descriptive responses of the participants to the survey questions related to contributing factors to the susceptibility of root to fracture

III. Which of the following contribute/s to the susceptibility of root to fracture	Answers, Number (%)			
	Yes	No	I don't know	Total
Shape of root cross section.	177 (78.7%)	19 (8.4%)	29 (12.9%)	225(100%)
Excessive occlusal loads or high concentration of such loads at a specific point.	185 (82.2%)	19 (8.4%)	21 (9.3%)	225(100%)
Pre- existing micro cracks.	191 (84.9%)	16 (7.1%)	18 (8.0%)	225(100%)
Excessive root canal preparation.	192 (85.3%)	15 (6.7%)	18(8.0%)	225 (100%)
Design of nickel-titanium rotary and reciprocation files.	114 (50.7%)	55 (24.4%)	56(24.9%)	225(100%)
Uneven thickness of remaining dentin	138 (61.3%)	39 (17.3%)	48 (21.3%)	225(100%)
Types of spreaders used.	87(38.7%)	89 (39.6%)	49 (21.8%)	225(100%)
Obturation techniques - lateral compaction exert a lot of strain on radicular dentin.	122 (54.2%)	59(26.2%)	44 (19.6%)	225(100%)
Excessive use of various root canal irrigation solution and medicaments.	38 (16.9%)	142 (63.1%)	45 (20.0%)	225(100%)
Post selection, design and seating.	182 (80.9%)	14 (6.2%)	29 (12.9%)	225(100%)
Crown design and ferrule effect.	133 (59.1%)	57 (25.3%)	35 (15.6%)	225(100%)

As shown in Table 7, The relationship between the knowledge score of the Libyan dentists regarding the contributing factors to the susceptibility of root to fracture and the demographic variables (gender, specialization, and years of experience in dentistry) was not significantly different, with p-value (0.679, 0.185, 0.062) respectively. However, the endodontists had the highest knowledge score.

Table 7

The relationship between the knowledge score of the Libyan Dentists regarding the Contributing factors to the susceptibility of root to fracture and demographic variables

The Contributing factors to the susceptibility of root to fracture	Gender No. (%)		Specialization No. (%)			Years of experience in dentistry No. (%)				
	Male	Female	General	Specialist (not an endodontist)	Endodontis	1-5 years	6-10 years	11-15 years	16-20 years	More than 20 years
Low Knowledge score	5 (9.8%)	19 (10.9%)	17 (10.1%)	7 (14.6%)	0 (0%)	7 (6.9%)	4 (7%)	7 (21.2%)	1 (7.1%)	5 (25%)
Moderate Knowledge score	11 (21.6%)	48 (27.6%)	45 (26.8%)	14 (29.2%)	0 (0%)	29 (28.7%)	15 (26.3%)	4 (12.1%)	4 (28.6%)	7 (35%)
High Knowledge score	35 (68.6%)	107 (61.5%)	106 (63.1%)	27 (56.2%)	9 (100%)	65 (64.3%)	38 (66.7%)	22 (66.7%)	9 (64.3%)	8 (40%)
Total	51 100%	174 100%	168 100%	48 100%	9 100%	101 100%	57 100%	33 100%	14 100%	20 100%
P value	0.679		0.185			0.062				

IV. Dentist's knowledge regarding the preferred treatment for VRF in single and multi-rooted teeth

Almost half (46.2%) of the respondents participants in this study had high Knowledge scores about the preferred treatment for VRF in single and multi-rooted teeth, Whereas (31.1%) had moderate Knowledge scores, and (22.7%) had low knowledge scores, (Fig. 1). As shown in Table 8, the descriptive responses of the participants to the survey questions related to the preferred choice for VRF in single and multi-rooted teeth, (52.4%) of respondents reported that wait and see is not the preferred treatment for VRF in single and multi-rooted teeth. More than half (56.9%) of respondents are aware that the replantation procedure combined with the bonding of the fractured segments is not the preferred treatment for VRF in single rooted. While almost half (45.3%) and a half (50.7%) of respondents knew that (application of Mineral trioxide aggregate) and (Flap elevation and cementation of the root fracture) respectively are not preferred treatments for VRF in single rooted teeth. The majority (77.3%) of respondents reported that extraction is the preferred treatment for VRF in single rooted teeth. Half (44.9%) and more than half 142 (63.1%) of respondents aware that root amputation and hemisection respectively are the preferred treatment for VRF in multi rooted teeth. Whereas Less than half (33.3%) and more than half (53.8%) of respondents reported that (bicuspidization), (Flap elevation, and cementation of root fracture) respectively are not preferred treatment for VRF in multi rooted teeth.

Table 8

The descriptive responses of the participants to the survey questions related to the preferred treatment for VRF in single and multi-rooted teeth.

IV- In your opinion: what is the preferred treatment for VRF in single rooted teeth	Answers, Number (%)			
	Yes	No	I don't know	Total
Wait and see.	77 (34.2%)	118 (52.4%)	30 (13.3%)	225(100%)
Replantation procedure combined with bonding of the fractured segments.	49 (21.85%)	128 (56.9%)	48 (21.3%)	225(100%)
Mineral trioxide aggregate (MTA)	75(33.3%)	102 (45.3%)	48 (21.3%)	225(100%)
Flap elevation and cementation of the root fracture	54 (24.0%)	114 (50.7%)	57 (25.3%)	225 (100%)
Extraction	174 (77.3%)	21 (9.3%)	30 (13.3%)	225(100%)
In your opinion: what is the preferred treatment for VRF in multi rooted teeth				
wait and see	70 (31.1%)	118 (52.4%)	37 (16.4%)	225(100%)
Root amputation.	101(44.9%)	68 (30.2%)	56 (24.9%)	225(100%)
Hemisection.	142 (63.1%)	43 (19.1%)	40(17.8%)	225(100%)
Bicuspidization	78 (34.7%)	75 (33.3%)	72(32.0%)	225(100%)
Flap elevation and cementation of root fracture.	47(20.9%)	121(53.8%)	57(25.3%)	225(100%)
Extraction	170 (75.6%)	26 (11.6%)	29(12.9%)	225(100%)

Table 9

The relationship between the knowledge score of the Libyan Dentists regarding The preferred treatment for VRF in single and multi-rooted teeth and demographic variables

The preferred treatment for VRF in single and multi-rooted teeth	Gender No. (%)		Specialization No. (%)			Years of experience in dentistry No. (%)				
	Male	Female	General	Specialist (not an endodontist)	Endodontis	1-5 years	6-10 years	11-15 years	16-20 years	More than 20 years
Low Knowledge score	4 7.8%	47 27%%	34 20.3%	17 35.4%	0 0.0 %	19 18.8%	14 24.6%	9 27.3%	3 21.4%	6 30%
Moderate Knowledge score	11 21.6%	59 34%	56 33.3%	10 20.8%	4 44.4%	35 34.7%	14 24.6%	9 27.3%	6 42.9%	6 30%
High Knowledge score	36 70.6%	68 39%	78 46.4%	21 43.8%	5 55.6%	47 46.5%	29 50.8%	15 45.4%	5 35.7%	8 40%
Total	51 100%	174 100%	168 100%	48 100%	9 100%	101 100%	57 100%	33 100%	14 100%	20 100%
P value	0.00		0.068			0.814				

As shown in Table 9, the relationship between the knowledge score of the Libyan dentists regarding the preferred treatment for VRF in single and multi-rooted teeth and gender was statistically significant difference p value <0.05. The male participants in this study had higher knowledge scores than female participants regarding this section. More than half (70.6%) of male and (39%) of females had high knowledge score, (21.6%) of male and (34%) of female had moderate knowledge score and (7.8%) of male and (27%) of female had low knowledge score. The relationship between the knowledge score of the Libyan dentists regarding the preferred treatment for VRF in single and multi-rooted teeth and demographic variables (specialization and years of experience) was not statistically significant different p value (0.068 and 0.814) respectively.

4. Discussion

The primary objective of this study was to determine the level of knowledge of Libyan dental practitioners about the vertical root fracture etiology, diagnosis, predisposing factors and treatment. The knowledge was assessed by using reliable and valid questionnaire. The questionnaire was designed to be easy to read and straightforward to complete. The survey was carried out online. Hopefully, this will increase participation in this study. Several studies have been conducted to meet this important aspect. However, the survey-based researches about (VRF) are rare, so we have not found in literature any study similar to ours to compare with. In 2017, Mehrvarzfar et al. designed a survey about vertical root fracture, but the content of the study was different from the questionnaires used in current study (Mehrvarzfar *et al*., 2017). They concluded that the knowledge and clinical judgment of general dentists are in low levels needing serious improvement. In this study, 77.3% (174 of 225) were females, the highest proportion of females currently graduating from Libyan dental schools. Similar sample feminization was observed in other surveys conducted in Libya and other countries, (Crespo-Gallardo *et al*., 2018; Peeran *et al*., 2015).

In relation to the item of definition and general information of VRF, only 37.8% of the respondents who report that VRF is complete or incomplete fracture initiated from the root at any levels usually directed bucco-lingually and rarely have a mesiodistal orientation. On the other hand more than half of the participants agree with the literature (Fuss *et al*., 1999; Tsesis *et al*., 2010) that VRES are longitudinally oriented (an apico-coronal direction). They can originate at any level in the root commonly beginning in the apical part. The fractures originate in the root canal wall and extend to the root surface (Revera *et al*., 2008). Cone Beam Computed Tomography (CBCT) has high accuracy and sensitivity in detecting vertical root fractures, (Talwar *et al*., 2016; Byakova., 2019). The findings of Moudi (2014) and Neves (2014), who found that the presence of intracanal radiopaque materials (post and gutta-percha) negatively influences the diagnostic efficacy of CBCT, are not supported by 68% of the participants in the current study. In our study, only 36% of the participants agree that the prevalence of "clinical VRFs" as evaluated in extracted endodontically treated teeth was reported to range from 11 to 20 % (Pilo *et al*., 2000). On the other hand, 63.6% thought that both cracked teeth and trauma-related fractures are types of VRF. Conversely, VRF, trauma-related fractures, and cracked teeth are types of dental fractures (Blankland *et al*., 2015). In the present study, almost half of the respondents had moderate knowledge scores in definition and general information & the signs, symptoms, and diagnostic process of VRF.

Differential diagnosis of VRF and other pathological entities can be difficult because there are no typical features signs or symptoms associated with VRF (Tamse *et al*., 1999). A diagnostic process of VRF is based on the combination of the patient's subjective complaints and objective clinical and radiographic evaluation (Berman *et al*., 2006). Local chronic inflammation due to infection leads to discomfort and soreness, mild to moderate pain, pain on biting, bad taste and swelling of soft tissues (Moule *et al*., 1999). Palpation will often show swelling and tenderness over the root itself. The bottom line was that absence of symptoms, lack of radiographic changes, or normal probing depths alone or in combination did not rule out the presence of a VRF (Walton, 2017).

In this current study, only 22.7% knew that VRF does not elicit symptoms that bring the patient to the dentist While 65.8% of respondents answered wrong. On other hand, the most common signs and symptoms of VRF described in the literature are deep osseous defects, especially on the buccal aspect of the susceptible teeth and highly located sinus tract (Tamse *et al*., 1999; Meister *et al*., 1980) closer to the gingival margin. While the combination of a sinus tract and a deep periodontal pocket in such teeth is considered pathognomonic for clinical diagnosis (Revera *et al*.,2008; Goldberger *et al*., 2021), in most cases this combination does not exist. (Goldberger *et al*., 2021). In this current study, (54.7%) of respondents knew that VRF produces narrow and deep defects on facial and /or lingual surfaces. Almost half of the respondents 47.6% were aware that one of the signs of VRF is draining sinus tract while (52.0%) of respondents identified that a combination of probing defects coupled with the sinus tract in an endodontically treated tooth (with or without a post) is often pathognomonic for VRF.

VRF' radiographic findings are interesting. In fact, most displayed the "halo" ("J shaped") appearance lesions (Walton. 2017; Pradeepkumar, 2016) which described by Tamse (2006) termed it "apical-coronal-lateral". This is a combined periapical and lateral radiolucency along the side of the root or a lateral radiolucency on one or both sides of the root. Many other images showed other configurations. Importantly, in several images, there were no radiographic changes (Walton.,2017) or uniform widening of the periodontal ligament space (Pradeepkumar.,2016) or there were lesions that exhibited the classic "hanging-drop" shape, thereby suggesting failed endodontic treatment (Walton, 2017). In the current study, almost half of respondents (53.8%) thought that a most frequent radiographic feature of VRF is the "halo" (J shaped). Less than one third of the participants (26.7%) agreed that a Flap reflection is the only reliable method of identification of VRF. On the other hand, many investigators (Walton, 2017; Pradeepkumar, 2016; Khandelwal, 2020) have confirmed that when clinical and radiographic evaluations are ambiguous in detection of a suspected VRF, exploratory surgery is recommended. A full thickness flap has to be raised and granulation tissue has to be removed to directly visualize presence of VRF line. In the current study, there was a significant difference between Libyan dentists' level of knowledge of the signs, symptoms, and diagnostic process of VRF and gender with a p-value <0.05. The male participants in this study showed a higher level of knowledge than the female participants in this part. The relationship between the mentioned knowledge value and specialization (general, specialist, and endodontist) was statistically significantly different at P value <0.05. (89%) of endodontists have the highest levels of knowledge in diagnosing VRF. The reason for that could be endodontists are more likely to be updated with the current literature.

More than half (63.1%) of the respondents in this study had a high level of knowledge about the factors that contribute to root fracture susceptibility. Vertical root fractures can be caused by a variety of factors, some natural and others iatrogenic caused by dental procedures such as endodontic treatment and subsequent restorative procedures (Bender, 1983). There are several natural predisposing factures related to VRF (Khandelwal, 2020). In non-endodontically treated teeth, fractures might be related to special diet patterns or chewing habits (Yang *et al*., 1995), excessive, repetitive, and heavy masticatory stress (Yeh., 1997) referred to as "fatigue root fractures." On the other hand, excessive occlusal loads or high concentrations of such loads at a specific point can be another predisposing factor. This can be due to malocclusion or due to improper load sharing among the teeth, (Revera *et al*., 2008). Another predisposing factor is pre-existing micro cracks that may be present in radicular dentin due to parafunctional habits or repeated heavy occlusal loads (Khandelwal, 2020). In the present study, a relatively high proportion of answers (80%) were correct regarding the excessive occlusal loads or high concentration of such loads at a specific point and pre-existing micro cracks are the most common causes for tooth/root fracture in vital teeth. About (78.7%) of the participants are consistent with the literature that teeth with oval-shaped root canals are at higher risk of VRF (Vertucci, 1985). The shape of the root cross-section in an oval-shaped canal usually the buccolingual diameter more than the mesiodistal diameter; the strain concentration on the inner side of the remaining dentin wall at the highest convexity in the buccal and lingual sides is very high (Salma *et al*., 2012; Oliet., 1984; Goodacre *et al*., 1995)

A previous study by Dhawan *et al*. (2014) found that the iatrogenic causes of VRF are mainly related to the different stages of root canal treatment: Excessive cutting at different stages of root

canal treatment (Lertchirakarn *et al*., 1999; Yang *et al*., 2001). Increased stress generation of threaded and tapered posts (Standlee *et al*., 1972; Akkayan *et al*., 2002). The increased wedging force with Lateral compaction of gutta-percha. The development of these stresses can initiate crack initiation and propagation, ultimately leading to root fracture (Lertchirakarn *et al*., 2003). The majority (80.9%) of respondents reported that post-selection; design and seating are the contributing factors of VRF. On the other hand, about half of the respondents indicated that the NiTi rotary, reciprocating file design, and filling technique were factors that contributed to vertical root fractures.

The spreader design or the metal used can also be a contributing factor to a VRF (Dang *et al*., 1989). Brosh *et al*. (2018) revealed that previous studies and their results suggest that NiTi finger spreaders induce less strain in dentin compared with stainless steel finger spreaders, and thus may contribute less to VRF risk. Conversely, less than 40% of respondents reported that the type of spreads used is one of the factors. In the present study, only 16.9% of respondents were aware that overusing different root canal irrigation solutions and medications would affect the susceptibility of the root to fracture. According to the literature, the use of different various medicaments and irrigation solutions alters the quality of the root canal wall dentin, suggesting that these may affect the future fracture resistance of the root (Qian *et al*., 2011). Erosion of the dentin wall has been demonstrated by various irrigation solutions and by prolonged exposure of root canal dentin to EDTA (Seidberg *et al*., 1974), calcium hydroxide and various other chemical agents (Gasic *et al*., 2012).

Around half (46.2%) of respondents in this study had high knowledge score about the preferred treatment for VRF in single and multirooted teeth, whereas one-third (31.1%) had a moderate knowledge score. Traditionally, the prognosis of VRF roots has been considered hopeless (Tsesis *et al*., 2010; Taschieri *et al*., 2010). Treatment of vertically fractured teeth is difficult and depends on the type of tooth and the extent, duration, and location of the fracture (Moule *et al*., 1999). In the current study, only half of the respondents (52.4%) reported that wait-and-see is not the preferred treatment for VRF, while the majority of respondents reported that extraction is the preferred treatment for VRF in single-rooted teeth and multi-rooted teeth. These responses are justified by studies showing if VRF is established, it is recommended that the affected tooth or root be extracted as soon as possible. Any delay increases the likelihood of additional periradicular bone loss and may affect the placement of intraosseous implants, (Moule *et al*., 1999; Metzger *et al*., 2016). A series of clinical studies have shown that multirooted teeth can often be successfully treated by resecting the fractured root, either by root amputation or hemisection (Tsesis *et al*., 2015). Bicuspidization is no option for the treatment of VRF. The prognosis for posterior teeth is good provided the fracture can be removed in its entirety (Buhler, 1988). The current study revealed that more than one third (44.9%) and more than half (63.1%) of respondents are aware that root amputation and hemisection respectively are the preferred treatment for VRF in multi-rooted teeth. In recent years, due to advances in material science, properties have improved, allowing practitioners to think more conservatively and innovatively, providing an alternative to tooth extraction (Neelammital *et al*., 2020). Numerous surgical and non-surgical modalities have been suggested to reduce fractures or preserve roots: ligation or bonding of fractured segments, attempts to fix them with adhesive resins, epoxy resins, glass ionomers, or MTA, (Taschieri *et al*., 2010; Floratos *et al*., 2012; Venkatesh *et al*., 2021). Recent evidence suggests that intentional replantation can be considered a viable treatment option in some cases (Becker *et al*., 2018; Cho *et al*., 2016; Patel *et al*., 2022). However, additional clinical studies are indicated to evaluate the prognosis of these new treatments (Neelammital *et al*., 2020; Kawai *et al*., 2002). This is in line with the current study which found that more than half (56.9%) of respondents are aware that the replantation procedure combined with the bonding of the fractured segments is not the preferred treatment for VRF in single-rooted. In addition, half (50.7%) of respondents knew that flap elevation and cementation of the root fracture respectively are not the best treatment for VRF in single-rooted teeth.

5. Conclusion

Within the limitation of this study, around half of the participants had moderate to high knowledge regarding to different aspects of vertical root fracture. There were no significant differences between Libyan dentists' knowledge scores and demographic variables in all aspects, except for VRF signs, symptoms, and diagnostic process (male participants had higher knowledge scores than female participants. Endodontists had the highest level of knowledge in VRF diagnosis) and in the preferred treatment of VRF for single and multiple teeth (male participants scored higher than female participants in this aspect).

References

Akkayan, B. and Gülmez, T. (2002) 'Resistance to fracture of endodontically treated teeth restored with different postsystems' *The Journal of prosthetic dentistry'*, 87(4), pp. 431-437.

Becker, B.D. (2018) 'Intentional replantation techniques: A critical review', *Journal of endodontics*, 44(1), pp. 14-21. doi: 10.1016/j.joen.2017.08.002.

Bender, I.B. and Freedland, J.B. (1983) 'Adult root fracture', *The Journal of the American Dental Association*, 107(3), pp. 413-419. doi: 10.14219/jada.archive.1983.0276.

Berman, LH., Hartwell, GR. (2006) 'Diagnosis', in Cohen S, Hargreaves, KM. (eds). *Pathways of the pulp*. St Louis, MO: Mosby, pp.2–39.

Blankland, L.K., Tamse, A. (2015) 'Categorization of Dental Fractures', In Tamse, A., Tsesist, I. and Rosen, E. (eds.) *Vertical root fractures in dentistry*. Switzerland, Springer International Publishing, pp. 97-107.

Brosh, T., Metzger, Z. and Pilo, R. (2018) 'Circumferential root strains generated during lateral compaction with stainless steel vs. nickel-titanium finger spreaders', *European journal of oral sciences*, 126(6), pp. 518-525. doi:10.1111/eos.12569.

Bühler, H., (1988) 'Evaluation of root-resected teeth: Results after 10 years', *Journal of Periodontology*, 59(12), pp. 805-810. doi: 10.1902/jop.1988.59.12.805.

Byakova, S.F., Novozhilova, N.E., Makeeva, I.M., Grachev, V.I. and Kasatkina, I.V. (2019) 'The accuracy of CBCT for the detection and diagnosis of vertical root fractures in vivo', *International Endodontic Journal*, 52(9), pp. 1255-1263. doi: 10.1111/iej.13114.

Cho, S.Y., Lee, Y., Shin, S.J., Kim, E., Jung, I.Y., Friedman, S. and Lee, S.J. (2016) 'Retention and healing outcomes after intentional replantation', *Journal of endodontics*, 42(6), pp. 909-915. doi: 10.1016/j.joen.2016.03.006.

Crespo-Gallardo, I., Martín-González, J., Jiménez-Sánchez, M.C., Cabanillas-Balsera, D., Sánchez-Domínguez, B. and Segura-Egea, J.J. (2018) 'Dentist s knowledge, attitudes and determining factors of the conservative approach in teeth with reversible pulpitis and deep caries lesions', *Journal of Clinical and Experimental Dentistry*, 10(12), pp. e1205. doi:10.4317/jced.55395.

Dang, D.A. and Walton, R.E. (1989) 'Vertical root fracture and root distortion: effect of spreader design', *Journal of Endodontics*, 15(7), pp. 294-301. doi: 10.1016/S0099-2399(89)80050-0.

Dhawan, A., Gupta, S. and Mittal, R. (2014) 'Vertical root fractures: An update review', *Journal of Restorative Dentistry*, 2(3), p. 107.

Floratos, S.G. and Kratchman, S.I. (2012) 'Surgical management of vertical root fractures for posterior teeth: report of four cases', *Journal of endodontics*, 38(4), pp. 550-555. doi.org/10.1016/j.joen.2011.12.030.

Fuss, Z., Lustig, J. and Tamse, A. (1999) 'Prevalence of vertical root fractures in extracted endodontically treated teeth', *International endodontic journal*, 32(4), pp. 283-286. doi.org/10.1046/j.1365-2591.1999.00208.x.

García-Guerrero, C., Parra-Junco, C., Quijano-Guauque, S., Molano, N., Pineda, G.A. and Marín-Zuluaga, D.J. (2018) 'Vertical root fractures in endodontically-treated teeth: A retrospective analysis of possible risk factors', *Journal of investigative and clinical dentistry*, 9(1), p. e12273. doi.org/10.1111/jicd.12273.

Gasic, J., Popovic, J., Živković, S., Petrovic, A., Barac, R. and Nikolic, M. (2012) 'Ultrastructural analysis of the root canal walls after simultaneous irrigation of different sodium hypochlorite concentration and 0.2% chlorhexidine gluconate', *Microscopy Research and Technique*, 75(8), pp. 1099-1103. doi.org/10.1002/jemt.22036

Goldberger, T., Rosen, E., Blau-Venezia, N., Tamse, A. and Littner, D. (2021) 'Pathognomonic Combination of Clinical Signs for Diagnosis of Vertical Root Fracture: Systematic Review of the Literature', *Applied Sciences*, 11(22), pp. 10893. doi.org/10.3390/app112210893

Goodacre C.J., Spolnik, K.J. (1995) 'The prosthodontic management of endodontically treated teeth: a literature review. Part II. Maintaining the apical seal', *Journal of Prosthodontics*, 4(1), pp. 51-3. doi: 10.1111/j.1532-849X.1995.tb00315.x.

Kawai, K. and Masaka, N. (2002) 'Vertical root fracture treated by bonding fragments and rotational replantation', *Dental Traumatology: Case report,* 18(1), pp. 42-45. doi.org/10.1034/j.1600-9657.2002.180106.x.

Khandelwal, A. and Palanivelu, A. (2020) 'Decision Analysis for Management of Vertical Root Fracture', *Journal of Evolution of Medical and Dental Sciences*, 9(46), pp. 3474-3479. doi: 10.14260/jemds/2020/760.

Lertchirakarn, V., Palamara, J.E. and Messer, H.H. (1999) 'Load and strain during lateral condensation and vertical root fracture', *Journal of endodontics*, 25(2), pp. 99-104. doi:10.1016/S0099-2399(99)80005-3.

Lertchirakarn, V., Palamara, J.E. and Messer, H.H. (2003) 'Finite element analysis and strain-gauge studies of vertical root fracture', *Journal of Endodontics*, 29(8), pp. 529-534. doi:10.1097/00004770-200308000-00009.

Mehrvarzfar, P., Mohebbi, P., Akrami-Afshari, M. and Tour-Savadkouhi, S. (2017) 'Knowledge and clinical judgment of Iranian general dentists on vertical root fracture', *Journal of Oral Health and Oral Epidemiology*, *7*(1), pp. 1-7 doi:10.22122/johoe.v7i1.253.

Meister Jr, F., Lommel, T.J. and Gerstein, H. (1980) 'Diagnosis and possible causes of vertical root fractures', *Oral Surgery, Oral Medicine, Oral Pathology*, 49(3), pp. 243-253. doi: 10.1016/0030-4220(80)90056-0.

Metzger, Z, Berman, LH., Tamse, A. (2016) Cracks and fractures, in Cohen, S., Hargreaves, K.M. and Berman, L.H.(eds.) *Pathways of the pulp*. St Louis, MO: Elsevier Inc. pp. 793–818.

Moudi, E., Haghanifar, S., Madani, Z., Alhavaz, A., Bijani, A. and Bagheri, M. (2014) 'Assessment of vertical root fracture using cone-beam computed tomography', *Imaging Science in dentistry*, 44(1), pp. 37-41. doi:10.5624/isd.2014.44.1.37.

Moule, A.J. and Kahler, B. (1999) 'Diagnosis and management of teeth with vertical root fractures', *Australian dental journal,* 44(2), pp. 75-87. doi: 10.1111/j.1834-7819.1999.tb00205.x.

Neelammittal, Kumar, T., Kumar, P. and Parashar, V. (2020) 'New Treatment Option for an Incomplete Vertical Root Fracture; Case Study', *IOSR Journal of Dental and Medical Sciences*, 19(4), pp. 30-33. doi:10.1186/1746-160X-10-9.

Neves, F.S., Freitas, D.Q., Campos, P.S.F., Ekestubbe, A. and Lofthag-Hansen, S. (2014) 'Evaluation of cone-beam computed tomography in the diagnosis of vertical root fractures: the influence of imaging modes and root canal materials'. *Journal of Endodontics*, 40(10), pp. 1530-1536. doi:10.1016/j.joen.2014.06.012.

Oliet, S. (1984) 'Treating vertical root fractures. *Journal of endodontics'*, 10(8), pp. 391-396. doi:10.1016/S0099-2399(84)80161-2.

Patel, S., Bhuva, B. and Bose, R. (2022) 'Present status and future directions: vertical root fractures in root filled teeth', *International endodontic journal*, 55 (3), pp.804–826. doi:10.1111/iej.13715.

Peeran, S.W., Kumar, P.N., Ramalingam, K., Peeran, S.A., Elhammali, N.A.J.N., Elhassan, A. and Alsaid, F.M. (2015) 'Knowledge and attitudes of Libyan dental students about HIV/AIDS infection and HIV-positive patients', *Dentistry and Medical Research*, 3(1), pp.8. doi:10.1111/iej.13715.

Pilo, R. and Tamse, A. (2000) 'Residual dentin thickness in mandibular premolars prepared with gates glidden and ParaPost drills', *The Journal of prosthetic dentistry*, 83(6), pp. 617-623.

PradeepKumar, A.R., Shemesh, H., Jothilatha, S., Vijayabharathi, R., Jayalakshmi, S. and Kishen, A. (2016) 'Diagnosis of vertical root fractures in restored endodontically treated teeth: a time-dependent retrospective cohort study', *Journal of Endodontics*, 42(8), pp. 1175-1180. doi:10.1016/j.joen.2016.04.012.

Qian, W., Shen, Y. and Haapasalo, M. (2011) 'Quantitative analysis of the effect of irrigant solution sequences on dentin erosion', *Journal of endodontics*, 37(10), pp. 1437-1441. doi:10.1016/j.joen.2011.06.005.

Reeh, E.S., Messer, H.H. and Douglas, W.H. (1989) 'Reduction in tooth stiffness as a result of endodontic and restorative procedures', *Journal of endodontics*, 15(11), pp. 512-516. doi:10.1016/S0099-2399(89)80191-8.

Rivera, E.M. and Walton, R.E. (2008) 'Cracking the cracked tooth code: detection and treatment of various longitudinal tooth fractures', *Am Assoc Endodontists Colleagues for Excellence News Lett*, 2, pp. 1-19.

Salma, B., Malik, S.A., Norhayati, L.N., Adam, H. and Fadhll, K.M. (2012) 'Comparison of over flared root canals of mandibular premolars filled with mta and resin-based: an in-vitro', *Smile Dental Journal*, 7(2), pp. 38-40.

Seidberg, B.H. and Schilder, H. (1974) 'An evaluation of EDTA in endodontics', *Oral Surgery, Oral Medicine, Oral Pathology*, 37(4), pp.609-620.

Sezgin, G.P. and Şirinoğlu Çapan, B. (2020) 'Assessment of dentists' awareness and knowledge levels on the Novel Coronavirus (COVID-19)', *Brazilian oral research*, 34:e112. doi:10.1590/1807-3107bor-2020.vol34.0112.

Standlee, J.P., Caputo, A.A., Collard, E.W. and Pollack, M.H. (1972) 'Analysis of stress distribution by endodontic posts', *Oral Surgery, Oral Medicine, Oral Pathology*, 33(6), pp.952-960.

Talwar, S., Utneja, S., Nawal, R.R., Kaushik, A., Srivastava, D. and Oberoy, S.S. (2016) 'Role of cone-beam computed tomography in diagnosis of vertical root fractures: a systematic review and meta-analysis', *Journal of Endodontics*, 42(1), pp.12-24. doi:10.1016/j.joen.2015.09.012.

Tamse A., Tsesist I., Rosen E. (2015). *Vertical root fractures in dentistry*. Switzerland, Springer International Publishing.

Tamse, A. (2006) 'Vertical root fractures in endodontically treated teeth: diagnostic signs and clinical management', *Endodontic topics*, 13(1), pp.84-94. doi: 10.1111/j.1601-1546.2006.00200.x.

Tamse, A., Fuss, Z., Lustig, J. and Kaplavi, J. (1999) 'An evaluation of endodontically treated vertically fractured teeth', *Journal of endodontics*, 25(7), pp. 506-508. doi: 10.1016/S0099-2399(99)80292-1.

Tamse, A., Kaffe, I., Lustig, J., Ganor, Y. and Fuss, Z. (2006) 'Radiographic features of vertically fractured endodontically treated mesial roots of mandibular molars', *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*, 101(6), pp. 797-802. doi:10.1016/j.tripleo.2005.09.014.

Tang, W., Wu, Y. and Smales, R.J. (2010) 'Identifying and reducing risks for potential fractures in endodontically treated teeth', *Journal of endodontics, 36*(4), pp.609-617. doi:10.1016/j.joen.2009.12.002.

Taschieri, S., Tamse, A., Del Fabbro, M., Rosano, G. and Tsesis, I. (2010) 'A new surgical technique for preservation of endodontically treated teeth with coronally located vertical root fractures: a prospective case series', *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*, 110(6), pp. 45-52. doi:10.1016/j.tripleo.2010.07.014.

Torbjörner, A., Karlsson, S. and Ödman, P.A. (1995) 'Survival rate and failure characteristics for two post designs', *The Journal of Prosthetic Dentistry*, 73(5), pp. 439-444. doi:10.1016/S0022-3913(05)80072-1.

Tsesis, I., Beitlitum, I., Rosen, E. (2015) Treatment alternatives for the preservation of vertically root fractured teeth, In Tamse, A., Tsesist, I. and Rosen, E. (eds.) *Vertical root fractures in dentistry*. Switzerland, Springer International Publishing, pp. 97-107.

Tsesis, I., Rosen, E., Tamse, A., Taschieri, S. and Kfir, A. (2010) 'Diagnosis of vertical root fractures in endodontically treated teeth based on clinical and radiographic indices: a systematic review'. *Journal of endodontics*, 36(9), pp. 1455-1458. doi: 10.1016/j.joen.2010.05.003.

Venkatesh, A., Saatwika, L., Prakash, V. and Subbiya, A. (2021) 'Management Of Vertical Root Fractures–A Review', *International Journal of Aquatic Science*, 12(3), pp. 2115-2118.

Vertucci, F.J. (1985) 'Management of a vertical root fracture', *Journal of endodontics*, 11(3), pp. 126-131. doi: 10.1016/S0099-2399(85)80231-4.

Walton, R.E. (2017) 'Vertical root fracture: Factors related to identification', *The Journal of the American Dental Association*, *148*(2), pp.100-105. doi: 10.1016/j.adaj.2016.11.014.

Yang, H.S., Lang, L.A., Molina, A. and Felton, D.A. (2001) 'The effects of dowel design and load direction on dowel-and-core restorations', *The Journal of prosthetic dentistry*, 85(6), pp. 558-567. doi: 10.1067/mpr.2001.115504.

Yang, S.F., Rivera, E.M. and Walton, R.E. (1995) 'Vertical root fracture in nonendodontically treated teeth', *Journal of endodontics*, 21(6), pp. 337-339. doi: 10.1016/S0099-2399(06)81013-

Yeh, C.J. (1997) 'Fatigue root fracture: a spontaneous root fracture in non-endodontically treated teeth', *British dental journal*, 182(7), pp. 261-266. doi: 10.1038/sj.bdj.4809363.