**EVALUATION OF TREATMENT OUTCOMES OF CRACKED POSTERIOR TEETH.**

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**Abstract**

**Aim**: To document the clinical features associated with cracked posterior teeth and determine the outcome of their treatment among adult patients.

**Materials and methods**: A prospective clinical study among consecutive patients that assessedthe signs and symptoms associated with cracked teeth, which were grouped based on diagnosis into: Class A (asymptomatic), Class B (reversible pulpitis), Class C (irreversible pulpitis, pulpal necrosis, apical periodontitis and apical abscess) and Class D (features of class C with extension of cracks into the pulpal floor, roots, with periodontal complication and or swelling). In order to determine the class of cracks the teeth fell into, the teeth were examined for presence of mobility, periodontal pocket and tenderness to percussion**;** and chewing pain was verified with bite tests. Treatment protocols applied included counseling, composite restoration and occlusal adjustment, root canal treatment and crowning and extractions. Baseline and post-treatment assessments of chewing pain were performed with visual analog scale (VAS). The data generated were analysed using the IBM SPSS version 23 and the variables compared with chi square, student t test (paired and independent) and analysis of variance (ANOVA) tests. The level of statistical significance was set at p<0.05.

**Results**: Of the 264 cracked teeth, 129(48.9%) were asymptomatic (Class A). Twenty-five (9.5%) were in Class B, 71 (26.9%) in Class C and 39 (14.8%) in Class D. From the 135 teeth in symptomatic classes (B, C and D), chewing pain was seen in 117 (86.7%) and thermal sensitivity in 92 (68.1%). One hundred and four teeth (39.4%) were tender to percussion. Frequency of chewing pain was higher in classes C (93%) and D (82.1%), while class B had a higher frequency (76%) of thermal sensitivity. One hundred and nine (84.5%) of the asymptomatic cracks (class A) available for review at 3 months remained asymptomatic. Also, 22 (88%) of class B and 65 (91.5%) of class C were asymptomatic at 3 months. There were no complaints following extractions for class D cracks. There was a great reduction in mean VAS scores for chewing pain between baseline and review periods for classes B and C and this was statistically significant (p < 0.05).

**Conclusion:** Almost half of the patients with cracked teeth were asymptomatic. Chewing pain was the commonest complaint while the most prevalent sign was tenderness to percussion. The treatment protocols gave positive outcomes, and can be recommended for treatment of cracked teeth.

**Keywords**: cracked posterior teeth, signs, symptoms, treatment outcome.

**Introduction**

Incomplete longitudinal fracture of a vital posterior tooth that involves the dentine or extends into the pulp and periodontal space may present with symptoms ranging from discomfort to severe prolonged pain.1 Cameron referred to this type of fracture with associated signs and symptoms as “cracked tooth syndrome”, (CTS).2 However, controversies surround the use of the term, “syndrome”, which is defined as “a number of signs and symptoms occurring together and characterizing a specific disease”.3 Cracked tooth is not a disease or a pathological entity, rather a finding with inconsistent symptoms, thus the reason for controversy about the term “syndrome”.4Cracked tooth can either be asymptomatic or symptomatic depending on the extent of the crack.1,5 It may cause several diseases: reversible pulpitis (RP), irreversible pulpitis (IP), pulpal necrosis (PN), apical periodontitis (AP) and apical abscess (AA) that may present with their specific associated symptoms and signs.1 Individuals with cracked teeth may therefore present with different symptoms and signs, thus creating a major dilemma in clinical practice as a result of its diverse presentations, difficulty in confirming the presence of a crack, associating it with the presenting complaints, and instituting appropriate treatment.

Cracks in teeth usually result from periodical occlusal cyclical forces. The resultant fracture line may eventually cause dentine exposure5, thereby creating a route for bacterial penetration to the pulp. Initially limited to enamel and dentine, without symptoms, the crack may however propagate and present with symptoms. The earliest are pain on biting and thermal sensitivity. Other signs and symptoms, depending on the duration and extent of the crack include: swelling, discolouration, periodontal pocket, tooth mobility and tenderness to percussion. Pain on biting which becomes worse on release of biting pressure has been used to describe the classical sign or symptom of CTS.2

The initial symptoms of pain and thermal sensitivity have been explained by the hydrodynamic theory of pain described by Gysi7and substantiated experimentally by Brännström.8 Rapid movement of dentinal fluid stimulates mechano-receptors that activate myelinated A- delta nerve fibers, resulting in a sharp pain of short duration. Pain is produced in cracked teeth as dentinal fluid moves when the crack is opened by pressure on the cusp, as well as when the dentinal fluid moves back on releasing the pressure from the tooth. With bacterial invasion through the crack, damage to the pulp and periapical tissues may occur with different signs and symptoms.9

There are various treatment modalities for managing cracked teeth. These treatment protocols are usually determined by patients’ presenting signs and symptoms.6,10 These include: counseling, desensitization, occlusal adjustment, restorations (bonded amalgam, composite resin and glass ionomer cement (GIC) restorations), root canal treatment (RCT) followed by full coverage crowns (FCC), and extraction in cases with poor prognosis. Choice of treatment is usually a problem to the clinician and patient due to the uncertainty, as cracks are known to propagate even after treatment.6 It is, therefore, important to counsel the patient thoroughly on the need for further treatment and regular reviews, before commencing treatment.

Awareness of the signs and symptoms is paramount in early diagnosis and treatment of cracked teeth. Clinicians should be familiar with these presentations and able to give prompt and adequate treatment. There is presently no treatment protocol for cracked teeth at the Obafemi Awolowo University Teaching Hospitals Complex (OAUTHC). Also, having routine screening for cracks in teeth based on signs and symptoms could help reduce the burden associated with this condition on the clinician and patient. Therefore, the aim of this study was to determine the various pulpal and periapical diagnoses from the signs and symptoms associated with cracked teeth and to assess the treatment outcome of the various treatment protocols implemented among adult patients.

**Methodology**

This was a prospective clinical study done among healthy, consenting, consecutive patients aged 18years and above, with cracked teeth within a period of 12 months (May 2016 – April 2017) at the Restorative Clinic of the Dental Hospital of OAUTHC, Ile-Ife, Osun State. The Hospital is one of the major Tertiary Hospitals and a referral centre in the South Western geopolitical zone of Nigeria and has a dental centre which provides specialist dental care. Approval (ERC/2014/11/07) for the study was obtained from the Ethics Committee before commencement.

Criteria for inclusion were the presence of one or more inseparable, clinically visible cracked posterior tooth or teeth with or without symptoms. All patients, irrespective of the reason for dental visit were examined for cracked posterior teeth, and where present, were recruited into the study following consent. Detection was through necessary history and examination from the criteria set by the American Association of Endodontists (AAE).1 Initially, identification of the cracks were carried out by the naked eye, while use of one or more adjuncts as necessary were subsequently used to detect cracks not visible to the naked eye. These diagnostic aids included: a 3.5X (14 diopter) magnification lens (SE Japan), transillumination using Micrrolux transilluminator (Microlux Diagnostic System), methylene blue dyeusing unidose packaging of Vista Blue TM (Vista Dental Products, Racine, WI) and bite test done with tooth slooth (by Professional Results Inc., Laguna Niguel, California, United States). All examinations were performed by one pre-calibrated examiner. The examiner was calibrated against an experienced standard examiner (a consultant restorative dentist) before commencement of the study. Both examined 10 volunteers (with and without cracked teeth), independently, on two occasions at one-week interval for cracked teeth. The intra-examiner agreement yielded Cohen’s kappa value of 0.84.

History taken from the subjects included symptoms of chewing pain, thermal sensitivity and swelling. This was followed by clinical examination to assess for associated signs suchasswelling, sinus tract, tooth discoloration, tooth mobility, periodontal pocket and tenderness to percussion. Presence of chewing pain was elicited with a tooth slooth while the sensibility and status of the pulpal tissue was confirmed with the electric pulp tester (Digitest II tooth vitality tester, Parkell Inc.) Bite test was used to confirm the presence and intensity of chewing pain. A visual analog scale (VAS) which ranged from 0 (no pain) to 100mm (extreme pain) was provided on a sheet of paper to measure pain severity of the cracked tooth with tooth slooth (WS) and without tooth slooth (WOS).Each subject’s response was quantified by measuring the distance in millimeters from the first anchor words, no pain, to the mark made by the subject.

Periapical radiographs were taken to assess periapical and periodontal status of the cracked teeth. The pulpal and periapical diagnosis: asymptomatic, reversible pulpitis (RP), irreversible pulpitis (IP), apical periodontitis (AP), pulpal necrosis (PN) and apical abscess (AA) were made following the history, examination and investigations.

Classification and treatment plan of cracked teeth

Based on the associated symptoms, signs and diagnosis the cracked teeth were divided into classes A, B, C and D for different treatment protocols.

**Class A**: Cracked teeth without symptoms.

**Class B:** Cracked teeth with symptoms of RP (chewing pain and thermal sensitivity) of short duration without radiographic evidence of periodontal or periapical changes.

**Class C:** Cracked teeth with irreversibly damaged pulp (IP, AP, PN and AA) with or without radiographic evidence of periodontal and periapical involvement.

**Class D:** Cracked teeth with irreversibly damaged pulp as in class C. In this class, the fracture line extends into the pulpal floor, the roots, with deep probing defects, furcation involvement and other features such as mobility and swelling which confer a poor prognosis.

**Treatment protocol**

**Class A:** Routine monitoring and occlusal adjustment when necessary.5,11

**Class B:** Direct resin composite restoration using universal nanohybrid resin composite (3M ESPE) was done.12,13,14

Rubber dam (HandiDam-LF) isolation was done following shade selection and administration of local anaesthesia. Occlusal adjustments were done as necessary using a flame shaped diamond bur, as well as preparation along the crack line using a tapered diamond bur (Henry Schein) mounted on a fast handpiece with simultaneous irrigation with water jet. The teeth were cleaned, etched using 37% phosphoric acid (Scotchbond universal etchant, 3M ESPE) for 30 seconds, irrigated with water and dried afterwards with an air jet. Bonding agent (Scotchbond universal adhesive, 3M ESPE) was applied over the prepared tooth surface and cured using a composite curing light source (Woodpecker LED composite curing light, Guilin Woodpecker Medical Instrument Co., Ltd. China). Resin composite (Universal nanohybrid composite, 3M ESPE) was placed incrementally into the prepared cracked portion and cured. The occlusal contacts were checked using an articulating paper to ensure the presence of centric stops in the intercuspal position, at the same time to avoid any contacts in lateral or protrusive mandibular movements. The restorations were adjusted as necessary.

**Class C**: Root canal treatment (RCT) followed by full coverage crowns (FCC) with a tooth coloured temporary acrylic jacket crown (Protemp plus temporization material, 3M ESPE) 1 week after RCT and porcelain fused to metal crown (PFM) 3 weeks after.15,16

Orthograde RCT was performed manually under standardized clinical conditions, using the crown-down technique. At completion, canals were obturated using the cold lateral compaction technique with gutta percha (gapadent) and zinc oxide eugenol-based sealant (Tubliseal, Kerr Dental). Access cavities were restored with resin composite (Universal nanohybrid composite, 3M ESPE), occlusion checked and postoperative radiographs were taken. Tooth preparation for FCC was done 1 week after the RCT provided there were no symptoms. At this visit, impressions were taken for the fabrication of a PFM crown, and these was cemented 2-3 weeks after, using GIC (GC gold label).

**Class D**: The teeth were extracted and various forms of replacement suggested accordingly.17

**Post – operative reviews and assessments**

Subjects in classes A, B and C were reviewed at 1 week, 1 month and 3months while subjects in class D had a one-week post-extraction review. Reviews in classes A, B and C involved assessing for swelling, thermal sensitivity and pain using VAS.

**Data analysis**

Analysis was carried out using IBM SPSS for windows (Version 20). Associations between categorical variables were determined using Chi square tests. Student t test (paired and independent) was used to compare the mean chewing pain scores with and without tooth slooth. One–way ANOVA was used to compare mean chewing pain scores across classes B, C and D at baseline while paired student t- test was used to compare mean chewing pain scores for classes B and C at baseline and review periods. The level of significance was set at p < 0.05.

**Results**

There were 264 cracked teeth in 152 subjects. Their ages ranged from 18 – 84 years with a mean age of 50.43±14.18 years. Cracked teeth was noted to be most common (78, 29.5%) amongst the 51 – 60 years age group and least (2, 0.8%) among subjects ≤ 20 years of age. Seventy – nine males had 139 (52.7%) cracked teeth while 73 females had 125 (47.3%) cracked teeth. The present study is the continuation of a previous one18 that reported detailed findings on the socio-demographics of the subjects, arch distribution of the cracked teeth and number of cracked teeth per subject.

Among the 264 cracked teeth, 129 were asymptomatic (class A), while 25, 71, and 39 symptomatic cracked teeth were diagnosed and placed in classes B, C and D respectively.

**Clinical features associated with cracked teeth.**

Out of the 135 cracked teeth in Classes B, C and D, chewing pain occurred in 117 (86.7%) and thermal sensitivity in 92 (68.1%). Concerning the whole group, tenderness to percussion was observed in 104 (39.4%) of the teeth while 25 (9.4%) had periodontal pockets (>3mm). There were no significant differences in the occurrence of chewing pain or thermal sensitivity between classes B, C and D cracks (p = 0.060 and p = 0.302 respectively). Almost all the cracks associated with swelling (9 out of 10) were found in class D and the differences in prevalence between the various classes were statistically significant (p <0.001). There was no significant difference in the prevalence of discoloured cracks between the four classes (p = 0.926). Increased periodontal pockets (>3mm) were only observed in class D and the difference was significant (p <0.001); in addition, a significantly higher proportion of class D cracks had tooth mobility >1mm (p <0.001). Tenderness to percussion was detected in significantly higher proportions of classes C and D cracks (p<0.001) **(Table 1)**.

From 117 cracked teeth with chewing pain, the tooth slooth reproduced the pain in 115 (98.3%) of the teeth. These included 19 (76.0%) teeth in class B, 65 (91.5%) in class C and 31 (79.5%) in class D.

Out of the total 264 cracked teeth, 129 (48.9%) were asymptomatic (class A), and 25 (9.5%) were diagnosed with RP (class B). In classes C (71) and D (39) with irreversibly damaged pulp, there were 6 (2.3%) cases of IP, 4(1.5%) PN, 60 (22.7%) AP and 1(0.4%) AA in class C while class D had 4(1.5%) of IP, 1(0.4%) PN, 25(9.5%) AP and 9(3.4%) AA **(Table 2)**.

**Table 1: Clinical features of cracked teeth according to their different classes**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sign / Symptom | Classification |  | ClassAn1=129 | Class Bn2=25 | Class C n3=71 | Class D  n4=39 |  x2 | p value |
| Chewing pain | PresentAbsent  | 117(86.7) 18(13.3) |  ~~-~~ | 19(76.0) 6(24.0) | 66(93.0) 5 (6.7) | 32(82.1) 7(17.9) |  5.612 | 0.060 |
| Thermal sensitivity | PresentAbsent |  92 (68.1)  43 (31.9) |  ~~-~~ | 19(76.0) 6(24.0) | 50(70.4)21(29.6) | 23(59.0)16(41.0) |  2.391 | 0.303 |
| Swelling  | PresentAbsent |  10 (7.4) 125(92.6) |  0(0.0) 129(100) |  0 (0.0)25 (100) |  1 (1.4)70(98.6) |  9 (23.1)30(76.9) |  46.982 | <0.001 |
| Tooth discolouration | PresentAbsent |  47 (17.8)217(82.2) | 22 (17.1)107(82.9)  | 5 (20.0)20(80.0) | 14(19.7)57(80.1) |  6 (15.4)33(84.6) | .466 | 0.926 |
| Periodontal pocket | No pocket> 3mm | 239(90.5) 25 (9.4)  | 129 (100) 0 (0.0)  | 25 (100)  0 (0.0) | 71 (100) 0 (0.0)  | 14(35.9)25(64.1)  |  59.318 | <0.001 |
| Tooth mobility | Nil> 1mm | 239(90.5) 25 (9.6) | 129 (100)  0 (0.0) | 25 (100) 0 (0.0) | 65(91.5) 6 (8.5)  | 20(51.3) 19(48.7)  |  86.272 | <0.001 |
| Tenderness to percussion | PresentAbsent | 104(39.4)160(60.6) |  0 (0.0) 129(100)  |  0 (0.0)25 (100) | 67(94.4) 4 (5.6) | 37(94.9) 2(5.1) | 240.243 | <0.001 |
|  |  |  |  |  |  |  |  |  |

Note: some teeth had both chewing pain and thermal sensitivity while some had either chewing pain or thermal sensitivity.

**Table 2: Periapical and pulpal diagnosis of cracked teeth**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **NT = 264** | **Asymptomatic** | **Reversible Pulpitis** | **Irreversible Pulpitis** | **Pulpal Necrosis** | **Apical Peridontitis** | **Apical Abscess** | **Total****n** |
| **CLASS A** | 129 (48.9%) | - | - | - | - | - | 129 |
|  |  |  |  |  |  |  |  |
| **CLASS B** | - | 25 (9.5%) | - | - | - | - | 25 |
|  |  |  |  |  |  |  |  |
| **CLASS C** | - | - | 6 (2.3%) | 4(1.5%) | 60 (22.7%) | 1(0.4%) | 71 |
|  |  |  |  |  |  |  |  |
| **CLASS D** | - | - | 4 (1.5%) | 1(0.4%) | 25 (9.5%) | 9(3.4%) | 39 |
|  |  |  |  |  |  |  |  |

**Treatment and outcome within and across categories treated.**

**Treatment done**

The 129 (48.9%) asymptomatic cracked teeth in Class A were routinely monitored for signs and symptoms associated with cracked teeth. One hundred and nine (84.5%) out of these 129 asymptomatic cracks were available for review at 3 months and remained asymptomatic. Twenty-five (9.5%) cracked teeth diagnosed with RP had composite restorations. RCT was performed on 73 (27.6%) cracked teeth: 2 from class B that later developed symptoms of IP and 71 from class C. Sixty-eight (25.8%) symptomless endodontically treated cracked teeth in class C were crowned. Forty-five (17.0%) cracked teeth were extracted: one that had a split in class B, five from class C (2 subjects with persistent pain who opted for extraction and 3 with splits) and 39 cracked teeth in class D **(Table 3)**.

**Table 3: Treatment modalities for cracked teeth**

|  |
| --- |
|  |
| **Treatment done** | **Total** **n (%)** | **Asymptomatic****after treatment** **n (%)**  |  **Failed** **n (%)**  |
| **Counselling** | 129 (48.9) |  109 (84.5) |  - |
| **Composite restoration** |  25 (9.5) |  22 (88.0) |  3 (12.0) |
| **Root canal treatment\*** |  73 (27.6) |  68 (93.2) |  5 (6.8) |
| **Crowning\*** |  68 (25.8) |  68 (100) |  - |
| **Extraction\*** |  45 (17.0) |  - |  - |

\*Teeth with multiple treatment: 2 class B cracked teeth had RCT, thus adding to the 71 teeth in class C. Sixty-eight symptomless cracked teeth following RCT in class C were crowned and 6 teeth (1 from class B and 5 from class C) were added to class D with 39 teeth resulted into 45 extracted cracked teeth.

**Treatment outcomes.**

**Table 4** shows cracked teeth with chewing pain with and without tooth slooth in classes B and C at baseline and at reviews. There were noticeable reductions in the number of cracked teeth with chewing pain WOS across the classes during the reviews; in class B, the number gradually reduced from 19 at baseline to 14 at 1 week, 4 at 1 month and 0 at 3 months while66 cracked teeth in class C with chewing pain showed a gradual decline to 25 teeth at 1 week and further reduced to 3 at 1 month and 0 at 3 months. Using the tooth slooth, chewing pain in class B reduced from 19 cracked teeth to 14 at 1 week, reduced further to 4 at 1 month and 0 at 3 months while 65cracked teeth in class C with chewing pain showed a gradual decline to 27 at 1 week, 4 at 1 month and 1 at 3 months. The 39 cracked teeth in class D were extracted, with no complaint of pain at the one-week post-extraction review. Therefore, the reviews of chewing pain and thermal sensitivity were not applicable to this class.

**Table 4: Cracked teeth with chewing pain with and without tooth slooth at baseline and reviews in classes B and C**.

|  |  |  |
| --- | --- | --- |
|  |  **CLASS B** **n = 25 (%)** |  **CLASS C** **n = 71 (%)** |
|  | **WOS** | **WS** | **WOS** | **WS** |
| **Baseline** | 19 (76.0) | 19 (76.0) | 66 (93.0) | 65 (91.5) |
| **1 week** | 14 (56.0) | 14 (56.0) | 25 (35.2) | 27 (38.0) |
| **1 month** |  4 (16) | 4 (16.0) |  3 (4.2) |  4 (5.6) |
| **3 months** |  0 | 0 |  0 |  1 (1.4) |

**WOS – without tooth slooth, WS – with tooth slooth**

**Table 5: Cracked teeth with thermal sensitivity at baseline and at reviews in classes B and C.**

|  |  |  |
| --- | --- | --- |
|  |  **CLASS B** **n = 25 (%)** |  **CLASS C** **n = 71 (%)** |
| **Baseline** | 19 (76.0) |  50 (70.4) |
| **1 week** |  8 (32.0) |  1 (1.4) |
| **1 month** |  0 |  0 |
| **3 months** |  0 |  0 |

**Table 5** shows a marked reduction in the number of cracked teeth with thermal sensitivity during the review periods: the number reduced from 19 to 8 at 1 week and 0 at 1 month in class B and from 50 to 1 at one – month review for class C.

Class A cracked teeth were asymptomatic at baseline and throughout the reviews. **Table 6** shows comparison of mean VAS scores for chewing pain WOS or WS within and across classes. There were no statistically significant differences (p > 0.05) between VAS scores for pain elicited by the tooth slooth and pain WOS in the symptomatic classes at baseline (B, C and D) and reviews (B and C).

However, the reduction of mean VAS scores WOS or WS between the baseline and the review periods were statistically significant (p < 0.05).

**Table 6: Comparison of mean VAS scores for chewing pain WOS and WS.**

|  |  |
| --- | --- |
|  |  |
|  |  |  |
|  |  | **BASELINE** | **1 WEEK** | **1 MONTH** | **3 MONTHS** |
|  |  |  |  |  |  |
| **B** | **WOS** | 32.72(23.63) | 16.52(11.30) | 8.0(3.60) |  0 |
|  | **WS** | 36.92(28.21)(p>.05)  | 19.72(7.53)(p>.05) | 8.4(1.86)(p>0.05) |  0  |
| **C** | **WOS** | 45.90(21.57) | 7.19(2.72) | 1.51(0.16) | 0.24(0.02) |
|  | **WS** | 49.55(24.30)(p>.05) | 8.14(4.61)(p>.05) | 1.04(0.02)(p>.05) | 0.55(0.01)(p>.05) |
| **D** | **WOS** | 45.21(24.90) | - |  |  |
|  | **WS** | 47.49(28.21)(p>.05) | - |  |  |

 **WOS –** without tooth slooth **WS –** with tooth slooth **Note**:No values were recorded for the extracted teeth in class D at the reviews.

The differences in mean VAS scores without tooth slooth between classes B and C were statistically significant at baseline (p = 0.012), 1 week (p = <0.0001) and 1 month (p = <0.0001) but not at 3 months (p = 0.321).

One-way ANOVA statistics showed that there was a statistically significant difference in the VAS scores for chewing pain (WOS) among classes B,C and D at baseline (p = 0.042), while with WS there was no significant difference in the VAS scores (p = 0.117) **(Table 7)**.

The post-hoc analysis (LSD) showed that the significant difference in the mean VAS score for chewing pain (WOS) obtained from ANOVA statistics is between classes B and C (p = 0.033).

**Table 7:** Comparison of mean VAS scores for chewing pain WOS across treatment classes.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Classes** | **Mean (SD)** | **Mean difference** |  **95% CI** **lower upper** | **t** | **F** | **P** |
| **Baseline** |  |  |  |  |  |  |  |
| **B** | 32.72 (23.63) | - 13.18 | -23.39 | -2.97 | 2.163 | - | 0.012 |
| **C** | 45.90 (21.57) |  |  |  |  |  |  |
| **1 week** |  |  |  |  |  |  |  |
| **B** | 16.52 (11.30) | 9.33 | 6.48 | 12.18 | 6.497 | - | <0.0001 |
| **C** | 7.19 (2.72) |  |  |  |  |  |  |
| **1 month** |  |  |  |  |  |  |  |
| **B** | 8.00 (3.60) | 6.49 | 5.65 | 7.33 | 15.297 | - | <0.0001 |
| **C** | 1.51 (0.16) |  |  |  |  |  |  |
| **3 months** |  |  |  |  |  |  |  |
| **B** | 0.0 (0. 0) | -0.24 | 23944 | -.23810 | 1.000 | - | 0.321 |
| **C** | 0.24(0.02) |  |  |  |  |  |  |
| **Baseline**  |  |  |  |  |  |  |  |
| **WOS across B, C and D** | - | - | - | - | - | 3.247 | 0.042 |
| **WS across B, C, and D** | - | - | - | - | - | 2.177 | 0.117 |

**Discussion**

In this study, the detection of cracked tooth with resultant pulpal and periapical diagnosis followed a detailed dental history, examination and investigations. Chewing pain, thermal sensitivity, swelling, periodontal pocket, tooth mobility and tenderness to percussion were the signs and symptoms assessed. Various treatments given followed the pulpal and periapical diagnoses.

Almost half of the cracked teeth were asymptomatic. This was probably due to the cracks being specifically sought, thus increasing the rate of detection, as against what occurs in a routine examination. Another factor is thought to be the use of adjuncts (magnification, dyes, tooth slooth and transillumination), as was donein this study, in the detection of the cracks that can be missed during routine examination in the absence of symptoms.18 This is a fact corroborated by Clark19 in 2007 and more recently by the AAE20 in 2015 that cracks in teeth are a silent epidemic which propagate over a long period of time without symptoms. The symptoms may result subsequently from the involvement of the pulp depending on the location and extent of the fracture.

The commonest symptom was pain on chewing, which is consistent with previous studies.2,6,21,22The pain associated with a cracked tooth is said to result from the rapid movement of dentinal fluid in the dentinal tubules caused by transient independent movement of the tooth segments, which stimulates the mechanoreceptors in close proximity to the odontoblastic cells.7 The delta A fibers are activated, resulting in short sharp pain.

To a lesser extent, history of thermal sensitivity to hot and cold stimulus was also reported and this is also in consonance with other studies2,6,10,23,24 that reported thermal sensitivity to be the second most common complaint by patients. The thermal sensitivity results from seepage through the cracks with subsequent contact with dentine. As the crack progresses, the seepage of irritants (from bacteria in the cracks) result in the release of neuropeptides with subsequent lowering of C fibers’ pain threshold in the dental pulp.25 The tooth may then become hypersensitive to thermal stimuli. None of these investigatorsgave reasons why thermal sensitivity is second to pain on chewing among patients studied. It may, however, be due to lesser chance of seepage through the cracks as opposed to a greater chance of fragment displacement during chewing in the early stages of the crack. In addition, for subjects that present late, the cracked teeth will also not exhibit thermal sensitivity where the pulp is already necrotic.

Swelling is usually observed in cracks with extension below the alveolar bone. These cracked teeth undergo PN followed by inflammation of the periodontium which leads to swelling. Furthermore, the destruction of periodontal tissues is complicated by increased periodontal pocket depth and tooth mobility. These complications were observed in cracks with poor prognosis (Class D) and thus necessitated their extractions in this study. Similarly, studies17,26 have reported swelling, tooth mobility and increased periodontal pocket depth in cracks with extension below the alveolar bone.

Cracked teeth with periodontal and periapical involvement might have tenderness to axial percussion of the teeth which is suggestive of periradicular inflammation secondary to crack extension.27 The commonest clinical sign observed in this study was tenderness to percussion, seen in 39.4%. Higher scores have been reported; Roh and Lee10 reported 57.1% while Detar27 recorded 73% in 52 cracked teeth with pulpal involvement and more severe periapical inflammatory response.

Cracks in teeth usually trap stains from food, especially in long standing cracks or seen as stained cavity floors when a previous amalgam restoration is removed. About half of the discoloured cracks in this study were asymptomatic,suggesting that these cracks may be long standing and were only detected on routine examination. The above is affirmed by the study of Hilton and colleagues28 that observed that across different classes of cracked teeth examined, the stained cracked teeth were the least symptomatic.

In this study, the bite test using tooth slooth was quite complimentary, most especially in locating the offending tooth in subjects with complaints suggestive of RP (Class B). These subjects found it difficult to localize the cracked teeth because the periodontal ligament was not yet involved. Although, the difference between the severity of chewing pain WOS or WS was not statistically significant, it was observed that the severity elicited by the tooth slooth was higher. This is expected because the tooth slooth localises and exerts more force on the affected cusp thus translating to more painful response. Comparing the tooth slooth’s reproducibility of chewing pain in 98.5% of the cases in this study with previous studies of 100%23, 96.1%10 and 82.2%29, it shows that bite test is a reliable diagnostic aid for reproducing chewing pain in cracked teeth.

The commonest treatment in this study was counseling and routine monitoring of asymptomatic cracks. This is expected as most of the cracked teeth were in class A and majority of these remained symptomless after three months. This corroborates the assertion of the American Association of Dental Consultants11 that asymptomatic cracked tooth does not need any restorative intervention. On the contrary, it has also been advocated that different forms of restorative treatment should be performed on asymptomatic cracked teeth because of the possibility of crack progression to caries and other pathologies.5,30 However, it should be noted that there is limited available knowledge on the management of asymptomatic cracks, and therefore the clinical experience of the clinician is paramount in assessing the benefits and risks of observing or treating asymptomatic cracks.5 Regular follow up and monitoring is, therefore, recommended so that further propagation of cracks can be detected early and managed accordingly.

Cracked teeth with RP were treated with composite restorations. This was done to seal cracks, and prevent further propagation of cracks and bacterial invasion. In this study, occlusal adjustment was done for every case treated. Studies12,13,31 have shown that cracked teeth with RP can be conservatively treated with composite restoration and occlusal adjustment. Similar to these studies,12,31 majority of the teeth were symptomless at the end of review period. Krell and Rivera14 however reported that a fifth of cracked teeth with RP treated with crowns required RCT within a 6-month period.Other authors10,32-34 have advocated the use of extracoronal restorations in place of composite restoration, because with the use of composite, occlusal stresses on the teeth could stress the adhesive layer between the tooth and restoration.

FCC are expected to prevent flexure of the remaining tooth structure as it transfers occlusal stress to the area of the tooth circumscribed by the fabricated crown margin; this reduces the tendency for continued crack propagation, improving the biomechanical stability of the crackedtooth.4Complete crown was chosen as the appropriate option by 61% of dentists for restoration of cracked teeth in a national practice-based study conducted in America.35 However, occlusal adjustment could be done to reduce the stress on teeth treated with composite.12,13 Furthermore, there is tooth conservation and less tendency to pulpal degeneration with the use of composite.14

It has been advocated that non-surgical endodontic treatment should be done for irreversibly damaged cracked teeth.21,36 The majority of cracked teeth belonging to this group in the present study had non-surgical RCT followed by placement of FCC. Most of these teeth had resolution of signs and symptoms after three months. This is similar to the findings of studies done by Tan et al16 and Liu and Sidhu.37

Those with fracture plane extending beyond the alveolar bone, increased periodontal pocket depth and mobility were extracted in this study. There were no complaints following the extractions. Similarly, other studies12,13 reported extraction of such cases of cracked teeth. It is important that a post-extraction review be carried out as cases of misdiagnosis have been reported.38,39 In such instances, patients complain of persistent pain following extractions because the extracted tooth was not responsible for the patient’s initial complaints. This may cause a negative experience for the patient with concomitant psychosocial impact.

There was a marked reduction in mean VAS score for chewing pain one week after treatment in the symptomatic classes. This is expected as adequate and appropriate treatment would bring about resolution of pain through blockage of exposed dentinal tubules, extirpation of pulpal tissues and removal of the offending tooth as the case may be. Subsequently, gradual reduction in chewing pain was reported at one month and three months. It is expected at this point that there would be total resolution of inflammatory process and formation of dentinal bridges.

The statistically significant difference in VAS scores WOS observed at baseline between classes B and C may be due to the diagnosis of reversible pulpitis (with minimal symptoms) of teeth in class B, as opposed to the more severe and painful symptoms associated with cracked teeth in classes C and D. Furthermore, the reduction in chewing pain after treatment was more in class C compared to class B. This was because the entire pulp had been extirpated in class C. However, there was no statistically significant difference between the treatment outcomes of these classes of cracked teeth by the end of three months after treatment. This may be due to the accurate diagnosis and prescription of appropriate treatment for these classes of cracked teeth.

**Limitations of the study**

The study is limited by the relatively short (3 months) follow up evaluation period, which prevents assessment of treatment in the long term, and limits its comparison with other long-term studies.

**Conclusion**

Almost half of cracked teeth were asymptomatic. Chewing pain and thermal sensitivity were the most common symptoms associated with cracked teeth while tenderness to percussion was the commonest sign observed. Cracked teeth that required extraction were more likely to have had associated swelling, increased periodontal probing depth and increased mobility. All treatment modalities, which were tailored to the diagnoses, produced good outcomes and thus should be considered as appropriate treatment regimens for various classes of cracked teeth.

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