Original Research Article

Use Chemical Materials in Automatic Segmentation of Teeth Using X-ray

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ABSTRACT

One of the most complicated tasks in digital image processing is image segmentation. Due to increasing attention to this technique by researchers and turning it into a vital role, it is used in many practical fields such as medical applications. Today, in modern dentistry, techniques based on the use of computers, such as planning and planning before surgery, are being developed day by day. Each of these sub-bands contains important information that can be used in image segmentation. This important information is ignored in image segmentation. The main idea is to somehow add this information to the original image. The sub-bands of wavelet coefficients are added to the first sub-band of wavelet transform coefficients, corresponding to approximation coefficients, which are closer to the original image in terms of value and appearance, using integration methods. After that, the wavelet transform image is done. In this case, the obtained image contains more information than the original image, and better and more accurate segmentation is done. In this study, the EM algorithm was used to segment the dental radiology images, and to improve this algorithm, the k-means algorithm was used for the initial estimation of the parameters of the EM algorithm. Despite its simplicity, this algorithm is considered a basic method for many other clustering methods. Morphological operators have been used to improve segmentation.
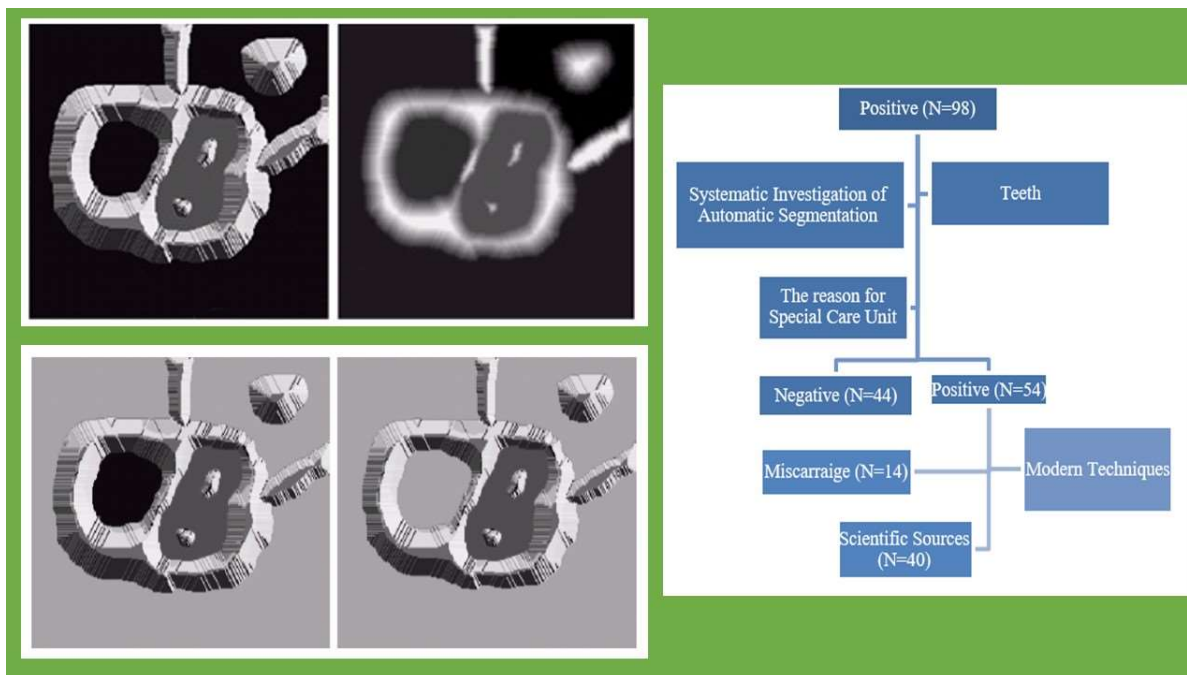
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G R A P H I C A L   A B S T R A C T

Introduction

X-rays, also known as radiographs, are an essential part of any dental care treatment plan. With the help of a dentist, they can prevent dental problems before they become a major problem. With aid of a dentist, they can diagnose possible oral care problems in the patient's mouth [1-3]. X-rays are a form of energy that passes through soft tissue and is absorbed by dense tissue. Teeth and bones are very dense, so they absorb X-rays, while X-rays pass more easily through the gums and cheeks. X-rays are divided into two main categories: intraoral and extraoral as well as intraoral and extraoral: Intraoral is a type of x-ray that is taken inside the mouth. Internal X-rays are the most common type of radiography performed in dental practices.

Based on the results of the research conducted in the field of the number of remaining teeth in old age and the chewing ability of the elderly, if a person has at least 20 teeth in his mouth, he can chew most of the food. To have 20 or more teeth in old age, we recommend prevent the accumulation of plaque and tartar on the teeth by daily brushing, flossing, and periodic scaling, and visit the dentist regularly to check for signs of dental problems. The early stages should be diagnosed and treated in time. However, if you currently have less than 20 teeth, you can regain the ability to chew again by using dental prostheses. Thus, try to take good care of the remaining teeth [4].

The X-ray dose is so low that it is considered a safe procedure for most children and adults. However, the dentist or radiologist may use a lead apron to protect your chest, abdomen, and pelvic area. Tell your dentist if you think you are pregnant. Because even the smallest dose of radiation is dangerous for the fetus development. **Periapical X-ray:** In this type of radiograph, the overall structure of the tooth from the crown to the root and the surrounding bone is clearly defined. Through this type of radiography, gum problems under the teeth, impacted teeth, jaw

and mouth cysts, dental abscesses, tumors, and bone changes can be checked.

Occlusal X-ray: In this type of imaging, problems of the roof of the mouth and the floor of the mouth can be checked. In this type of occlusal radiograph, teeth that have not erupted from the gums, as well as cleft tissue in the roof of the mouth and jaw, oral cysts and extra teeth can be recognized [5-7].

Panoramic X-ray: This type of OPG radiograph shows all the parts and the general view of the jaw, teeth, sinuses, temporomandibular joints, and the nose area. In this type of imaging, the doctor can detect all the parts of the hidden teeth, abnormalities in the jaws, bones, the presence of tumors, cysts in the jaw, infections, and cracks in the teeth [8-10].

Digital X-ray: This type of digital imaging can be stored or sent to a computer. During the time of the person's first visit, a complete series of periapical images is prepared, which is about 14 to 21 films. This type of radiographic image is used to check decayed teeth [11-13].

Search strategy and selection of articles

Search in Scopus, Google scholar, PubMed databases, and by searching with keywords such as "Automatic Segmentation", "Teeth", "X-ray" and "Covid-11" to obtain articles related to the selected keywords [14-16]. Case report articles, editorials, and articles that were not published or only an introduction of them were available, as well as summaries of congresses and meetings that were in languages other than English, were ignored. Only the original research articles evaluated the effectiveness of different drugs in the COVID-19 treatment using standard methods were studied (Figure 1) [17-19].
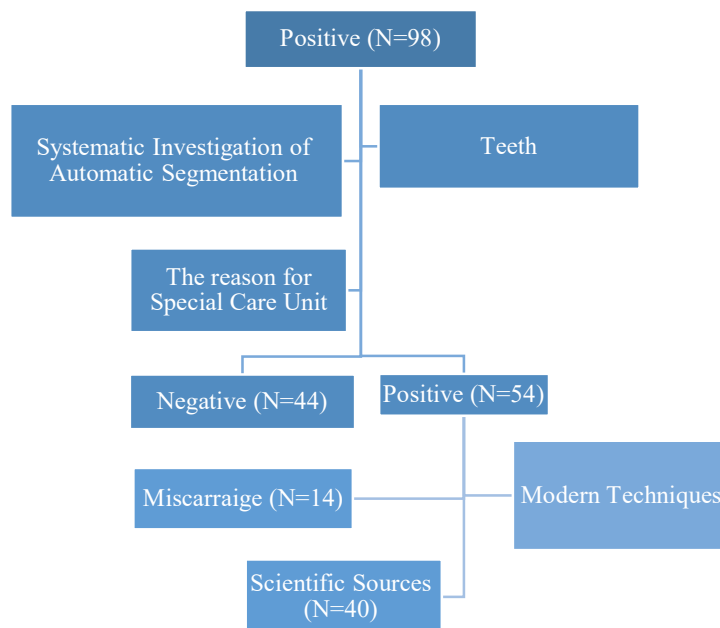
Figure 1. Flowchart of the included subjects.

Materials and Methods

Noise removal: Image noise reduction is one of the most important steps in most image processing applications. The goal in most image processing methods and algorithms is to preserve the image structure, such as the discontinuities and its inside edges. Noise is annoying in terms of appearance, and in addition, it causes problems in performing various images processing such as segmentation, recognition and interpretation. Therefore, increasing the image quality and removing the noise created in the image is a fundamental step before any processing operation [20].

Threshold

Due to the intuitive properties of ease of implementation and speed of calculations, image threshold plays an important role in the image segmentation. In this section, techniques are discussed based on the brightness intensity values or the properties of these values, for direct division of images into several regions.

Optimum global thresholding using the Atsu method

Thresholding is concerned to be a problem of statistical decision theory, which aimed to minimize the average error caused by assigning pixels to two or more groups. This problem has a closed solution called Bayes decision law. This solution is based on two parameters, the probability density function related to the brightness levels of each group and the probability that each group can occur.

Image thresholding is one of the most popular image segmentation methods. In this method, a histogram is used to specify the threshold values. In this article, a multi-level thresholding method for histogram-based image segmentation using learning and teaching-based optimization algorithm is presented. This algorithm is a new crowd-based algorithm inspired by the influence that a professor has on his students. The cost function used in this research was Kapur's entropy maximization criterion. The efficiency of the proposed method has been evaluated on 5 standard images. Likewise, its efficiency has been compared with three genetic algorithms (GA), particle optimization (PSO), and differential evolution (DE).

Unfortunately, estimating the probability density function is not a simple task, so this problem is simplified by making assumptions about the probability density function (such as the assumption that they are Gaussian functions). The method discussed in this section, which is called the Atsu method, is an interesting alternative [2].

This method is optimal in the sense that it maximizes the variance between groups, which is a well-known criterion in accurate statistical analysis. The main idea is that groups with good thresholding are separate in terms of the intensity values of their pixels, and conversely, the threshold that provides the best separation between groups based on their intensity values will be the best threshold (the optimal threshold). In addition to its optimality, the Atsu method has this important feature that it is completely based on the calculations performed on the image histogram and is easily obtained from a one-dimensional array.

Segmentation using watershed algorithm

The treatment of root-treated teeth whose crown structure has suffered severe destruction has always been considered. To restore such teeth, patients and dentists have been looking for a method that has more durability and survival and is exempt from exorbitant costs and complicated procedures. Nowadays, many dentists prefer to use the prefabricated post systems because they are very functional, low cost, and in some cases, more conservative than cast posts and blinds. In severely degraded roots, an adhesively bonded fiber post may improve fracture toughness and provide better stress distribution and transmission, thus strengthening the tooth.
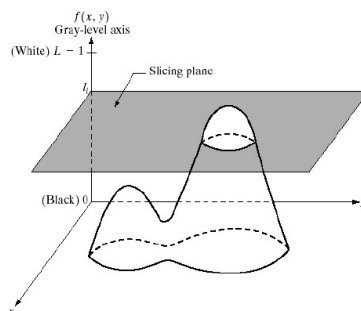
Figure 2. Topographical interpretation: (a) (points belonging to regional minimum), (b) (points on the hill), and (c) (points on the geyser) [2].

Among the methods of restoring endodontic teeth, are the use of posts and blind casts, prefabricated posts, crown build-ups with the help of restorative materials such as amalgam, composite, etc. Of course, each of them has advantages and disadvantages. Due to the wide use of this type of treatment, and given that most canal filling materials (gutta-percha) is emptied to create a post space, and there is also the possibility of sub-canals, and the remaining gutta-percha in the apical part of the canal cannot be filled. To provide the channel, it is important and necessary to create a flood by means of post and blind construction materials and adhesive material [21-23].

The connection of cement to the post is always one of the problems of cementing the post. It seems that using a composite instead of a cement post, one of the bonding interfaces is removed and the bonding discussion is only postponed to the adequacy of the bond between the teeth/glue/composite and the problem of high C. -Invoice when cementing the posts. If we assume

that one of the main causes of failure in the restorative treatments is the reduction of fracture resistance and tooth restoration, the purpose of this study is to investigate the fracture resistance of root teeth with different crown and root restoration methods.

The main goal of the segmentation algorithms based on these concepts is to find watershed lines. The main idea is simple. Suppose a hole is created in any minimum area and the entire topography should flow from below and allow the water to come up through the hole at a uniform rate. When the rising water in the catchment is close to merging, a dam is built to prevent merging. Finally, when the flood flow reaches a stage where only the top of the dams can be seen above the water lines, the borders of the dam correspond to the dividing lines of the watershed.

Therefore, they are the (connected) boundaries extracted by the water spreader algorithm. These ideas are demonstrated as in Figure (2).
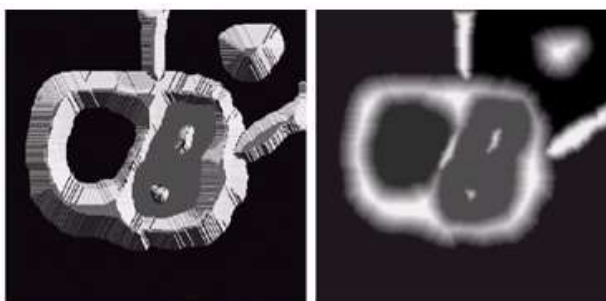
Figure 3. Main image and topographic view [2].

The general topology of the 3D display is intended to prevent water from dripping from the edges of the image. We assume that the entire environment of topological image is surrounded by barriers with a height higher than the highest possible mountain, whose value is determined by the highest possible brightness intensity in input image. Suppose a hole is created in each minimum area and the entire topography has flowed from the bottom, allowing water to rise through the holes at a uniform rate [24].
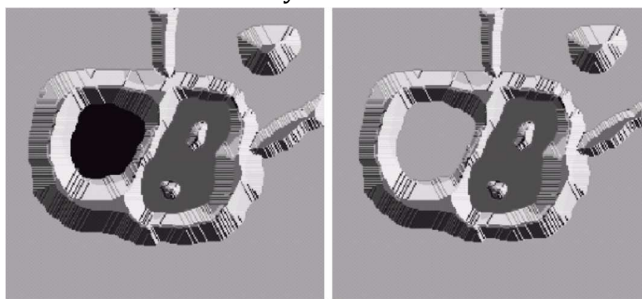
Figure 4. The first stage of the flow is shown in light gray and water flows in the first and the second drainage catchment [2].

Figure (3) (left) displays the initial stage of the flow, where the water is shown in light gray and covers only the areas that correspond to the very dark background in the image. In Figure (3) (right), it can be seen that the water flows in the first and the second drainage catchment.

Segmentation based on graph theory

The compatibility of the computational cost of graph-based algorithms with the power of today's computers has led to the use of graph theory in various applications of image processing, such as the processing and analysis of two- and three-dimensional images, identification in biometric systems, the segmentation, and classification of medical images.

In the following, after providing the essential definitions, one of the primary methods of image segmentation by graph theory is presented [4].

Definition 1: A simple graph G with n vertices and m edges consists of the set of vertices V (G) = {v_1, v_2, .., v_n} and the set E (G) = {e_1, e_2,.., e_3}, which is each edge is expressed as an unordered pair of vertices.

Definition 2: A simple graph and a weighted graph are graphs in which a label (weight) is assigned to each edge.

Definition 3: A simple graph G is connected if for every pair of arbitrary nodes v_i, v_j there is a path between them.

Definition 4: A tree T is a connected graph, in which there is no closed path.

Definition 5: A spanning tree corresponding to a connected graph G is a tree containing all the nodes of G and whose edges are subsets of the edges of G.

Definition 6: A minimum spanning tree for a connected graph G is a spanning tree whose sum of weights assigned to its edges is less than this sum for other possible spanning trees for the graph G.

In image processing algorithms based on graph theory, first the input image is converted into a weighted graph [5].

In this way, each pixel of the image becomes a node in the graph and the presence or absence of an edge between these two nodes in the image is determined. This neighborhood can be considered as a neighborhood of four or neighborhood of eight. The weight of each edge is

also determined based on the type of application and characteristics of the image and is usually considered as equal to the absolute value of the difference between the brightness levels of two pixels corresponding to the end nodes of each edge. Therefore, a two-dimensional image is characterized by a simple and weighted graph G (V,E), where the pixels v are mapped to the nodes of the graph and the neighboring pixels v_i, v_j form the edges (v_i, v_j).

Fuzzy clustering

In traditional clustering methods, clusters are produced, in each of which, each pattern belongs to only one cluster [6]. This classification is called hard clustering. In fuzzy clustering, the concept of each sample belonging to all clusters is proposed using the membership function. The result of fuzzy algorithms is a clustering, not a classification [25].

Segmentation of gray images is usually done by performing some transformations on the brightness of the pixels. Segmentation is usually highly complex. In [22], a new algorithm for the segmentation of dental images is presented, which is inspired by a biological technique based on information crowding and a cellular automata model. This algorithm tries to find similar pixels using a sensor function to determine which useful pixels are in that area. The method presented in this article is an imitation of an ant colony.
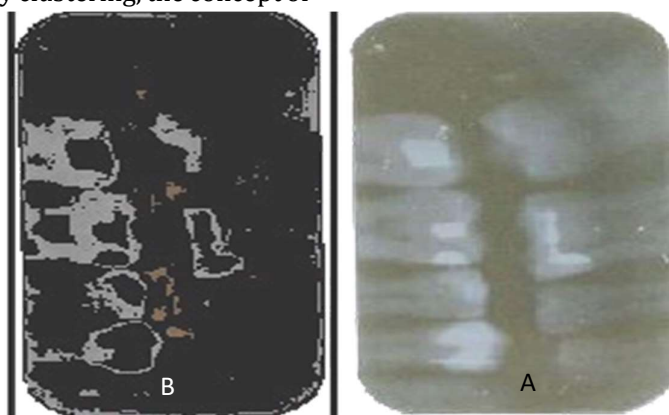
Figure 5. (A) Original image and (B) Segmented image using a biological technique and based on information crowding and a cellular automata model [21].

When there are a large number of unknown victims in accidents, identification based on dental features is more important [23]. Teeth segmentation using radiographic images is an important step to obtain a powerful automatic identification system. In this article, the anatomy of the teeth, the distance between the teeth and their placement angle, as well as the space between the upper and lower jaw are used for segmentation. An example of segmented image is demonstrated in Figure 6.
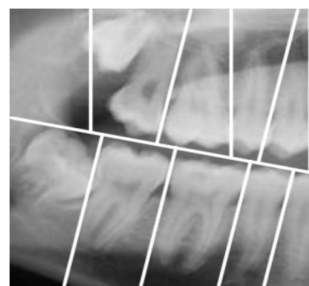

Figure 6. Segmented image using the anatomy of the teeth, the distance between the teeth and their placement angle [23].

Another method presented by Robert Vanat in [24] for the segmentation of dental images is based on the distance between the neck (the middle part indicated in Figure (7)) of the teeth, and there is no need for a large distance between adjacent teeth. The result of this method is illustrated in Figure 7.


Figure 7. The segmented dental neck based on the distance between this part and the adjacent tooth [24].
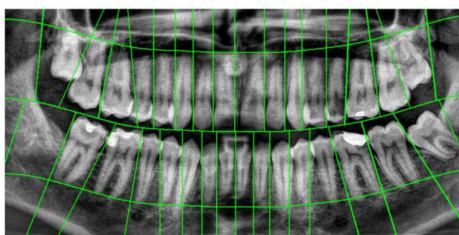
Figure 8. An example of the segmentation image by the algorithm provided based on the distance between the neck of the middle part of tooth.

Another method presented in [25] uses dental images using active edges for segmentation. This method is based on the brightness intensity of all dental images; the results of this method are depicted in Figure 9.
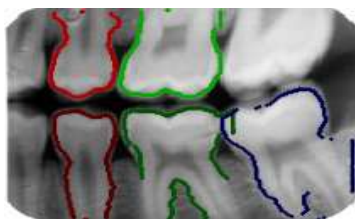
Figure 9. Segmentation using active edges (25).

Radiographic effect of low power laser

Panoramic radiography is a kind of radiography equipment used in which the patient's head is fixed and the part of the ray shot is rotated from one side of the face to the other side and a complete panoramic image of the teeth, maxilla, and temporomandibular joints is prepared. The amount of radiation to the patient in this technique is much less than that of complete dental periapical radiography, which in the new samples, the total radiation is almost equal to the amount of two periapical radiations. Figure 3-2 shows an example of a panoramic radiographic image.

Panoramic radiography has conventional and digital types. The expansion of digital technology has made a big change in the continuous development of this device and its technique and quality. Some panoramic devices are basically digital and some of them are conventional that can work by connecting additional digital devices. Cephalometric radiography device can be also connected to it. The American Society of Radiological Health recommends that only one panoramic radiograph be taken for routine dental examinations. Another name of these devices is APG or orthopantograph.

Traumatic dental injuries are one of the most common events in childhood and adolescence. Among these injuries, ovalgen (falling out of the tooth from the socket) is considered as a real emergency and requires fast and accurate treatment by the dentist. Otherwise, it can lead to the loss of the patient's tooth, which is important considering that most of these Injuries occur in the anterior teeth and multiply. Many studies have shown that low power laser, in addition to have soothing and anti-inflammatory properties, increases blood flow and lymphatic drainage in the area and leads to increased immune system function and cell proliferation. Therefore, it can effectively improve the healing process.

Most of the injuries to permanent teeth, Traumatic Dental Injuries (TDI) are caused by

falls, and then traffic accidents, violence, and sports are the etiological causes of TDI. Boys are twice as likely to have TDI as girls and are more likely to have more than one injury. Furthermore, people with special needs are more prone to TDI. One of the most serious dental injuries is avulsion, which refers to the complete displacement of the tooth outside the dental socket. As a result of such injuries, the pulp, periodontal fibers and alveolar bone are severely affected and the nerve-vascular fibers of the tooth and periodontal joints are cut. The pattern of damage to the tooth, primarily, depends on factors such as:

1- Impact energy,

2- The impact direction, and

3- The elasticity of the periodontal structures supporting the tooth, among which the elasticity of the supporting tissues is the most important determining factor in the degree of extent. The severity of damage is concerned.

Damage to baby teeth due to the elasticity of the bone tissues around the baby teeth usually causes tooth displacement and less hard tissue fracture, but in permanent teeth due to the less elasticity of the tissues around the teeth, the opposite will happen. Ovalgen injuries include 0.5-16% of all dental injuries (8) and are often seen at the age of 7-9 years old and in the maxillary permanent central teeth, because at this age the central teeth are growing, the structures surrounding the tooth are flexible and periodontal ligaments show very little resistance against extrusive forces. More involvement of maxillary centrals can be due to the position of these teeth in the jaw because they are less protected than other teeth. The presence of increased overjet of incisors, anterior open bite, and lack of complete coverage of the lips and their failure to meet have been reported as the predisposing factors [26-28].

In children with an overjet of more than 3 mm, the probability of this occurrence increases. No relationship has been seen between socioeconomic status and traumatic dental injuries. In most cases, the trauma leading to avulsion involves one tooth, but in some cases, avulsion can occur in the form of involvement of multiple teeth. The loss of anterior teeth in children and adolescents due to visible defects causes them to be rejected from their peers, social exclusion follows, and they feel ashamed and embarrassed while smiling, and can cause consequences related to the reduction of social function and the quality of their lives.

The ideal treatment for an Avulsed tooth is immediate repositioning with an extra-alveolar time of less than 5 minutes. But unfortunately, most Avulsed teeth are replanted with a delay of about 1 hour, and this long extra-alveolar time causes the loss of PDL cells, followed by failure in placement. The current clinical studies show that the failure rate of replantation treatment during the first 5 years after implantation is approximately 30-40%.

Due to the factors related to the accident, such as the presence of the extensive and life-threatening injuries, the emotional state of the patient at the time of the injury, or the lack of knowledge, and self-confidence of people and even experts about the methods of placement, immediate placement rarely happens. Victims of jaw and facial injuries, including dental ovalgen, usually receive first aid from people other than trained dental personnel. Therefore, in most cases, important factors for the success of replantation cannot be controlled. Studies have shown that this scenario can be significantly improved by educating the general public and non-oral health professionals about dentoalveolar trauma and the maintenance environment to achieve successful treatment. Immediate tooth replantation leads to better restoration of PDL and significantly reduces the incidence of root resorption. Therefore, minimizing the time elapsed between trauma and tooth placement and keeping the avulsed tooth in appropriate intermediate environments may reduce the harmful effects of the extra-alveolar

period on the root surface and pulpal revascularization and lead to a significant increase in prognosis.

Normally, tooth placement occurs within 1 to 4 hours after avulsion, and after that, the degeneration of PDL cells is a common event, and the presence of necrotic PDL remnants on the root surface will stimulate the occurrence of inflammatory root analysis, which is the main reason for Avulsed tooth loss.

To have a good prognosis, the proper treatment plan after the injury is very important. Although Avulsed tooth placement cannot be done immediately in many cases, it is the treatment of choice for this type of injury. Of course, there are certain conditions in which tooth replantation is not indicated. For example, teeth with severe caries or periodontal disease, special medical conditions such as immune system deficiency, severe heart disease, uncontrolled epilepsy disorders, severe mental disability, severe uncontrolled diabetes, and lack of alveolar integrity, or patient non-cooperation are considered as contraindications for tooth replant. However, the use of guidelines can be used to continue to find the best medical care and achieve the maximum desired results. The American Association of Pediatric Dentists presented a guideline by reviewing dental articles; the last edition of which was published in 2011 (Figures 10 and 11).
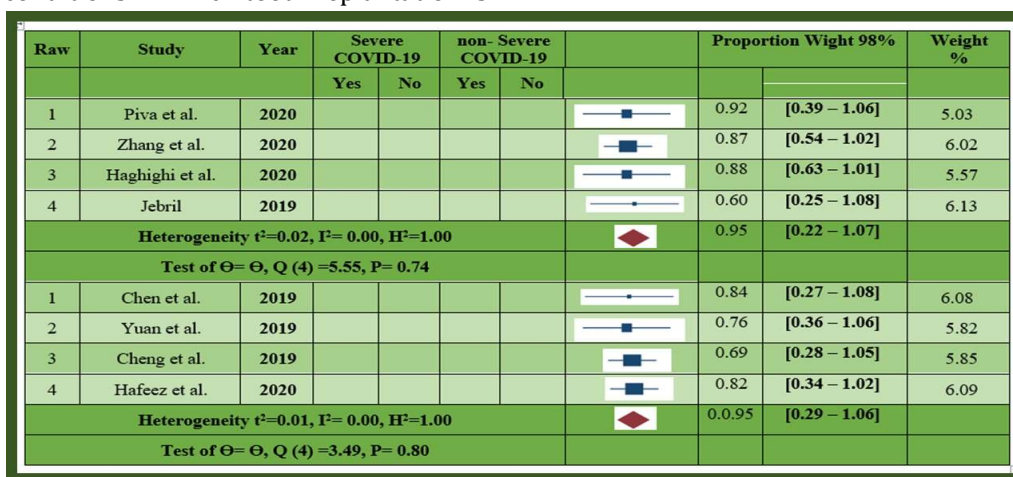
Raw	Study	Year	Severe COVID-19		non- Severe COVID-19			Proportion Wight 98%		Weight %
			Yes	No	Yes	No				
1	Piva et al.	2020						0.92	[0.39 − 1.06]	5.03
2	Zhang et al.	2020						0.87	[0.54 − 1.02]	6.02
3	Haghighi et al.	2020						0.88	[0.63 − 1.01]	5.57
4	Jebril	2019						0.60	[0.25 − 1.08]	6.13
Heterogeneity t^2=0.02, I^2= 0.00, H^2=1.00								0.95	[0.22 − 1.07]	
Test of Θ= Θ, Q (4) =5.55, P= 0.74										
1	Chen et al.	2019						0.84	[0.27 − 1.08]	6.08
2	Yuan et al.	2019						0.76	[0.36 − 1.06]	5.82
3	Cheng et al.	2019						0.69	[0.28 − 1.05]	5.85
4	Hafeez et al.	2020						0.82	[0.34 − 1.02]	6.09
Heterogeneity t^2=0.01, I^2= 0.00, H^2=1.00								0.0.95	[0.29 − 1.06]	
Test of Θ= Θ, Q (4) =3.49, P= 0.80										

Figure 10. Forest plot showed Systematic Review of "Automatic Segmentation" and "Teeth".

| Raw	Study	Year						Proportion Wight 98%		Weight %
1	Hosseini et al.	2008						0.56	[0.11 − 0.66]	1.55
2	Ibrahim et al.	2020						0.26	[0.15 − 0.48]	4.33
3	Kalantari et al.	2020						0.48	[0.19 − 0.55]	6.77
4	Rothan et al.	2020						0.24	[0.17 − 0.29]	3.03
Heterogeneity t^2=0.05, I^2= 0.07, H^2=0.78								0.22	[0.03 − 0.32]	
Test of Θ= Θ, Q (4) =3.01, P= 0.11										
1	Michler et al.	2021						0.77	[0.39 − 1.06]	3.11
2	Chiusano et al.	2020						0.65	[0.54 − 1.02]	6.05
3	Delin et al.	2020						0.73	[0.63 − 1.01]	4.06
4	Gadlage et al.	2010						0.41	[0.25 − 1.08]	7.03
Heterogeneity t^2=0.12, I^2= 0.01, H^2=0.99								0.48	[0.22 − 1.07]	6.03
Test of Θ= Θ, Q (4) =1.45, P= 0.14										
1	Samiei et al.	2021						0.84	[0.27 − 1.08]	6.08
2	Stoesal et al.	2020						0.76	[0.52 − 0.22]	5.82
3	Uzunova et al.	2020						0.11	[0.54 − 0.89]	5.85
4	Wang et al.	2020						0.39	[0.12 − 0.99]	6.09
Heterogeneity t^2=0.21, I^2= 0.04, H^2=0.39								0.77	[0.19 − 1.00]	
Test of Θ= Θ, Q (4) =3.35, P= 0.34										

Figure 11. Forest plot showed "Teeth", "X-ray", and "Covid-19".

Noise reduction

The low contrast and noise of digital radiology images make segmentation difficult in some areas, so pre-processing methods such as noise removal should be applied to the image. Noise reduction improves image segmentation operations in later stages [29]. One of the widely used filters to remove noise is the Wiener filter. This filter is also known as least mean square error. In this thesis, the Wiener filter was used to reduce the noise of the images, which was explained in the previous section. An example of the results obtained by applying this filter is depicted in Figure 12.
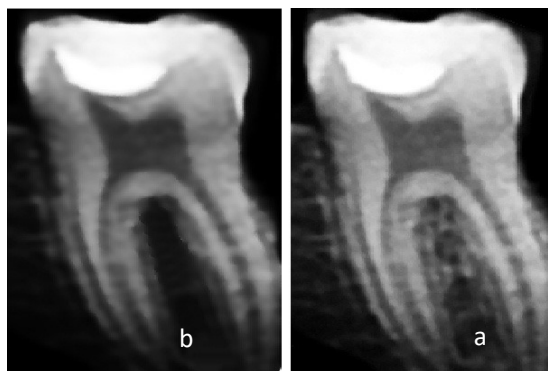
Figure 12. (a) The original image and (b) The image after applying Wiener noise removal filter.

Conclusion

The treatment of root-treated teeth whose crown structure has suffered severe destruction has always been considered. To restore such teeth, patients and dentists have been looking for a method that has more durability and survival and is exempt from exorbitant costs and complicated procedures (85). Today, many dentists prefer to use the prefabricated post systems, because they are very practical, low cost, and in some cases, more conservative than casting posts and blinds (86). Among the methods of restoring endodontic teeth are the use of posts and blind casts, prefabricated posts, crown build-ups with the help of restorative materials such as amalgam, composite, etc. Of course, each of them has advantages and disadvantages.

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