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Parameter study of the J-integral over a craze line in a root-channelled tooth

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Abstract

One of the principal issues in dental science, is their instability after operation. In this study, a root channelled tooth with initial craze lines has been concentrated to investigate the effect of crack location and length on changes of J-integral and stress concentration. The system of root-channelled tooth exposed to an external force and thermal loading is modelled by use of commercial software. Results show that extending the craze line length decreases the stress intensification factor, in conclusion, less amount of external force of heating load is enough to initiate the crack growth. In the same manner, the presence of the thermal shock changes strain and stress field. As well the results show that at the specific level of craze line the J-integral value is maximum, and more fracture stability of tooth obtained.

Introduction

One of the most sensitive part of human body is tooth. Teeth are white structures inside the mouth on the jaws of many vertebrates that are used to eat, chew, and chop food and talk. Usually the hard tissue of the teeth (enamel and dentin) loses calcium and phosphorus minerals due to acid secretion from cariogenic bacteria (mainly Streptococcus mutans) and gradually disappears. Tooth decay is an irreversible stage in the process of dissolving enamel minerals by acid and its treatment is possible only by replacing the lost hard tooth tissue with dental restorative materials. If the caries of the crown is not stopped and replaced in time and the caries reaches the pulp of the tooth, root canal treatment (RCT or denervation) is needed, and in more severe cases, it may even be necessary to remove or extract the tooth [1]. Hairy cracks in teeth or chrysalis are the name of vertical cracks that may form on the front teeth of people over time. These hair follicles are generally painless but cause discoloration and yellow or white lines in the teeth which can lead to loss of beauty in the teeth, fortunately now this problem in Teeth are easily soluble and treatable [2].

There are many reasons that can cause damage to teeth, fractures or cracks of teeth, each of which must be treated as soon as possible to prevent more serious problems in the future. Fractures in the teeth are divided into several categories according to the affected area, which are as follows [3]:

- Hair Cracks: The yellow or white vertical lines created on the enamel of the front teeth are called hair cracks that are generally painless.
- Caspian fracture: A fracture of a part of the masticatory surface of a tooth is called a cusp fracture.
- Cracking: Tooth cracking is a more serious crack that usually extends beyond the surface of the gum and extends to the root of the tooth. This type of crack can cause tooth loss quickly
- Tooth fragmentation: Tooth fragmentation means the fragmentation of a tooth, which occurs over time and lack of care for the tooth, and such teeth are no longer treated naturally.
- Vertical root fracture: If the crack and fracture in the tooth starts from the root area, it is called vertical fracture.
- Cracks in the teeth are more common and more common among people over 35, especially in women due to calcium deficiency.

Craze lines or hair cracks in the teeth are called yellow or white vertical lines that may develop over time in the hard part of people's teeth (enamel). Craze lines are caused by repeated use of teeth, chewing or pressing on the teeth, which can be easily prevented by proper care and observance of oral health [4]. These cracks in the teeth are known as the smallest and smallest cracks in the teeth, which generally do not pose a particular problem for people, but they can destroy the beauty of the teeth and the appearance of people, however, if these hair cracks Untreated teeth can cause cracks to develop and penetrate the tooth marrow and cause more serious damage to the teeth [5].

In general, chrysalis or hair cracks in the teeth do not need treatment if they are superficial, and in this case, the only reason that can cause people to demand treatment for hair cracks in the teeth is the appearance of the teeth. Many people are important; In this regard, medical science has a solution to treat such problems and any person can treat such damage in their teeth by referring to a specialist doctor to treat it. It is better to see a specialist as soon as possible if you see cracks and vertical lines in the teeth, because sometimes the same hair cracks can cause bacteria to penetrate the teeth and cause infections in the teeth.

Hair cracks in the front teeth do not cause much of a problem for the teeth, but these cracks over time due to the use of coloured foods cause yellowing and discoloration of the teeth, and this is the most important issue that causes maple. Treat hair cracks in the teeth, but there are many ways to get rid of hair cracks in the front teeth; These options include the following [6]:

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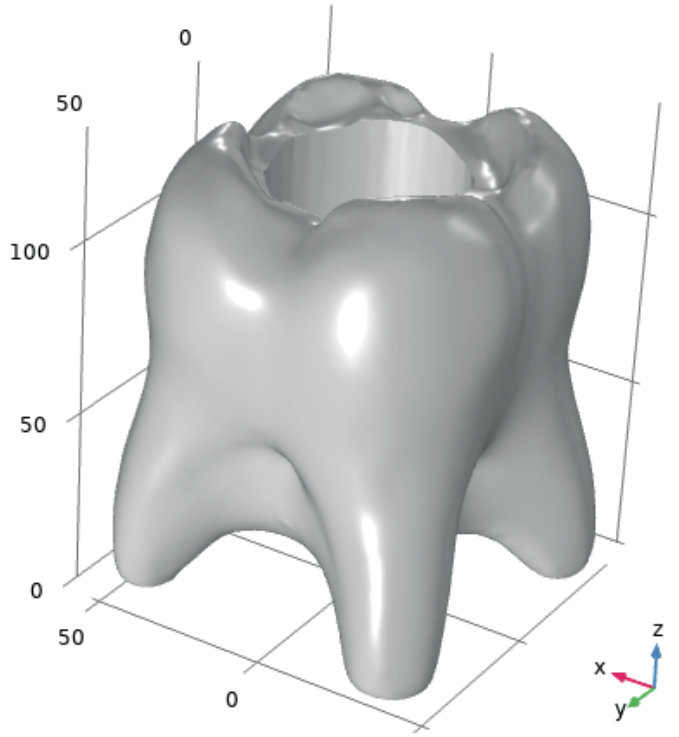

Figure 1: Schematic of the problem

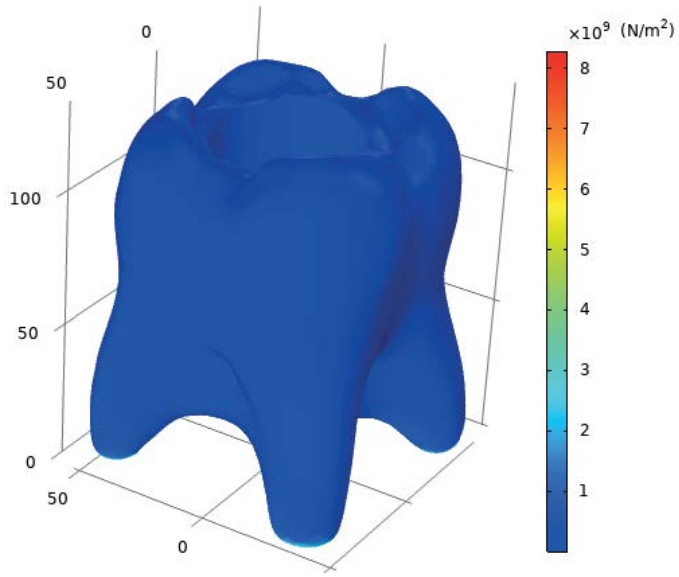

Figure 2: Stress field

- Use veneers to fill teeth that destroy chrysalis
- Cover cracks with dental fillings
- Teeth whitening

In teeth whitening, a specialist doctor or dentist shaves the surface of the patient's teeth to treat hair cracks in the teeth and covers them with fillers that are the same colour as our natural teeth, and this makes the appearance more beautiful. And the chrysalis is not seen, but in the treatment, method using veneer; In this method, doctors first rub the entire surface of the teeth and then cover the surface of the teeth with a kind of veneer, which not only eliminates hair cracks, but also makes the teeth more beautiful [7].

Mathematical model

Table 1 shows the mean Enamel and dentine modulus and Poisson's ratio. Stress field can be assessed using:

$$\nabla \cdot (\sigma) = 0 \tag{1}$$

With the fixed boundary at the root of tooth where the J-integral ($J = \int_{\Gamma} Wdy - \vec{T}\frac{\partial \mathbf{u}}{\partial x} ds$) evaluated by:

$$J = \int_{1,3,5} Wdy - \int_{1,2,3,4,5} T_i \frac{\partial u_i}{\partial x} ds \tag{2}$$

The considered fracture toughness of external and internal enamel as (0.67) MPa.m$^{0.5}$ and 1.13–3.93 MPa. m$^{0.5}$. Dentin fatigue crack growth exponent of 13.3 (hydrated environment) and 18.8 (dry environment) were reported.

Results and Discussions

(Figure 2) shows the stress field. The macroscopic stress of each point is computed in average $\left(J = \frac{1-\nu_s^2}{E_s} K_I^2\right)$.

The maximum stress happened at the root. (Figure 3) presents J-integral distribution over a small craze line. Trauma to the teeth as

Table 1: Mean Enamel and dentine modulus and Poisson's ratio.

	Enamel (Gpa)	Dentine (Gpa)
Young modulus	47±36	27±16
Poisson's ratio	0.21	0.239

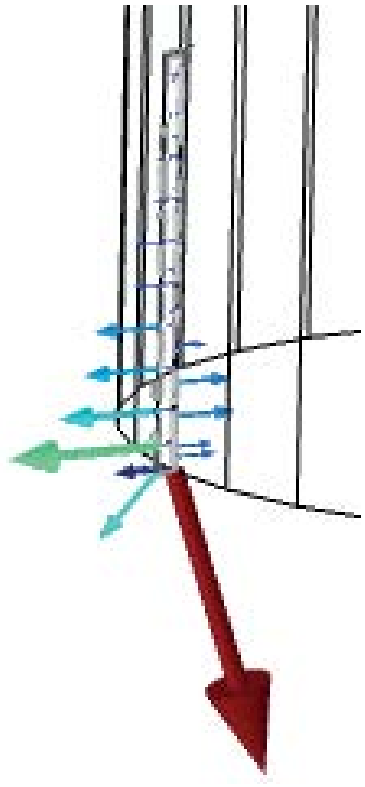

Figure 3: J-integral distribution over a small craze line

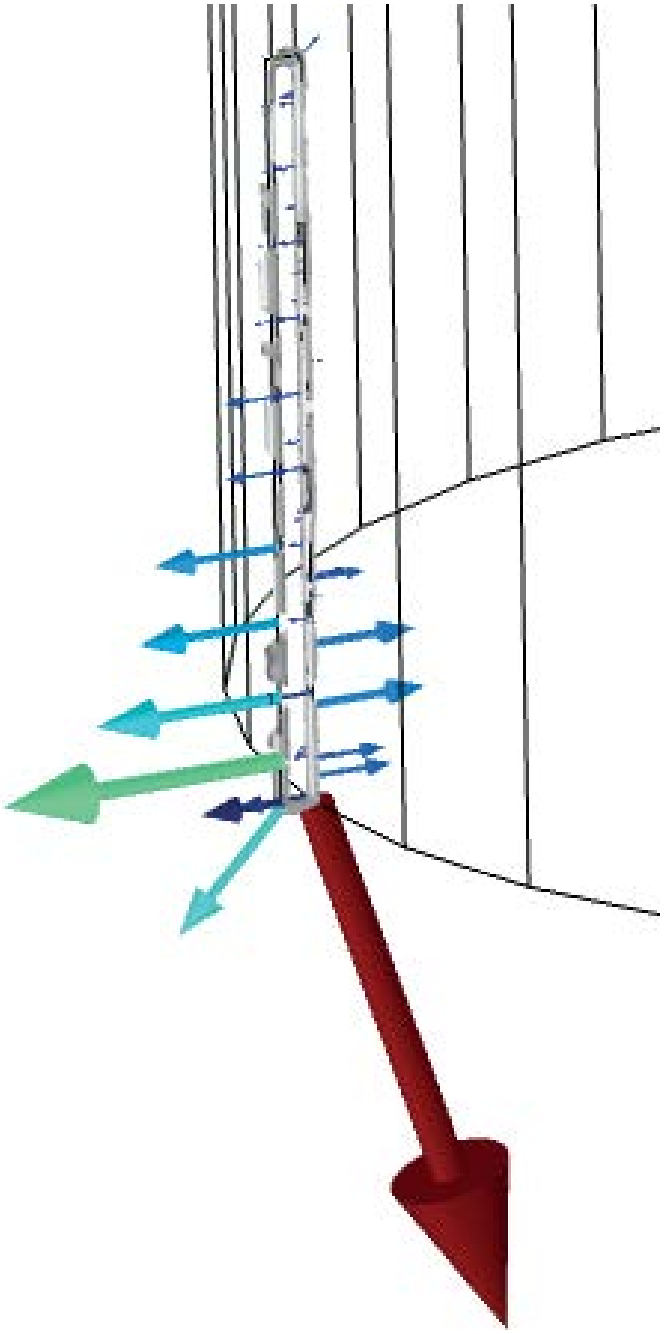

Figure 4: J-integral distribution over a medium craze line

a result of an accident, exercise, etc. can cause root fractures. Impact fractures are usually horizontal. This fracture can occur near the gingival edge of the root, the midline, or the end of the root. The location of the fracture and the age of the tooth affect the prognosis of the tooth. If the root fracture is horizontal and at the end of the tooth root, the chances of the tooth remaining are higher. But if the fracture is closer to the edge of the gum and more vertical, as it communicates with the gingival sulcus, it reduces the chance of long-term success. (Figure 4) reveals J-integral distribution over a medium craze line. As shown maximum J-integral value occurs at the bottom. Each J-integral point in a curve is a representation of the fracture measure without failure under loading sequences with decreasing load levels. The result is that there's no generalization from nonclinical to clinical stage. At any rate within the display test conditions, it appears certain that the ferrulized embed produces expanded resistance to disappointment. It is, in this manner, considered that other thinks about are required to affirm show results.

(Figure 5) depicts the value of J-integral distribution over a large craze line. The maximum J-integral value happened at the bottom with the orientation to inside the vacant tooth. Future investigates may got to make strides the current understanding of behavior of dental inserts supporting prosthesis rebuilding efforts as near as conceivable to the genuine clinical circumstance. So qualified professionals may set up the machine for weakness testing so as to imitate occlusal and horizontal drive as well.

(Figure 6) shows the stress intensity factor (SIF) versus crack length. The SIF value has maximum at the 10 percent of height level. The value is related to J-integral .

$$\left(J = \frac{1-\nu_s^2}{E_s} K_I^2\right).$$

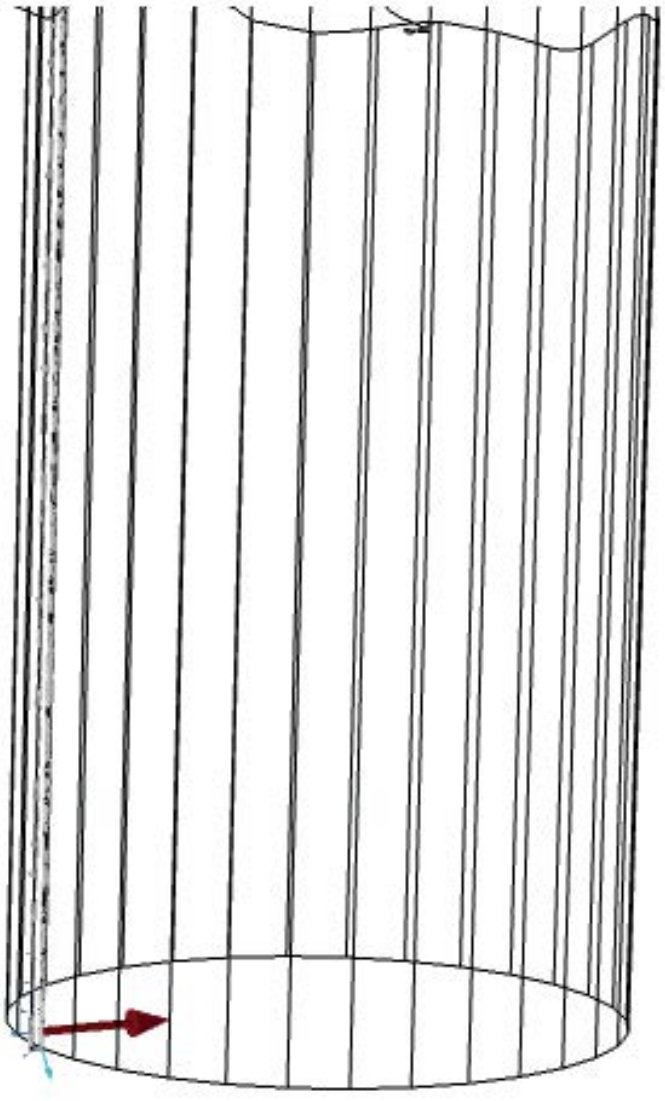

Figure 5: J-integral distribution over a large craze line

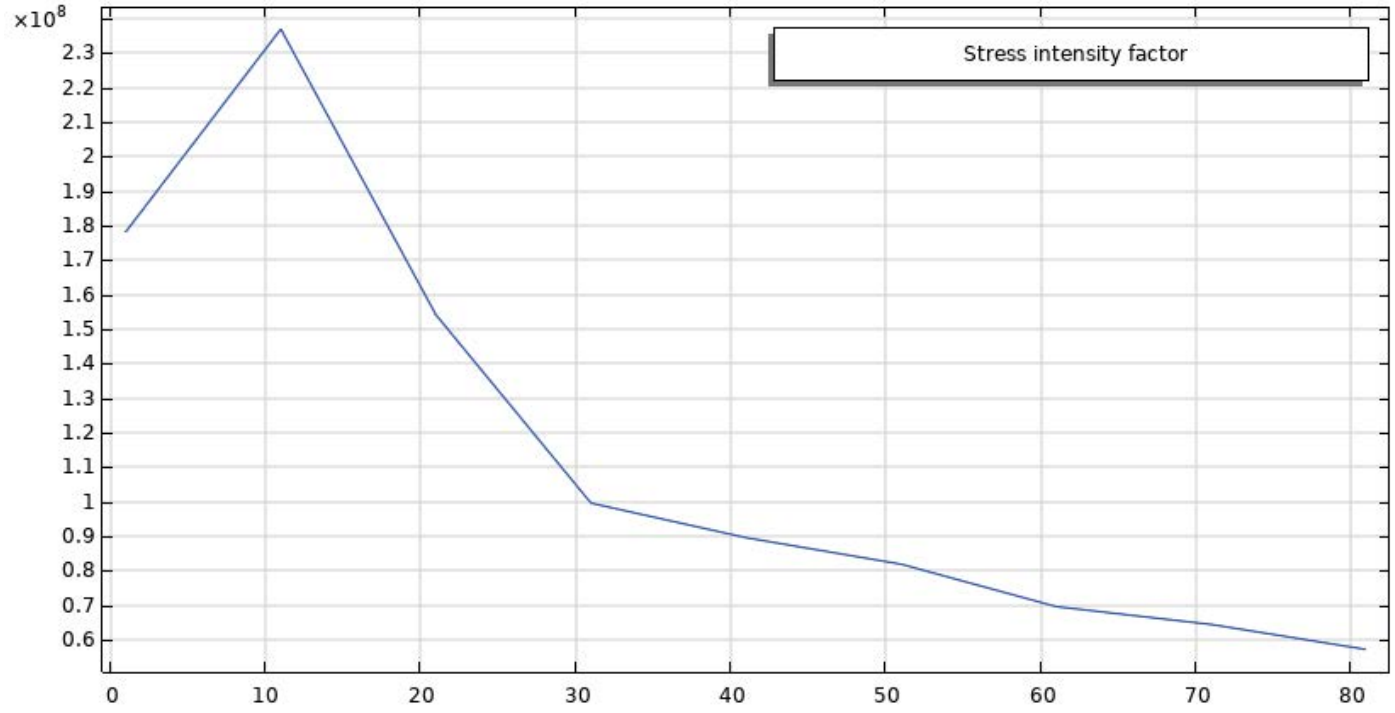

Figure 6: Stress intensity factor versus crack length

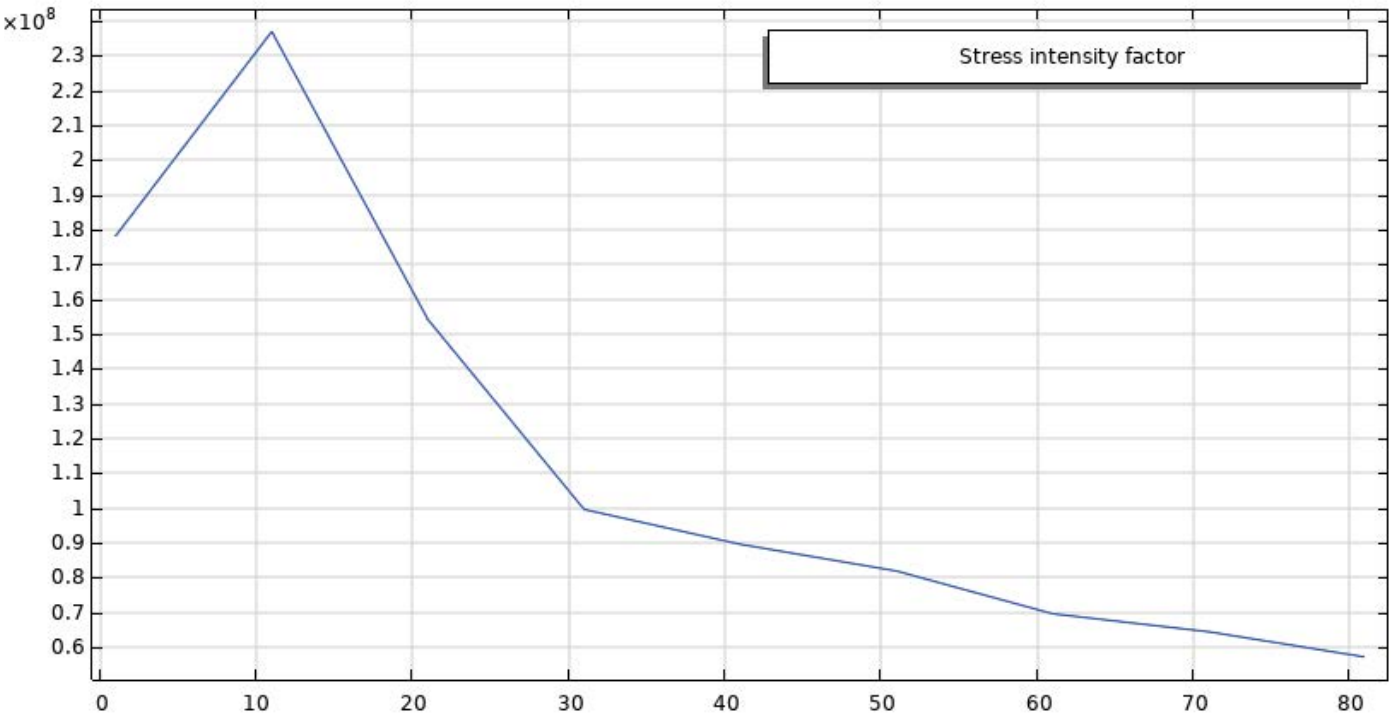

Figure 7: J-integral versus crack height

Using the domain integral method, the value of the J-integral is calculated on a number of contours around the crack at various stages of loading. The domain integral value agreed well with the value given by (7) for the prescribed amplitude KI. This consistency check ensures that the conditions for small-scale yielding are met. (Figure 7) presents the J-integral versus crack height. The j-integral value has maximum at the 10 percent of height level.

Conclusion

One of the major issues in dental science is the instability of the teeth after surgery. Commercial software is used to model the system of root-channelled teeth exposed to external force and thermal loading. The results show that extending the craze line length reduces the stress intensification factor; thus, less external force of heating load is required to initiate crack growth. Similarly, the presence of a thermal shock alters the strain and stress field. Furthermore, the results show that at the specific level of the craze line, the J-integral value is maximum, and the fracture stability of the tooth is increased. This study looks at the strain and stress field of a root channelled tooth in a normal condition. Taking into account the research finished, the following with results are obtained:

- The local peaks happen near the bottom of the root channelled tooth.
- Maximum stress happened at the root of the tooth.
- Faster growth of crack (in dry environment) can accelerated in inner craze line near the bottom of channel.

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