CLINICAL DECISION SUPPORT AND TRAINING SYSTEM FOR DIAGNOSIS AND MANAGEMENT OF COMPLETE DENTURE COMPLAINTS

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Abstract

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Background: Complete denture is considered one of the most challenging treatment modalities in dentistry. Any error occurs during any step of the complete denture fabrication can result in patient's complaint. Troubleshooting complete denture complaints is very challenging for several reasons. First, all the teeth are connected into one denture base that is supported by a movable resilient mucosa make it difficult to isolate the errors. Second, one patient's complaint could be due to several causes and at the same time one cause can lead to many patient's complaints. Third, the diagnosis of each patient's complaint must be approached systematically because adjusting the denture in a wrong spot may add another problem. Most of the complete denture treatment is provided by general dentists and depend only on their undergraduate training and clinical experience. There is a concern about the competency and level of skills of the undergraduate students in mastering the complete denture skills due to limited exposure to enough cases.

The purpose of this research is to develop a new clinical decision support and training system to aid the general dentists and undergraduate students in diagnosis and management of complete denture complaints.

Method: The new clinical decision support and training system was developed using Exsys Corvid Core software. The knowledge base of the system for the complete denture complaints, the complaints causes and the management protocol for each complaint were retrieved from the literature. The software was successfully loaded with 123 rules representing 48 patients' complaints along with its detailed diagnostic methods and management protocol. After system development, the system was validated by ten expert prosthodontists using a survey questionnaire. The questionnaire results were statistically evaluated using Cronbach's Alpha test.

Results: The Cronbach's Alpha reliability coefficient was 0.847, which represent a good internal consistency. The validation questionnaire results showed that all ten prosthodontists agreed on the need of such system and its user friendliness. Also, all prosthodontists agreed that the system is a good tool to assist the general dentists and undergraduate students in diagnosis and management of complete denture complaints. 90% of the prosthodontist agreed with the knowledge base of the system for the complete denture complaints, the causes of each complaints and the management protocol for each complaint.

Conclusion: The clinical decision support and training system to aid the general dentists and undergraduate students in diagnosis and management of complete denture complaints was developed. The overall agreement of the ten evaluating prosthodontists with the system indicates that the system was successfully developed.

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CHAPTER I: INTRODUCTION

1.1 Introduction:

Edentulism is complete loss of all natural teeth that is now considered as a disability that affects the patient's esthetic, function and quality of life. . Dental caries and periodontal disease are the most common causes of teeth loss. Other causes include trauma, congenital absence and oral cancer. According to National Health and Nutrition Examination Survey, 2011–2012, 18.9% of American citizens aged over 65 are edentulous.[1] Although the prevalence of edentulism is declining in the last two decades, the number of edentulous people is not declining but it may increase due to the growth of the overall population over time. The population of 65 years and over is growing faster than the rest of the population by 15.1% each decade when comparing the US census data in 2000 and 2010.[2]

The conventional complete denture is considered the most common treatment for edentulism. Almost 90% of edentulous patients ware complete dentures.[3] There is a misconception that the need for complete denture will decline over time. A study by Douglass et al investigated the subject and showed that in 2020 there will be 37.9 million edentulous people compared to 33.6 million people in 1991 that still need a complete denture treatment.[4]

The introduction of dental implants in dentistry provide better options for treatment of edentulism by replacing the missing teeth with a fixed partial denture or implant retained and /or supported overdenture. These options improve the patients chewing ability and retention of the prosthesis that considered as limitations of complete denture. The recent recommendation by experts for the first choice standard

of care treatment for the edentulous mandible is two implants retained overdenture.[5] Unfortunately, implant prosthesis could not be a viable option for the majority of edentulous patients for several reasons. First, the cost of the treatment with implant prosthesis is significantly high as compared to conventional complete denture. The analysis of demographic data in the United States showed that there is a higher prevalence of edentulism among people with low socio-economic status (13.9%) as compared to high socio-economic status population (2.5%).[6] The cost of implant-supported overdenture is 3.1 times more than the cost of conventional complete denture. Fixed implant prosthesis cost 6.5 times the cost of conventional complete denture.[7] Therefore, most of the edentulous patients have low socio-economic status and cannot afford dental implants cost. Second, The residual ridge resorption that occurs after the teeth extraction is a chronic and continuous disease that continue throughout the patient's life at a steady rate.[8] This can cause significant decrease in the amount of alveolar ridge bone height and width required for the dental implants especially in the mandible. Third, most of the edentulous patients are of old age and most likely to have systemic diseases and use medications that make the dental implant surgery contraindicated for them.[9]

1.2 Background and statement of the problem:

Complete denture is considered one of the most challenging treatment modalities for dentists because it requires high degree of competency and skills. The complete denture is a full mouth construction that requires several clinical visits and laboratory procedures that must be carefully executed. Any error occurs during any step of the complete denture fabrication can result in complications and patient dissatisfaction. Troubleshooting complete denture complaints after delivery is more

challenging than that of fixed prosthesis because all the teeth are connected together into one denture base. This denture base is supported by a movable resilient mucosa. Having an error in one area of the denture affect the rest of the denture and is difficult to be isolated and corrected unlike the fixed prosthesis of individual crowns or bridges that is easy to diagnose. A study by Walton and MacEntee compared between the maintenance requirements between fixed partial dentures and complete dentures prosthesis. The results showed that the complete denture prosthesis required about three times more adjustments than the fixed prosthesis.[10] The clinical experience also has an effect in troubleshooting complete denture complaints. A study by Kimoto[11] was done to compare between the experienced clinician (more than 10 years of practice) and the non-experienced clinicians (less than 5 years of practice) in the number of denture adjustments after insertion. The results showed that the non-experienced clinician required seven visits while the experienced clinician required only 4 visits in order to gain patient's satisfaction with the denture. Therefore, complete denture treatment is more efficient when specialist or a prosthodontist provides it.

The reality is that more general dentist provides complete denture than the prosthodontists in the United States. The reason could be due to the significant higher cost for dentures done by prosthodontists as compared to those done by general dentists. A recent survey about the cost of complete denture among general dentists and prosthodontists showed that the average fees for complete denture in general practice was 2,900 USD while the average fees of prosthodontist was 3,500 USD and can reach up to 10,000 USD.[12] Public and private insurances can take some of the financial load of the patients. However, only 53% of prosthodontics patients have

private insurance and 3% are supported by public insurance like Medicaid while the remaining 44% are paying out of their pocket for treatment.[13] The number of practicing prosthodontists can also play a role. According to the American Dental Association, 79% of all active dentists in the United States practicing in general practice while 21% are practicing in a specialty practice (Figure 1). The prosthodontists represents 8.6% of all dentists giving a number of 3372 prosthodontist that is small number to treat millions of edentulous patients.[14] A survey of 701 prosthodontists in the United State about the time provided for different prosthodontics treatment showed that they spend only 11.7% of their time in providing complete denture treatment and most of the remaining time for fixed partial denture and implant services.[13] Therefore, more general practioners nowadays providing complete denture service for the patients depending only on their undergraduate training and clinical experience but they lack the comprehensive training and skills that the prosthodontists gained through their prosthodontics training.

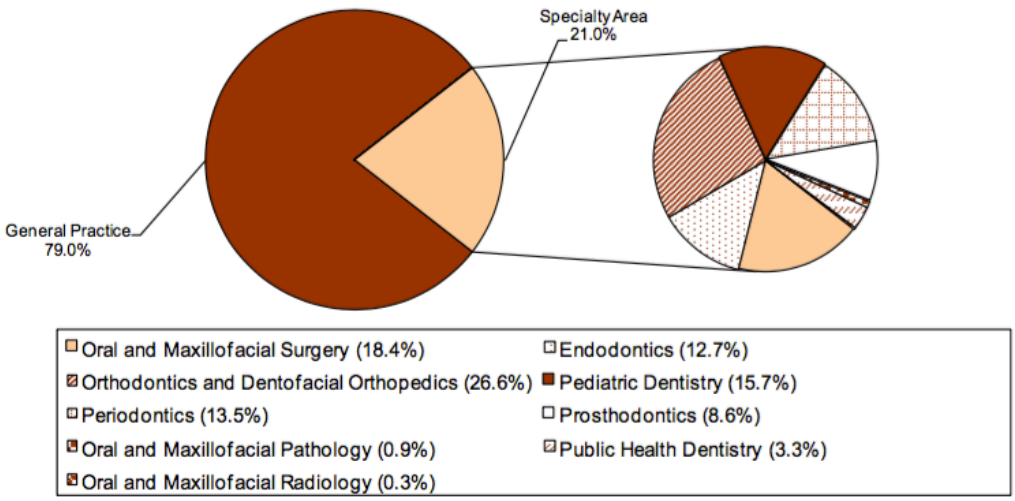

Figure 1: Distribution of all professionally active dentists in the United States by practice[14]

There is a concern about the competency and level of skills of the undergraduate students in mastering the complete denture skills due to limited exposure to denture cases. A survey study investigated the requirements of complete denture units needed for graduation in 44 dental schools in the United States. The results showed that 83% of the schools required the students to finish three units and each unit represent either upper or lower denture or a removable partial denture. The remaining school had no minimum number of dentures to graduate.[15] The reason for that is the increased number of students and decrease number of edentulous patients seeking treatment in the dental schools as advocated by dental educators. As a result the dental students have difficulty in troubleshooting complete denture complaints during the school time and after graduation as a general practioners.[16]

Complete denture complains can be divided into four main categories: comfort, function, esthetics and phonetics. Each category includes several complaints that lead to patients' dissatisfaction. Among these complaints are lack of retention, lack of stability, pain, burning sensation, sore spots, difficulty in chewing, tongue space restriction, difficulty in speech, gagging reflex, food accumulation under the denture, bad breath, temporomandibular disorders and etc. [17]

The diagnosis of these complaints is very challenging because one patient's complaint could be due to several causes and at the same time one cause can lead to many patient's complaints. For example, loss of retention of maxillary denture can be caused by six different causes: (1) overextension of the denture borders, (2) underextention of the denture borders, (3) absence of the posterior palatal seal, (4) anterior placement of the posterior palatal seal on the hard palate, (5) unbalanced

occlusal contacts unilaterally and (6) occlusal interference in the anterior teeth. On the other hand, If the maxillary denture borders is overextended palataly, the patient can have many complaints such as: (1) sore spots, (2) loss of retention, (3) difficulty in swallowing and (4) gagging reflex. The diagnosis of each patient's complaint must be approached systematically by checking the prosthesis step by step until reaching the patient satisfaction. Adjusting the denture in a wrong spot that is not the cause of the problem may add another problem that will complicate the case.[18]

Several studies investigated the most frequent complaints that occur in complete denture patients. A study by Brunello and Mandikos [19] evaluated 100 patients who are referred to specialist care by general dentists because they are unable to diagnose the patient's complaints at their existing dentures. The sample included 63 men and 37 women with a mean age of 68.7 years. The results were divided into two parts. The first part was about the common patients complaints from their complete dentures while the second part was about the existing construction errors in the denture. The most common complaint was pain and discomfort in the tissues under the denture in 75% of the patients. 61% of patients complained from difficulty in chewing and 59% of the patients complained from denture looseness. Accumulation of food and difficulty in speech were the least frequent complaints that occurred in 17% and 16% of patients respectively. In regards to existing denture assessment, it showed that 94% of dentures had incorrect jaw relationship, 88% had underextended borders, 72% had premature tooth contact and 68% had incorrect occlusal vertical dimension. The study showed also the lack of enough skills of general dentists in diagnosis and /or correction of complete denture complications since they referred them to specialist care. Another study by Aghdaee et al[20] evaluated 80 complete

denture wearers having difficulties with their dentures. The results showed that 80% of patients complained from food accumulation under the denture, 78.8% complained from denture looseness, 77.5% complained from difficulty in chewing, 37.5% complained from pain and discomfort under the dentures and 22.5 % have difficulty in speech. After assessment the existing dentures, there was a significant relationship between the existence of underextended denture borders and food accumulation and also between the existence of overextended maxillary denture borders and the mucosa ulceration.

The complexity of complete denture complaints makes a challenge for general dentists and undergraduate students to diagnose and manage them. A study by Cabot compared between prosthodontists, general practioners and dental students, who finished the prosthodontic course in their dental school, in their ability to assess the complete denture faults. 30 general practioners, 30 students and 10 prosthodontists participated in the study. Three patients with known faults either in maxillary or mandibular border extensions, freeway space or in centric relation position were examined by the practioners. The results showed that there was a significant variation between the three groups in relation to assessment of maxillary base extension, mandibular border extension, freeway space and the need of maintenance before renewal the complete denture. Most of the prosthodontists agreed on the proper diagnosis for the denture faults. On the other hand, the general practioners and dental students agreed for some factors but did not agreed on most of the other factors for assessment of the complete denture. This variability could leads to accentuation of patients' problems due to unobserved errors by general practioners and dental students.[21] Therefore, the presence of rule based system that provides a step-by-step

approach for diagnosis and management of complete denture complaints at the point of care is quite beneficial. In order to achieve that, we propose developing a clinical decision support system (CDSS) that helps the inexperienced clinician and students to reach to the final diagnosis and troubleshooting the patient's complaints. The system will provide the user with a list of all reported patient's complaints to select one. After that, the system will ask the user, in step-by-step way, to check the most common causes for the problem and providing the needed illustrations and method of examination along with the armamentarium needed. The user will follow the steps to solve the problem to reach the patients' satisfaction. If the patient's complain dose not resolved, the system will suggest checking another cause for the patient's complaint and so on. All the information that stored in the system's knowledge base is all built according to evidence-based knowledge available in the literature to provide the ideal treatment method. The final outcome of the system is to advice the user according to the entered data to:

1. Correct the existing denture if the problem is correctable.
2. Replace the denture with a new conventional complete denture if the problem is not correctable.
3. Replace the denture with implant retained/supported over denture if the problem will still exist with the conventional complete denture.

1.3 Significance of the study:

Most of the general dentists and the inexperienced clinicians have difficulty dealing with complete denture patients' complaints. They think that replacing the denture with a new one will solve the problem. Many simple corrections can be done to the existing denture that prevent the unnecessary cost and time for making a new

denture. Also, the new denture might have the same problem if it is done in the same way. Other dentists try to solve the problem by adjusting the denture without complete knowledge and skills that might worsen the situation. For example, if a patient visited his dentist complaining from loose denture and difficulty in chewing. The dentist might start adjusting the denture borders or adjusting the denture teeth while the reason could be lack of posterior palatal seal. The build up of posterior palatal seal area will improve the denture retention but now the patient have another problem with short denture borders or unbalanced occlusion from the unnecessary adjustment.

The failure in solving the patients' complaints and wasting multiple visits until reach the patients' satisfaction could affect the dentist practice. It will decrease the patients' confidence in their dentists that might lead them to switch to another dentist. Also, it will affect the dentist practice by decreases the patients' referrals. The satisfied patient is the best advertising tool for the dentist and lead to more referrals from the patients' family and friends.

The clinical decision support systems have proven its importance efficiency in improving patients' care in medicine as well as in dentistry.[22] Our study proposes a rule based clinical decision support system to help in diagnosis and managing the complete denture complaints to solve the previous mentioned problems. In order to facilitate using the system at the point of care when needed, the proposed system will be web-based and easy accessible on any computer or smartphone using the Internet.

The proposed CDSS will also provide several advantages for the complete denture patients. It will encourage the general dentists to treat more edentulous patients with complete denture instead of referring them to specialists as they become more confident in managing the complete denture complaints. The new system is an efficient way in managing complete denture patients by decrease the number of post-delivery visits, saving the trips and money for the patients and saving the clinic time for the dentist to see another patient. The system also can be used as a training system for the undergraduate student in the clinical floor. Understanding the different causes of patients complaints and the protocol to manage them will help the student to avoid those problems during denture construction.

1.4 Objectives and goals of the study:

The study is designed to achieve the following goals and objectives:

1. **Design and develop a new CDSS for diagnosis and management of complete denture complaints at point of care:** As mentioned before in this chapter, the complexity of diagnosis and management of complete denture complaints necessitates a high degree of skills to manage them. Therefore, most of the general dentists having difficulty in troubleshooting the problem at the point of care. Although there is many CDSS in the field of dentistry but there is a gap in the domain of troubleshooting complete denture complaints. Therefore, our main objective in this study is to develop the CDSS needed to help managing such cases.

2. **Design a training tool for dental students and inexperienced clinicians:** One of the goals of the new CDSS is to be used as training system even in the absence of patients as part of the dental students electronic curriculum or as part of continuous education courses for the inexperienced clinicians. Knowing the complaint and what cause it will help in avoiding that problem during the denture construction and provide more efficient treatment for the complete denture patients.

3. **Provide a system with evidence-based knowledge and not depending on clinical experience only:** The current direction of dentistry is that all treatment interventions have to be supported by evidence. Our goal in the new CDSS is to ensure that all the knowledge rules built-in in the system are supported by literature in order to provide the best treatment for the patient.

4. **Usability and flexibility of the system:** one of our goals is to make the new system user friendly and easy to access through any web browser to ensure the system availability at the point of care. With the advancement of the dentistry everyday, a new treatment modalities and new materials may exist and proof its superiority to the old techniques. Therefore, the new CDSS has to be flexible in accepting and modifying the existing knowledge rules as needed. The flexibility of the system also allow for future capability to include other complex applications in dentistry.

1.5 Hypotheses:

1. Is it possible to design and develop a clinical decision support system using evidence-based knowledge to serve general dentists in diagnosis and management the complete denture complaints at the point of care?
2. Is the proposed clinical decision support system helpful as training tool for dental students and general dentists in diagnosis and management the complete denture complaints?

CHAPTER II: LITERATURE REVIEW:

2.1 Factors Associated with complete denture success:

Several factors are associated with the success of complete denture therapy. The majority of these factors are associated with the patients' condition at the time of the treatment while the rest are depending on the clinician's skills. The factors associated with the success of complete denture can be divided into three categories. The first category is the biological factors that involve patients' salivary secretion, systematic diseases, medications, residual alveolar ridge anatomy and mucosal health. The second category is the factors related to the quality of the denture that involve complete denture retention, stability, support, esthetics, vertical dimension and occlusion. The last category is the psychological factors that involve presence of psychological disorders, patient-dentist relationship and the patients' expectations.

2.1.1 Biological factors associated with complete denture success:

One of the most critical biological factors that affect the complete denture success is the salivary secretion. The saliva plays an important role in complete denture retention by enhancing the adhesion, cohesion and surface tension. The adhesion is the bond between the patient's mucosa and the denture base as a result of presence of saliva between them. The cohesion is the bond between the saliva particles itself that enhance the denture retention. The surface tension is the resistance to denture separation from the mucosa due to the presence of the saliva and the intimate contact between the denture base and the patient's mucosa. All of these mechanisms create a vacuum pressure that increase the denture retention and patient's satisfaction with the denture in presence of the adequate amount and consistency of saliva.[23] Reduced salivary secretion or dry mouth is a common complain especially in

the older population wearing prosthesis. The subjective complaint of dry mouth by patients is called xerostomia. The prevalence of xerostomia among the population of 65 and older is 30%.[24] Dry mouth can lead to several effects on the oral health in edentulous patients beside decrease the denture retention including fungal infection, mucosal soreness, impaired taste, difficulty in swallowing and halitosis. The causes of xerostomia can be categorized in four categories. (1) The local factors as the bacterial or viral infection of salivary glands, obstruction of salivary gland duct and tumor in one of the salivary glands. (2) The systemic diseases as Sjogren syndrome, rheumatoid arthritis, diabetes mellitus and HIV infections. (3) The medications, which are the most common cause of xerostomia in old population, can cause dry mouth due to the anticholinergic effect. Examples of these medications are antihistamines, antidepressants, blood pressure medications, seizure medication and sedative medications. (4) The radiation of the head and neck region due to the presence of neoplasm can also lead to persistent dry mouth by affecting the salivary glands tissues. The treatment of xerostomia includes mainly identifying and treatment of the underlying cause. If the cause is untreatable, the patient can use artificial saliva, medications to stimulate the saliva and increase the water intake frequency during the day.[23]

Arslan et al evaluated the effect of xerostomia on patients' satisfaction with their complete dentures. Ninety-eight complete denture patients with mean age of 66.4 years were included in the study. 29 patients, representing 12.6% of the patients, complained from dry mouth in a self-administrated questionnaire. The questionnaire also included questions about the difficulties that the patients experienced while using the denture in food mastication, tasting and speaking. It also included questions about

mouth soreness and the overall satisfaction with using their complete dentures. The results showed that the patients with xerostomia experienced statistically significant more difficultly in food mastication, tasting, speaking and denture stability. They showed also significant more sore spots under the denture. The overall satisfaction with the complete denture was fairly satisfied in the xerostomia group while the overall satisfaction in the healthy group was mostly satisfied with their dentures. The authors also evaluated the association between the smoking and the xerostomia. The results showed that the smoking is significantly associated with xerostomia.[25]

Another important biological factor that affect the patient satisfaction with complete denture is the alveolar ridge resorption. This resorption occurs after teeth extraction due to the alteration in functional stimulus on the alveolar bone. The presence of teeth is the best stimulus to maintain the ridge bone. With the reduction of number of teeth, the biting force decreases considerably. The complete denture patient exert only one eighth the biting force exerted by the dentate patient. Also, the activity of muscles of mastication reduced after four weeks from denture insertion. All of these factors cause resorption of the alveolar ridge because they lead to decrease the functional stimulation to the alveolar ridge bone.[26]

Atwood et al evaluated the rate of residual ridge resorption in 76 edentulous patients using clinical examination and cephalometric radiographs. They found that the average rate of resorption is 0.5 mm per year. This rate varied significantly between the maxillary and mandibular arches. The average rate of resorption in the maxilla was 0.1 mm per year while the rate was 0.4 mm in the mandible. Thus, the mandibular arch resorp four times faster than the maxillary arch.[27] The ridge

resorption can continue throughout the patients' life in a steady rate. Tallgren evaluated the residual bone resorption rates in two groups of complete denture patients. The first group of nine patients was followed up from the denture insertion to 13.5 years. The second group of 20 patients was examined 10 years after denture insertion and followed up to 25 years after denture insertion. The amount of bone loss from the residual ridge was evaluated using cephalometric radiographs. The mean mandibular ridge resorption after 13.5 years of denture wear was 7.7 mm with annual rate of resorption of 0.2 mm per year while the mean resorption in the maxilla was 2.2 mm with annual rate of 0.05 mm per year. The same rate of resorption was found in the second group that followed up from 10 years to 25 years where the mandible resorbed 3 mm during the 15 years while the maxilla resorbed 0.75 mm. The ridge resorption has shown to be a chronic and continuous process throughout the patient's life with the same rate of resorption of 4:1 of the mandible to maxilla.[28] Most of the resorption occurs in the first few months after teeth extraction but with a great variation in the resorption rate between individuals and in the same individuals. The cause of residual ridge resorption is multifactorial. Atwood divided the factors that affect the ridge resorption into three main categories. The first one is the anatomic factors that include the ridge shape and size, the bone type and the mucoperiosteum type. The second category is the metabolic factors that include age, gender, hormonal balance, osteoporosis, etc. The third category is the mechanical factors that include the mount and direction of functional load to the ridge, the type of denture base, the type and form of denture teeth, the inter-occlusal space, etc.[8] Although the extensive research of these factors by many investigators in the complete denture patients, no single factor was found to be dominant in causing the alveolar ridge resorption.[29]

Huumonen et al evaluated the correlation between the residual ridge resorption, the mandibular denture stability and the subjective patients' complaints. 326 patients wearing mandibular denture participated in the study. The residual ridge resorption was evaluated from panoramic x-ray and classified into light and severe ridge resorption. The denture stability was evaluated clinically and classified as poor when the denture moved during the patient closure into centric occlusion. The patients' subjective complaints were recorded in a questionnaire about their satisfaction with the mandibular dentures, chewing ability and presence of ulceration, sore spots and difficulties with the denture. The results showed that there was a statistically significant more severe ridge resorption in female than male patients. The severe ridge resorption was associated with poor denture stability and poor satisfaction with the denture.[30] Another study by Narhi et al evaluated the correlation of subjective patients complaints with the severity of alveolar ridge resorption in 96 patients. The patients treated with complete denture in the dental school between 1985 and 1990 and contacted by phone in 1995 to fill a questionnaire about their subjective complaints from using complete dentures. The alveolar bone resorption was evaluated from the patients' panoramic radiographs and the patients were divided into two groups according to the amount of bone loss. The first group included patients who lost more than 50% of the alveolar ridge bone height and the second group included those who lost less than 50% of alveolar ridge bone height. The results showed that most frequent complaints were sore gums and impaired chewing ability. There were more frequent subjective complaints from the patients who lost more than 50% of alveolar bone than the patients who lost less than 50%. Statistical analysis showed no significant difference between the groups. This could be due to the small sample size of the study.[31]

Chewing efficiency also can be affected by alveolar ridge resorption. Fontijn-Tekampl et al evaluated the chewing efficiency between two complete denture groups with different mandibular alveolar ridge heights. The first group of 13 patients has mandibular alveolar bone height between 9 and 15 mm and referred to as low mandible group. The second group of 24 patients has mandibular alveolar bone height of 16 mm and more and referred to as high mandible group. The chewing efficiency was evaluated by the ability of the patient to break down artificial test food. The results showed that the patients with high mandible had significantly better chewing efficiency than those with low mandible.[32] This decrease in chewing efficiency showed the importance of alveolar ridge height for patients in order to function well with the complete denture and therefore it can affect the patients' satisfaction with the complete denture.

The best treatment for the alveolar ridge resorption is to prevent it by avoiding the extraction of all natural teeth. Retaining few teeth to be used as overdenture abutments has proven to preserve more mandibular bone. Also, placement of dental implants and use it to retain and/or support the complete denture are associated with significant less alveolar bone resorption. Surgical procedures to increase the bone height are also suggested but they are not completely predictable and associated with more complications.[29]

Mucosal health is one of the important biological factors that affect the complete denture success. Complete denture wearer will not be able to use the denture if the supporting tissues are inflamed and uncomfortable even with the best-

constructed denture. Understanding the anatomy and characteristics of oral mucosa enable the clinician to better utilization of the oral mucosa during denture construction and also enable him/her to distinguish between the physiologic and pathologic conditions.

There are three types of the oral mucosa presented in the oral cavity. The first type is the masticatory mucosa that covers the maxillary and mandibular alveolar ridges and the hard palate. This type characterized by presence of a superficial highly keratinized layer of the epithelium. Also, the deepest layer of the masticatory mucosa is attached directly and firmly to the underlying bone periosteum. Both characteristics enable the masticatory mucosa to withstand high degree of pressure during food mastication. In some pathological conditions, the deepest layer of the masticatory mucosa detached from the underlying bone causing inflammation in the area due to the friction with the underlying bone. The second type of mucosa is the lining mucosa, which covers the cheeks, lips, vestibules, soft palate, ventral surface of the tongue and floor of the mouth. It is characterized by presence of thin layer of non-keratinized epithelium with thin layer of lamina propria. In the vestibular fornix and floor of the mouth, the lining mucosa is movable and attached loosely to the underlying structures. In the cheeks, lips and soft palate, the lining mucosa is immovable and attached to the fascia of the underlying muscles. The mucosa in the later regions is highly elastic to prevent folding of mucosa during mastication and decreases the chance of cheek or lip biting. However, the elasticity of the lining mucosa decreases with aging that increase the susceptibility of cheek biting. The third type of oral mucosa is the specialized mucosa, which is present in the dorsal surface of the tongue. It characterized by roughness and irregularities due to the presence of

large number of specialized papillae such as the filiform, fungiform and circumvallate papillae.[33]

Healthy mucosal is needed to provide an ideal foundation for successful complete denture. However, there are several pathological conditions that compromise the healthy status of the oral mucosa. One of these conditions is the presence of flabby tissues on the ridge (Figure 2). This condition occurs due to the progressive resorption of the alveolar ridge bone that been replaced by soft and movable hyperplastic tissue. Flappy ridge has higher prevalence in the maxillary arch that can reach up 24% of cases while the prevalence in the mandible is only 5%. The classical treatment of the flabby ridge is surgical removal but caution must be taken in severe bone resorption cases where having the flabby ridge provide little retention for the prosthesis is better than nothing.[29] In case of retaining the flabby ridge, special impression techniques should be used in order to avoid permanent displacement of these tissues under the denture causing loss of retention.[34]

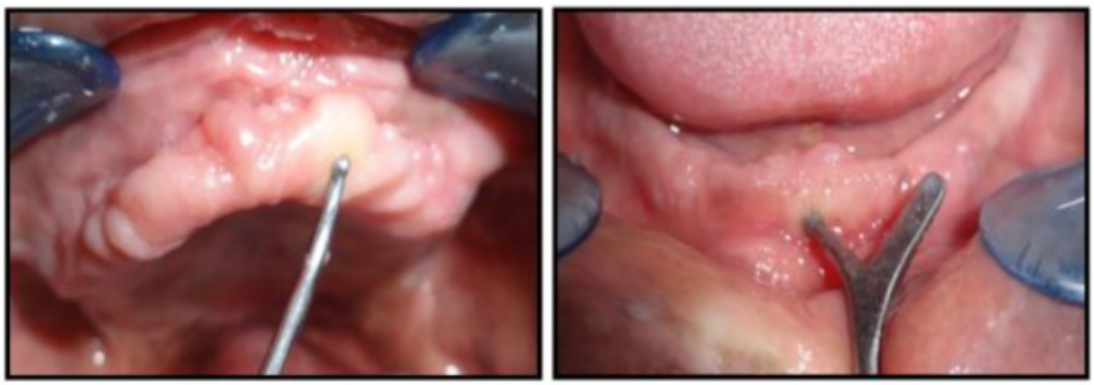

Figure 2: Flappy movable tissues.[35]

Angular cheilitis is another condition that affects the oral mucosa. It presents as inflammation at the corner of the mouth and usually associated with candida

infection (Figure 3). The nutritional deficiency and immune system impairment have an important role in developing angular cheilitis not as it was believed before that the reduced vertical dimension is the main cause of this disease.[29]

Figure 3: Angular cheilitis.[36]

Abuse the oral mucosa also can affect the normal healthy architecture of oral mucosa. Using the complete denture for long time without having regular follow up visits with the dentist can lead to several mucosal changes. A study was conducted to evaluate the oral health of 42 complete denture patients using the same dentures for long time. The patients were evaluated at baseline and after insertion of the new prosthesis at follow up appointment at average of 30 months. The average time for using the old denture was 17 years in the maxilla and 14 years in the mandible. At baseline, the results showed that 14% of patients had completely healthy mucosa in the maxilla and 57% in the mandible. 22% of the patients had mucosal inflammation in the maxilla while 7% of the patients presented with mucosal inflammation in the mandible. 64% of patients presented with mucosal inflammation with hyperplastic tissues in the maxilla while 36% of them presented with that in the mandible. After using the new dentures for 30 months on average, 52% of the patients showed completely healthy maxillary mucosa and 78% showed healthy mandibular mucosa.

The percentage of patients showed mucosal inflammation was 24% in the maxilla and 5% in the mandible. 24% of patients presented with mucosal inflammation with hyperplastic tissue in the maxilla and 17% in the mandible. The results showed a significant improvement in the patient' oral health after using the new complete denture. Also, the oral fungal infection was cultured and compared between the baseline and at the follow up appointment. The results showed a significant decrease in number of positive results. At baseline, 39 patients out of 42 showed a positive fungal infection while only 29 patients showed positive results in the follow up appointment. [37]

Among the other factors that affect the mucosal health is the radiation therapy. Patients who received radiation therapy in the head and neck region complained from several complications that include xerostomia, mucosal inflammation, pain, change in taste, difficulty in chewing, difficulty in swallowing and impaired denture retention. The severity of these complications increased in as the radiation dose increased. Most of the complications are caused by the decrease in salivary secretion. A study by Bernhoft and Skaug evaluated the oral finding in a group of irradiated edentulous patients. They found that at the beginning of the radiation therapy, the patients showed decreased oral hygiene that led to accumulation of plaque on the denture surfaces and oral mucosa. After instructing the patients to follow an oral hygiene regimen that include rinsing the mouth and denture soaking in 0.2% chlorhexidine gluconate mouthwash, they showed relief of their symptoms due to mechanical removal of the irritating micro-organisms from the mouth. Also, the use of artificial saliva helped in decreasing the mucosal pain and discomfort as well as it improve the denture retention.[38]

2.1.2 Factors related to denture quality associated with the complete denture success:

Complete denture therapy is an art based on science. Skills and clinical experience in fabricating complete dentures play an important role in providing a high quality denture. Each step during the denture fabrication starting from the primary impression to the delivery of the final prosthesis is critical. Misdiagnosis of any patient related factor during the initial examination can affect the denture quality. Therefore, ferrule evaluation of the patient's medical and dental history, clinical and radiographic examination is mandatory.

Using an ill-fitted old denture leads to permanent displacement of tissues under the denture. Taking the new final impression of these tissues under compression will cause loss of retention of the final denture because of tissue recoil. Management of the abused mucosal tissue is one of the critical factors that affect the denture quality. Lytle suggested six steps for management of the abused tissues. First, correction of denture occlusion and other faults that caused denture instability. Second, locate and correct the pressure areas on the intaglio surface of the denture. Third, reline the denture with soft tissue conditioning material then remove it and repeat the relining every few days. Forth, instruct the patient to use soft diet and remove the denture during sleep to minimize the stresses. Fifth, instruct the patient to massage the soft tissue to stimulate the mucosa to return to the normal condition. Sixth, before taking the final impression, instruct the patient to leave the denture outside his mouth for 48 to 72 hours.[39]

The main six properties in assessment of denture quality are retention, stability, support, occlusion, vertical dimension and centric relation position. The successful denture results from the optimization of these factors. There is a high degree of interrelation between these factors so that the change in one of them can affect the others.

Retention defined as the resistance of denture displacement away from the alveolar ridge. Good denture retention makes the patient psychologically comfortable and more satisfied with the denture. Denture dislodgment during speech or mastication can be very embarrassing for the patients. There are several factors that contribute to complete denture retention. These factors include adhesion, cohesion, peripheral seal, intimate tissue contact, surface tension, atmospheric pressure, gravity and neuromuscular control. All of these factors work together in order to provide the final retention of the denture. Accurate impression of the denture bearing area results in a final denture with intimate tissue contact and peripheral border sealing. Placing a posterior palatal seal on the posterior border of the maxillary denture ensures the peripheral seal in that area during function. Adequate salivary secretion is also an important factor for denture retention. The presence of thin layer of saliva between the denture base and the mucosa provides physical forces of adhesion (attraction between two dissimilar molecules like saliva with mucosa and saliva with denture base) and cohesion (attraction force between the saliva molecules) that maintain the denture retention. Also, the presence of thin layer of saliva and escape of air from under the denture create negative pressure in that layer during the dislodging force. The surface tension at the denture borders is important to maintain the difference between the pressure under the denture and the atmospheric pressure. All of these

factors maintain the denture in its place as a suction cup. Gravity effect can be seen in the retention of mandibular denture especially at rest. The tongue also plays an important role in retention of the mandibular denture by resting over the lingual flanges and lingual surface of mandibular teeth. The neuromuscular control is a learning process that comes with experience in which the patients control their muscles of the cheeks, lip and tongue in order to keep the dentures in place. This ability of neuromuscular control explains how some patients are completely satisfied with their dentures even if they are poor fitted.[40]

Denture stability defined as the ability of the denture to resist horizontal and rotational forces. Lack of stability can cause disturbance in the peripheral seal of the denture and therefore leads to decrease denture retention. There are several factors that contribute to denture stability that include alveolar ridge height and form, palatal form, denture base adaptation, intermaxillary relationship, occlusion and neuromuscular control. The anatomy of the alveolar ridge and palatal vault are patient related factors that cannot be controlled by the dentist but they can indicate the amount of stability expected in the final denture. High, square and broad alveolar ridge provides better resistance to horizontal forces (Figure 4). Also the square arch form resists denture rotation better than the ovoid one. A steep palatal vault provides more inclined surface that resist the horizontal forces and provides better denture stability.[41]

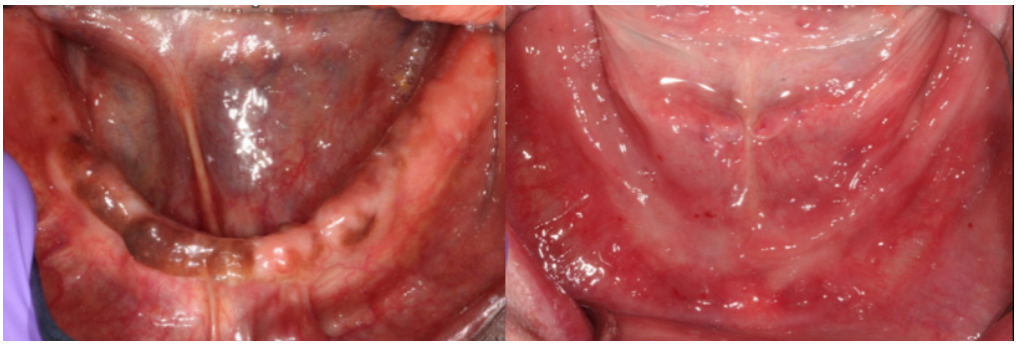

Figure 4: high and broad alveolar ridge (left) versus severely resorbed and narrow alveolar ridge (right)

Denture base adaptation, intermaxillary relationship, occlusion and neuromuscular control are factors related to the denture that can be modified by the dentist in order to provide better denture stability. Denture base adaptation results from accurate impression of denture bearing area. This adaptation at the facial and lingual flanges minimizes the horizontal denture movement during function and increases denture stability. However, the close adaptation of the denture flanges to the alveolar ridge is limited by the quality of the oral mucosa covering the ridge. Thin mucosal tissue covering the alveolar ridges cannot tolerate the stresses during function and need to be relieved.[41]

The intermaxillary relationship also has an impact on denture stability. The direction of alveolar ridge resorption in the maxilla is upward and inward while in the mandible, the direction is downward and outward according to the inclination of the roots of extracted teeth. This difference in direction leaving the maxillary and mandibular arches in crossbite relation. Setting the artificial teeth in normal relationship affects the denture stability. To overcome this problem, the posterior teeth need to be set in crossbite relation to increase the denture stability. Also, in class III patients, the mandibular arch is in forward relation to the maxillary arch. There

must be sufficient teeth contact posteriorly in order to prevent tipping of the maxillary denture in anterior posterior direction that minimizes the denture stability.[41]

The occlusion is one of the important factors that affect denture stability in several ways. The maxillary and mandibular posterior teeth must contact bilaterally and evenly in centric relation. The presence of occlusal interference cause torqueing forces that affect denture stability. Setting the denture teeth in bilateral balanced occlusion during excursive movement can ensure good distribution of forces during function and enhance denture stability. There are several teeth forms that can be used in denture occlusion according to the cusp height that include anatomic, semi-anatomic and non-anatomic teeth. The selection of teeth form depends mainly on the anatomy of the residual alveolar ridge. Using anatomic teeth form with a severely resorb ridge will cause more horizontal stresses that decrease denture stability. In this situation, the use of non-anatomic teeth is more advantageous. The patients also must be instructed to chew bilaterally to minimize the horizontal forces and ensure bilateral contact that prevents dislodgment of the denture during mastication. Occlusal plane position can also contribute to denture stability. A high occlusal plane can result from excessive vertical dimension of occlusion. Since the mandibular denture stabilized by the tongue, lips and cheek musculatures, high occlusal plane prevent the tongue from reaching over the occlusal table and therefore leads to decrease denture stability.

The neuromuscular control of the patients also can help in increase denture stability by balancing the forces from the lip, cheek and tongue musculature. The neutral zone concept has been suggested to ensure this balance during denture fabrication. In this concept, the polished surfaces of the denture are functionally

molded during the final impression. This will ensure that all the forces from the musculature surrounding the denture are in balanced condition and thus increase the denture stability.[41]

Support is defined as the resistance of denture displacement toward the ridge. It is concerned with the relationship between the tissue surface of the denture and the denture bearing area under function. The denture with good support will ensure the bilateral occlusal contact between the teeth when the dentures in occlusion and also it will ensue the maintenance of the maxillary mandibular relation on the long term. There is a variation in denture bearing areas according to the ability to withstand the pressure during function. The cortical bone resists pressure better than the cancellous bone. Also, the keratinized mucosa resists pressure more than the non-keratinized one. Therefore, the denture bearing area should be loaded selectively according to the underlying tissues in order to provide the maximal support. In the maxilla, the primary supporting area is the horizontal part of the hard palate excluding the median palatine raphe. The hard palate composed of dense cortical bone over a narrow core of cancellous bone, which makes it more resistant to the functional load. Also, the mucosa covering the hard palate is keratinized and overlies a distinct layer of submucosa that contains fatty and granular tissues that act as a cushion against the functional load. The secondary supporting area in the maxilla is the crest of the alveolar ridge. Although the maxillary alveolar ridge composed of cancellous bone, it is covered with thick and keratinized mucosa with intermediate layer of fibrous connective tissue fibers. This composition provides the alveolar ridge with the ability to resist the functional forces but as a secondary supporting area. The rest of the maxillary denture bearing areas as the buccal and labial vestibules do not participate

in providing support since it rests on movable tissue that does not provide any support. In the mandible, the primary supporting areas are the pear-shaped pad and the buccal shelf of bone. The pear-shaped pad is located in the most distal area of the mandibular alveolar mucosa and formed by the tissue scar result from extraction of the third molar tooth and its retromolar papilla. The muscle and tendons attachment at the pear-shaped pad provide a firm and keratinized mucosa that able to withstand the functional load and support the mandibular denture. The pear-shaped pad should be the posterior determinant of denture base extension and must be differentiated from the retromolar pad, which has less favorable composition to withstand the load. The buccal shelf of bone is composed of compact bone and is covered by dense keratinized mucosa due to the insertion of buccinator muscle fibers in that area. The alveolar ridge crest is considered as secondary support area when it is broad and well developed and covered with firmly attached keratinized mucosa. Special considerations must be taken during selecting the impression technique for the denture. The tissues in the primary stress bearing areas must be recorded under functional load. This makes the more resilient tissue to withstand more occlusal load than the less resilient one and provides the long-term maximum support to the denture.[42]

The vertical dimension refers to the face height according to the amount of separation between maxillary and mandibular teeth. There are two types of vertical dimension. The first one is the occlusal vertical dimension, which is the face height when the patient occludes his teeth and the mandible in centric relation position. The second type is the rest vertical dimension, which is the face height when the patient separates his teeth and the mandible in physiologic rest position. The occlusal vertical

dimension should be less than the rest vertical dimension by about 2-3 mm to provide a freeway space during rest.[43] The proper vertical dimension of occlusion is maintained by the presence of intact natural teeth. After teeth extraction the original vertical dimension need to be restored in the new complete denture. Improper vertical dimension can cause several consequences such as temporomandibular joint dysfunction, muscle tension, headache, angular cheilitis and chewing inability. There are several methods to restore the vertical dimension of occlusion. Wright suggested the use of pre-extraction records and old photographs measurements to reestablish the vertical dimension.[44] Boos suggested to use the maximum biting force in which the correct vertical dimension coincide with the patients maximum biting force measured by intraoral mechanical device called Boos Biometer.[45] The most commonly used method was introduced by pleasure. He measured the rest vertical dimension using two facial points on the nose and the chin. The patients is asked to relax his mandible with the lips is light contact and the distance between the two points measured. The occlusal vertical dimension is calculated by subtracting 3 mm from the rest vertical dimension measurement.[46] Shanahan suggested the use of swallowing to establish the vertical dimension. In this method, the maxillary and mandibular wax rims are heated and the patient is asked to swallow. The wax will be reduced to certain level to provide the proper vertical dimension of occlusion.[47] Silverman suggested the use of closing speaking space to determine the vertical dimension of occlusion. This method depends on the fact that in the proper vertical dimension of occlusion, the maxillary and mandibular anterior teeth is separated by a space of 1-2 mm during pronouncing the S sound.[48] There is no ideal or most accurate method for determining the vertical dimension so the dentist should utilize the most convenient method for him to produce a successful prosthesis.[43]

After establishing the vertical dimension, the next important step is to establish the centric relation position. With the presence of teeth, the patient always bites in the same position since the teeth cusps guide his occlusion. In complete denture patients, this position is lost and the patient can bite at any position. So, it is important to establish one position that is reproducible every time when the patient bites. This position is called the centric relation. According to the glossary of prosthodontic term, centric relation defined as "The maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective disks with the complex in the anterior-superior position against the shapes of the articular eminencies".[49] This position is bone-to-bone position and independent of any teeth contact. There are several methods described in the literature to establish the centric relation such as swallowing and free closure, chin-point guidance, bimanual mandibular manipulation and Gothic arch tracing. Dawson advocates the use bimanual mandibular manipulation because it is the most accurate method in optimizing the position of the condyle.[50] Keshvad et al compared the repeatability of three methods to establish the centric relation. The methods are the bimanual manipulation, chin-point guidance and Gothic arch tracing. The results showed that the bimanual manipulation is the most repeatable method in positioning the mandibular condyle.[51] To establish the centric relation using bimanual manipulation method, the fingers are placed at right angles of the mandible with upward pressure and thumbs are placed on the chin with downward pressure. Then the mandible is manipulated into pure hinge movement into the centric relation position.[50]

2.1.3 Psychological factors associated with the complete denture success:

The human factors are critical in treating the complete denture patient. Without giving attention to these factors, even the best made denture will not satisfy the patient. Some of these factors are related to the patients' personality such as the fear of pain, fear of change, fear of inability to chew or function and the expectations from the new denture. The patient must be assured to reduce his fear and anxiety from the first appointment. Also the patient expectation must be evaluated and correlated to his clinical condition. Unrealistic expectations could be the main reason for dissatisfaction. Other factors are related to the dentist-patient relationship. The patient must have confidence and trust in his dentist to accept the treatment. This confidence can be gained by respect, honesty, proper communication with the patient, understand and response to patient' feeling and showing the desire to work with the patient.[52]

House was the first one who classified the complete denture patient according to their mental condition to predict the denture success. He classified the patients into philosophical, exacting, hysterical and indifferent. The philosophical patients usually presented with recent extraction of their teeth and they have good health and physical condition. These patients are the ideal patients who understand the need for treatment, listens to the dentist advices about teeth extraction, diagnosis and treatment planning. The exacting patient usually presented with ill health condition. They have concerns about the efficiency of the denture in restoring their appearance and chewing function. Usually they do not accept the dentist advises and insist on a written guarantee and denture replacement at no fee if they are not satisfied. The third category is the

hysterical patients who usually presented with poor general health and neglect oral health condition. They have in mind that they will never adapt to the complete denture. They may try using the dentures but they will be very exacting and expect the dentures to be like their lost natural teeth. These patients are difficult to treat and required great effort from the dentist. The last category is the indifferent patients who are unconcern about themselves and dose not see the importance of denture for mastication. They feel that they can survive without the dentures and they luck motivation for treatment. Understanding the mentality of the patients help the dentist to predict the success of his treatment and the need to change his approach to each patient.[53]

Several studies were undertaken to find the relation between the psychological disorders and the patients' satisfaction with complete denture. Smith investigated the incidence and correlation to patients' satisfaction of four psychological disorders; hypochondriasis, hysteria, depression and manifest anxiety. Seventy complete denture patients participated in the study. The patients filled the MMPI personality questionnaire to measure their personality traits on the day of receiving the new complete dentures. After six weeks of using the complete dentures, the patients filled a questionnaire about their satisfaction with complete denture. The results showed that the highest incidence of personality traits was with hysteria (45.7%) followed by depression (38.6%). Hypochondriasis occurred in 32.4% while the manifest anxiety occurred in 24.3%. Regarding the patients satisfaction, 63.5% were completely satisfied, 23.8% were fairly satisfied and 12.7% were unsatisfied. Statistical analysis showed that there was no association between all personality traits and patients satisfaction. The author suggested that since there was no relation between the

patient's personality disorders and patients' satisfaction, the degree of dissatisfaction might due the patients' attitude toward the denture or due to the patient –dentist relationship.[54]

Van Waas investigated the relationship between the patients' satisfaction with complete denture and the patients' personality, patient-dentist relationship and the patients' attitude toward the dentures. 130 patients participated in the study. The patient personality was evaluated using Wilde's "neurotic liability" scale and the Health Locus of Control scale. The patient dentist relationship and the patients' attitude were evaluated using a questionnaire that was filled before receiving the new complete dentures. Patients' satisfaction questionnaire was filled three months after using the complete denture. The results showed that there was no correlation between the patients' satisfaction and the patients' personality scores. There was a significant correlation between dissatisfaction and the patients' opinion in his dentist's skills and the expectation about the denture.[55]

Al Quran et al investigated the correlation between patient's personality and the satisfaction with complete dentures. A hundred complete denture patients participated in the study. The patients personality was assessed using the NEO PI-R Personality Inventory which include five domains of personality; Neuroticism, Extraversion, Openness, Agreeableness and Conscientiousness. The results showed that there was a significant negative correlation between the patients' satisfaction and the Neuroticism. Identifying such patients with anticipated dissatisfaction can help the dentist to refer them to a psychiatrist consultation before the treatment.[56]

2.2 Patients' satisfaction with complete denture treatment:

Several studies investigated the patients' satisfaction with complete denture. This satisfaction can be affected by several factors as the denture quality, patients' clinical condition and the psychological factor. Yoshizumy evaluated the relation between the denture quality and the patients' satisfaction with their dentures. 239 patients were examined to determine the denture quality as satisfactory or not in relation to occlusion, vertical dimension, denture base adaptation and extensions of the borders. The patients also were asked if they are comfortable with their dentures or not. The results showed that 168 (70.3%) patients had dentures with good quality while the remaining had poor quality dentures. 180 (75.3%) patients are comfortable with their denture while the rest are not. After that, he evaluated the interaction between the denture quality and the patients' comfort in order to find if there was a relation between them. He found that out of the 168 patients that had dentures with good quality, 147 (87.5%) were comfortable with their dentures. In the other hand, out of the 180 patients comfortable with their dentures, 147 (81.7%) had dentures with good quality. There was highly significant correlation between the denture quality and the comfort of the patients. The relation between these two factors is not absolute because some patients try to adapt to their dentures even if they are not in good quality while other patients are never satisfy even with the best made dentures.[57]

Another study by Wass investigated the relationship between the denture quality, clinical mouth condition and the overall patients' satisfaction with their dentures. 130 patients received their new dentures from undergraduate students participated in the study. The patients' clinical condition was evaluated from clinical examination, cephalometric radiographs and stone casts in relation to (1) the quality

of the residual ridge and oral mucosa, (2) the maxillary and mandibular ridges relation, the inter-arch space, (3) the assessment of the vestibular space, tongue, floor of the mouth and soft palate and (4) the presence of abnormalities. After three months of the new denture insertion, the denture quality was evaluated by three prosthodontist in relation to (1) occlusion and vertical dimension of occlusion, (2) arrangement of the teeth and (3) the adaptation of the denture base to oral mucosa. The results showed that after three months of denture use, 15% of the patients were dissatisfied, 59% were completely satisfied and 26% were moderately satisfied with their new dentures. Statistical analysis showed that there was a positive correlation (r=0.36) between the denture quality and the patients' satisfaction whereas there was no correlation (r=0.12) between the patients' clinical condition and the patients' satisfaction with the denture. These results showed that the denture quality has an important role in gaining patient's satisfaction even if the patient has compromised oral condition.[58]

Peltola et al evaluated the effect of complete denture renewal on patients' satisfaction with complete denture. The study includes 42 patients using their old complete dentures with average of 15.5 years. The patients then received a new set of complete dentures and followed up for an average of 2.5 years. The patients also filled a questionnaire about their satisfaction with their new dentures at the follow up appointment. The clinical examination at baseline showed that 74% of the dentures showed poor retention. 43% of the cases showed too low vertical dimension of occlusion (freeway space more than 3 mm) and the average freeway space was 6 mm. The amount of alveolar ridge resorption was evaluated clinically and from the stone casts. 32% of the cases showed severe alveolar ridge resorption in the maxilla while

59% of cases showed a severe resorption in the mandible. At the follow up appointment of the new dentures, the clinical examination showed that poor denture retention was found in 34% of the maxillary dentures 32% of the mandibular ones. The vertical dimension was too low in 18% of cases and it was too high (freeway space was less than 1 mm) in 2% of cases .The average freeway space was 3 mm. 55% of the maxillary dentures and 69 % of the mandibular dentures needed relining. The questionnaire results showed that that 71 % of the patients were satisfied with the function of their dentures. All the dissatisfied patients need relining of their dentures and also had severe maxillary and mandibular ridge resorption that contributed to their dissatisfaction. The results indicate the importance of annual follow up appointments for the patients with their dentists in order to evaluate the dentures for the need of relining, improve functionality and maintain optimum oral health.[37]

De Baat et al introduced the concept of prosthetic condition, which involve the denture quality and the quality of alveolar ridge and correlate that concept with the patient satisfaction with complete denture. The study involved 397 complete denture patients. The denture quality was assessed in relation to denture occlusion, retention of the maxillary and mandibular dentures and stability of the mandibular denture. The quality of alveolar ridge was assessed in relation to residual ridge resorption, presence of fibrous hyperplasia in the maxilla and/or mandible and the presence of hypermobility in the residual maxillary or mandibular alveolar ridge. The scores of the denture quality and the alveolar ridge quality assessment were combined to provide the prosthetic condition score that is correlated to the patient's satisfaction scores. The results showed that 38% of the cases showed unsatisfactory occlusion. 44% of maxillary dentures and 59% of mandibular dentures showed lack of retention.

29% of dentures showed lack of stability. There was severe ridge resorption in 18% of maxillary and 68% of mandibular ridges. Fibrous hyperplasia was present in 8% of the cases in the maxilla and 18% in the mandible. The hypermobility in the residual ridge was present in 24% of cases in the maxilla and 40% of cases in the mandible. The combined score of the prosthetic condition was acceptable in 57% of the cases and minimally acceptable in 20% of the cases and poor in 23% of the cases. Regarding the patient's satisfaction, 75% of the patients were satisfied with their dentures. The statistical analysis showed no correlation between the patients' satisfaction and the prosthetic condition score. There was also no correlation between the patient' satisfaction and any of the six variable of the denture quality and alveolar ridge quality scores. The study concluded that there was no relation between the denture quality and the patients' satisfaction with complete denture even after including the alveolar ridge quality in the prosthetic condition concept.[59]

Celebic et al evaluated the factors associated with patients' satisfaction with their complete dentures and its relation the denture quality and quality of the denture bearing areas. The study included 222 patients with existed complete dentures. The patients filled a questionnaire about several factors related to their satisfaction with complete dentures. The dentures quality and the quality of denture bearing area were evaluated by a prosthodontist. The results showed that most of the patients are satisfy to some degree with their denture and only 7.2% are completely unsatisfied with their dentures. The highest rates of satisfaction were with speech (79.3%) and retention of maxillary denture (78.4%). The lowest rate of satisfaction was with mandibular retention with 14.4%. The age of the patients was correlated positively with mandibular denture retention and negatively with maxillary denture retention. So, the

older patients were less satisfied with maxillary denture and more satisfied with mandibular denture retention. Regarding the level of education, patients with high level of education were significantly less satisfied with their complete denture. Also, the edentulous patients for long time were significantly more satisfied with mandibular denture retention and less satisfied with the maxillary one. Moreover, the patients with older existed dentures were significantly more satisfied in general than the patients with newer ones. Regarding the patients' economic status, the patients with low economic status were significantly more satisfied with their dentures. The quality of the maxillary bearing area assessed by the prosthodontist was significantly correlated with the maxillary denture retention. The opposite was found in the mandible where the better the quality of mandibular bearing area the less the patient satisfaction with the retention. The quality of the denture was assessed by prosthodontist and showed a strong correlation with the patient's satisfaction. So, the better denture quality is more appreciated by the patients. [60]

Fenlon et al investigate if the quality of the denture can predict the patients' satisfaction after two years using Bayesian Belief Network. They also compared the patients' satisfaction at the time of insertion, after three months and after two years of insertion of complete denture. The study included 363 complete denture patients. The patients filled a questionnaire about their satisfaction with complete denture at baseline, three months and at two years follow up appointments. The questionnaire included questions about the quality, comfort, chewing ability and esthetics of the denture. The dentures were assesses at baseline for retention, stability, centric relation position and vertical dimension. The results showed that the denture quality was associated with patients' satisfaction at baseline and at three months follow up

appointment. However, there was no association at the two years follow up appointment. Thus, the denture quality at insertion cannot be used to predict patients' satisfaction after two years. The over all patients' satisfaction, denture esthetics and the comfort with the maxillary denture declined between the baseline and three months follow up appointment and further declined at the two years follow up appointment. The comfort with the mandibular denture improved between baseline and three months follow up appointments and further improved at the two years follow up appointment. This means that the patients need time to adapt and habituate with the new mandibular dentures. The chewing ability improved in both maxillary and mandibular denture between the baseline and three months follow up appointments. However, chewing ability with the maxillary denture was declined between the three months and two years follow up appointments but the opposite was true for the mandibular denture.[61]

Another study by Fenlon et al investigated the relation of denture quality and quality of the denture bearing area to patients' satisfaction using structural equation modeling. 522 patients with new complete dentures participated in the study. The patients' overall satisfaction, comfort, stability, chewing efficiency and esthetics were evaluated three months after insertion of the new dentures. The denture quality was assessed in relation to retention, stability, centric relation position and vertical dimension of occlusion. The mandibular alveolar ridge quality was assessed at baseline to determine the quality of the denture bearing area. The results showed that the denture quality and quality of the mandibular alveolar ridge were significantly associated with the patients' satisfaction with complete denture and can be used to predict the success of complete dentures.[62]

Turker et al investigated the effect of denture wearing experience on patients' satisfaction with complete denture. 342 patients received a new complete denture participated in the study. The patients were divided into two groups in which the first group included the patients who used complete dentures less than three years and the second group included the patients who used complete dentures for more than three years. The patients' satisfaction was recorded using a questionnaire about the overall satisfaction, chewing ability, tasting, speech and denture cleaning. The results showed that the patients using their denture more than 3 years were statistically more satisfied with their dentures regarding the overall satisfaction, chewing ability tasting and speech. The author concluded that the time of denture usage is an important factor in prediction of patients' satisfaction.[63]

Bilhan et al evaluated the effect of denture complications presence on patients' satisfaction with the existed complete dentures. Sixty-four complete denture patients with mean time for using their existed denture of 9.7 years participated in the study. The denture quality was assessed by prosthodontists in relation to retention, stability, borders' extension, vertical dimension, centric relation position and presence of complication in the dentures or the denture bearing area. The patients represent their satisfaction regarding the chewing ability, speech and denture esthetics on a Visual Analog Scale. The results showed that the most frequent complications were loss of retention (62.5%), ulcerations (51.6%) and loss of artificial teeth (26.6%). The patients' satisfaction was highest with the speech (76.1%) then with the denture esthetics (63%) and lowest with the chewing ability (57.7%). Assessment of the denture quality showed that 50.5% of the maxillary denture borders were overextended and 36.4% were underextended. The vertical dimension of occlusion

was too low in 71.7% of the patients and too high in 26.3% of the patients. The centric relation position was incorrect in 38.4% of the patients. Regarding the effect of presence of complication on patients' satisfaction, statistical analysis showed that the loss of retention and presence of ulceration significantly affected the patients' chewing ability. Also, the presence of ulceration significantly affected the patients' speech.[64]

Viola et al evaluated the impact of complete denture replacement on patients' quality of life. 70 complete denture patients needed prosthodontic treatment participated in the study. The patients filled a questionnaire before treatment and after using the new complete dentures for three months. The questionnaire included questions about six domains to assess Oral health-related quality of life. These domains were functional limitation, physical pain, psychological discomfort, physical disability, social disability and handicap. The results showed that there was a statistical significant improvement in patients' quality of life in all six domains after using the new complete denture for 12 weeks.[65]

2.3 Complete denture complaints:

2.3.1 introduction:

The complete denture complaints are any problem that arises following the insertion of complete denture prosthesis. Many of these complaints can be avoided with the proper diagnosis and examination before the denture construction. Also, the patients' adaptation factors should be evaluated to anticipate the patient acceptance of the new denture. Some patients cannot adapt physically and /or psychologically even

to the best technically made denture. Once the denture is delivered, it is important to establish a recall visits after 24 hours and one week since some complaints dose not appear immediately after insertion. Once the patient presented with complaints, it is important to address these complaints in a systematic way starting with carful listening to the patient about the complaint history and careful clinical examination of the mouth.[66] The successful diagnosis of the complaints required great power of observation, skills and knowledge base about the etiology of these complaints. Greater experience and training are required to troubleshoot the complete denture complaints than it is required for the initial denture fabrication.[33]

The frequency of complete denture complaints can varies according to the time of patient's presentation after complete denture insertion. The most frequent complaints during the immediate post insertion visits may become less frequent one-year or three years later. Several studies investigated the most frequent complaints by complete denture patients at different patient presentation timing. Amjad et al investigated the frequency of complaints by 100 patients who received new complete dentures between 2009 and 2010. The patients' complaints were collected retrospectively from the patients' charts during the post-insertion visits. The most frequent complain was pain and discomfort in 71% of the patients. Chewing difficulty and denture looseness were the next frequent complaints with 52% and 42% of the patients respectively. 19% of the patients complained from accumulation of food under the denture and 17% complained from speech difficulty with the denture.[67] Another study by Gosavi et al investigated the most frequent complications in 178 complete denture patients after at least one year of receiving their new dentures. The patients recorded their complete denture complaints in a self-structured questionnaire.

The results showed that the most frequent complaint was chewing difficulty in 49.4% of the patients. 44.4% complained from denture looseness and 29.8% complained from bad breathe. Pain and discomfort was present in 21.3% of the patients. 24.7% of the patients complained from food accumulation under the denture and 22.5% had speech problems.[17] Bilhan et al evaluated the frequency of complications in sixty-four patients after at least three years of using their complete dentures. The most frequent complication was loss of retention (85.9%) followed by ulceration in 44.2% of the patients. Loss or fracture of denture teeth was seen in 31.4% and denture base fracture was seen in 27.5% of the patients. 8.3% of the patients complained from denture stomatitis and 8.3 % complained from epulis fissuratum.[68]

Patients with old age are expected to present with more complete denture complaints due to the increased prevalence of systemic disease and the decreased neuromuscular coordination. Brunello et al investigated the association of age and gender with the presence of complete denture complaints. The study included a hundred patients treated with complete dentures with 63 male and 37 female. The mean age for the patients was 68.7 years and ranged from 43 to 90 years. The patients were divided into seven age groups in order to assess the influence of patients' age on the number and type of patients' complaints. The results showed that there was no significant difference between male and female gender regarding the type of complaints. Also, there was no significant relationship between the patients' age and the number or type of complaints.[19] Ogunrinde et al also investigated the influence of patients' age, gender, systemic disease condition and quality of the denture on the complete denture complaints. The study involved 82 patients with a mean age of 69.1 years and age range from 40 to 90 years. The patients' sample included 46 male

patients and 36 female patients. The patients' complaints were evaluated during the first week post-insertion. The results showed that there was no significant association between the patient's age, gender and systemic disease condition with the complete denture complaints. On the other hand, there was a significant correlation between the presence of denture construction faults and patients' complaints.[69] Thus, the denture quality has the main influence on the presence of patients' complaints regardless the patient's age or gender.

2.3.2 Troubleshooting and management of complete denture complaints:

The complete denture complaints can be classified into four different categories according to Morstad and Petersen[18]:

1. Pain and discomfort related complaints which includes:
    a. Sore spots.
    b. Burning sensation.
    c. Tongue and cheek biting.
    d. Generalized redness of all tissues contacted by the denture.
    e. Generalized redness in the bearing area.
    f. Denture stomatitis.
    g. Burning mouth syndrome.
    h. Pain in the temporomandibular joint.
2. Function related complaints which includes:
    a. Denture looseness.
    b. Difficulty in chewing.

c. Food accumulation under the denture.

d. Difficulty in swallowing.

e. Inability to open the mouth wide for food.

f. Teeth clicking during mastication.

g. Gagging reflex

3. Esthetic related complaints which includes:

a. Teeth shade is too light or too dark

b. Teeth mold is too small or too big.

c. Fullness under nose.

d. Distortion or depression of the philtrum and nasolabial sulcus.

e. Upper lip sunken in.

f. Showing too much of the teeth.

g. Artificial look.

4. Phonetics related complaints which includes:

a. Difficulty in speech

b. Whistle on “s” sound.

c. Lisp on “s” sound.

d. “Th” and “t” sounds indistinct.

e. “T” sounds like “Th”

f. “F” and “v” sounds indistinct.

2.3.2.1 Pain and discomfort related complaints:

Sore spots or ulcers are one of the most frequent complaints with complete denture especially in the first week after insertion of new complete dentures. The cause of sore spots differs according to its location in the oral mucosa. Sore spot in

the vestibule can be caused by overextended denture border, sharp edges or unpolished borders (Figure 5). The borders need to be checked for roughness or sharp edges and adjusted if needed. Also, borders need to be checked for overextension using disclosing wax. The wax is applied on one segment of dried denture border and warmed up in a water bath for five seconds. Then, the denture is inserted carefully into the patient's mouth and the patient is asked to do all border-molding movements. After that, the denture is removed carefully and evaluated. The area wiped off is adjusted using acrylic burs and the border is polished well after adjustment (Figure 6).[70]

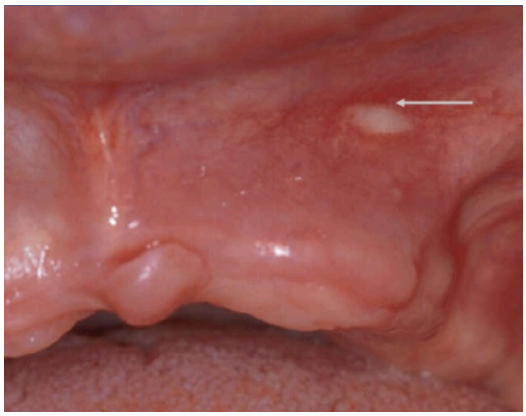

Figure 5: sore spot in the vestibule due to overextended denture border.

Figure 6: Using disclosing wax to check the denture border extension

Sore spots in the posterior limit of maxillary denture can be caused by too deep, sharp post dam area or overextended posterior denture border.[18] The post dam area must be checked for any roughness or sharp edges and smoothened if needed. The depth of the post dam must be between 0.5 and 1.5 mm below the mucosal surface as shown in the diagram (Figure 7). Also the location of the post dam area must be checked. The ideal location of the post dam is between the blow line anteriorly and the vibrating line ("Ah" line) posteriorly and extend from one humular notch to the other one. The blow line is the junction between the hard and soft palate. It can be located by asking the patient to blow out from the nose while his nostrils are closed that leads to downward expansion of the soft palate. The line then marked using indelible pencil indicating the anterior limit of the post dam area. The vibrating line situated slightly posterior to the blow line and anterior to the foveae palatinae. To locate the vibrating line, the patient is asked to say "Ah" repeatedly. The line between the moving and non-moving tissue of the soft palate is marked using indelible pencil as the posterior limit of the denture. [71] If the post dam is overextended posteriorly, border shortening is needed. If the post dam area is completely eliminated, new post dam area in the correct position must be added using heat cure acrylic resin.

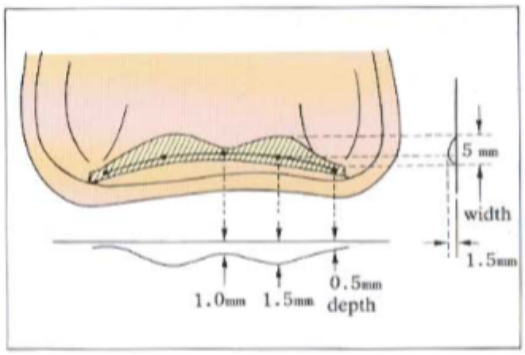

Figure 7: the ideal dimensions of the post dam area[71]

Single sore spot over the ridge usually caused by bone spicule, knife-edged ridge, presence of acrylic bubbles, pressure from the denture base or improper occlusion. First, the alveolar ridge must be checked manually for any bone spicules. Then, the oral mucosa must be checked for any visible ulcer or pressure area. The pressure area is marked using indelible pencil and transferred to the denture. If the pressure area is not visible, the intaglio surface of the denture must be checked using pressure-indicating paste (PIP) to locate the irritated area in the denture (Figure 8).[70] The paste must be applied using a brush to create an easy interpretable pattern. The brush bristles apply strokes in one direction going from right to left or from anterior to posterior on the denture to create parallel lines. The denture then is wetted with water. After denture insertion and removal, any area of disturbed previous pattern must be noticed because it indicates tissue contact.[72] After identifying the pressure area either by indelible pencil or PIP, the denture is adjusted carefully using acrylic bur. After ruling out the previous causes, the occlusion must be checked using occlusal indicator wax (Figure 9) to locate any area of premature contacts.[72] If the occlusion needs to be adjusted, clinical remount is needed. A new inter-occlusal record should be taken, the denture remounted on semi-adjustable articulator and the occlusion is adjusted by selective grinding.[66] The selective grinding procedure has several rules in order to perfect the occlusion as follow:[73]

1. The occlusion should be checked with horseshoe articulating paper with the blue color for centric contacts and the red color for excursive movements.
2. The vertical dimension should not be altered. Reducing the palatal cusps of the upper teeth and buccal cusps of the lower teeth will decrease the vertical dimension.

3. For centric occlusion adjustments: The cusp tips must not be grinded but rather the fossae can be deepened except if the cusp tip is high in centric and eccentric movements. The teeth must be adjusted until uniform contacts existed on all posterior teeth with no anterior teeth contacts.
4. For the working side interference: the BULL rule is used in which the lingual inclines of upper buccal cusps or the buccal inclines of the lower lingual cusps are reduced.
5. For the balancing side interference: the LUBL rule is used in which the buccal inclines of the upper lingual cusps and the lingual inclines of the lower buccal cusps are reduced.
6. For the protrusive interferences: if the anterior teeth is contacting with no contact in the posterior teeth, the lower anterior teeth should be reduced. If the posterior teeth contacting with no contact between the anterior teeth, the DUML rule is used in which the distal inclines of the upper teeth and the mesial inclines of the lower teeth are reduced.

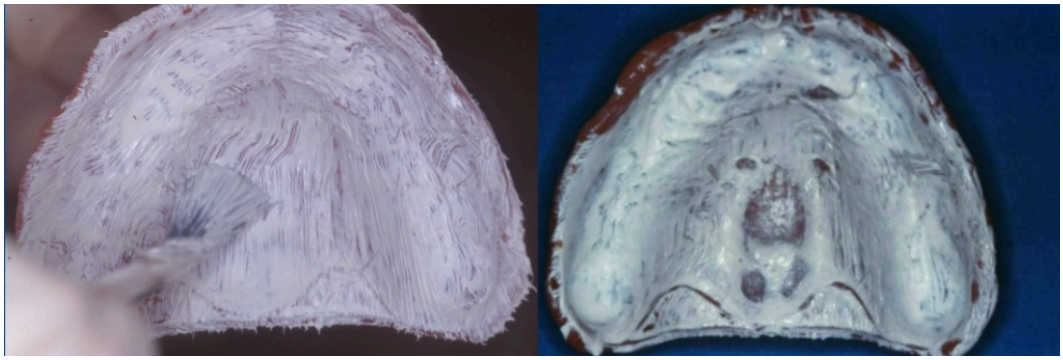

Figure 8: applying pressure-indicating paste to locate the pressure area.

Figure 9: occlusal indicator wax application to verify occlusion.

The presence of generalized soreness over the ridge can be caused by either increased vertical dimension or ill-fitted denture base.[18] The vertical dimension must be checked by calculating the difference between the physiologic rest position and occluding vertical dimension position. The normal difference is 2-3 mm. If the difference is less than 2 mm, the vertical dimension is excessive. Usually the excessive vertical dimension accompanied by masseter and temporalis muscle pain and the pain increases as the day progress. If the vertical dimension excess less than 1.5 mm, reduce the vertical dimension by occlusal grinding. If the vertical dimension excess more than 1.5 mm, one of the dentures needs to be redone if possible or both dentures need to be redone.[66] If the vertical dimension is normal, the fitting of the denture base must be checked using PIP. If the denture base is ill fitted and the denture teeth and occlusion are acceptable, the denture can be relined. Otherwise, the denture needs to be redone. [70]

Soreness under the lingual flange of the mandibular denture can be caused by overextended lingual flange, presence of lingual tori, disharmony between the centric relation and the centric occlusion driving the denture forward or improper occlusion. The extension of lingual flange needs to be checked using disclosing wax and adjusted if needed. In case of presence of lingual tori, the denture must be relieved

properly. If no overextension is found, the centric relation position must be checked using bimanual manipulation method in which the fingers are placed at right angles of the mandible with upward pressure and thumbs are placed on the chin with downward pressure. Then the mandible is manipulated into pure hinge movement into the centric relation position.[50] If the centric relation is not coincided with the centric occlusion, new centric relation record is taken and a clinical remount is needed to adjust the occlusion if the error is less than half width of the cusp. If the error is greater, the teeth need to be reset on at least one denture. If the soreness existed in the disto-lingual area of the mandibular ridge and the previous caused ruled out, the occlusion must be checked and adjusted accordingly.[70]

Sourness under the labial flange of mandibular denture can be caused by overextended labial flanges, chewing in protrusive position as a habit or excessive overbite.[18] The extension of the labial flange must be checked using disclosing wax and adjusted if necessary. The patient must be educated to chew on the posterior teeth to avoid the soreness in the labial area. If no overextension was found and the anterior teeth were set with excessive overbite, the mandibular anterior teeth height can be reduced if not interfering with the esthetics or the maxillary and mandibular incisors need to be reset.[70] Soreness in the posterior aspect of the maxillary denture on opening can be caused by too thick flange at the buccal aspect of the tuberosity that interferes with the coronoid process movement. The flange must be checked using disclosing wax, adjusted using acrylic burs and polished.[66]

Burning sensation in the anterior hard palate, upper lip and anterior alveolar ridge area can result from pressure on the anterior palatine foramen. The denture must

be relieved over the incisal papilla area using acrylic burs. Burning sensation in the maxillary premolars to molars area can result from pressure on the greater palatine foramen.[70] There are some anatomical variations in the location of the greater palatine foramen but is most commonly (87.5% of the cases) located medial to the third molar region and 1.6 cm from the median palatine suture.[74] The location of the greater palatine foramen must be located, marked with indelible pencil and transferred to the denture. The denture then relieved in the area using acrylic burs. Burning sensation in the mandibular anterior ridge area can be caused by pressure on the mental foramen.[70] The location of the mental foramen shows great variation especially between different ethnic groups. In Caucasians, it is located between the apices of the mandibular premolars in 70.4 % of the cases. In the edentulous patients, the average location is 28 mm from the midline of the mandible and 15 mm from the inferior border of the mandible.[75] After locating the mental foramen, the location is marked, transferred to the denture and relieved.[70]

Tongue biting can result from decreased vertical dimension, setting the posterior teeth too far lingual to the mandibular ridge or patient has a large tongue. The vertical dimension must be checked as mentioned before. If the vertical dimension was severely reduced and the freeway space was more than 4 mm, the dentures need to be remade. The position of the mandibular posterior teeth can be checked by placing a wax knife in the in the intaglio surface of the denture and observing the mandibular teeth position. The central fossae of the teeth should lie over the blade of the knife (Figure 10). If the teeth were set too far lingually, the lingual cusps of the teeth should be removed. If severe modification is needed, the

teeth need to be reset to the correct position. If the patient has large tongue, the teeth should be set in posterior crossbite relation using a narrow teeth mold.[76]

Figure 10: Testing the position of the mandibular teeth in relation to the alveolar ridge using the wax knife.[76]

Cheek biting can occurs due to setting the posterior teeth in edge-to-edge relation[18], insufficient thickness or extension of the buccal borders or setting the teeth too far buccally. If the teeth were set edge to edge, the buccal overjet need to be increased by grinding the buccal surfaces of the posterior mandibular teeth. If the borders are deficient, the functional width of the sulcus needs to be restored by adding to the border extension or thickness. If the teeth were set too far buccally, the teeth need to be reset.[70]

Generalized redness of all tissues contacted by the denture including the cheeks and tongue indicates allergy to the denture base acrylic resin. In this case, the denture needs to be redone using metal denture base. [70] Generalized redness of the

denture bearing area can results from either ill-fitting dentures or vitamin deficiency.[18] The ill-fitted denture needs to be relined. If the denture is well fitted, the patient must be referred to his physician to check for vitamin deficiency especially vitamin B complex.

Denture stomatitis is one of the common complaints that affect the oral mucosa. The prevalence of the denture stomatitis in the United States among denture users was 28%. It presents as inflammatory reaction of the mucosa in the denture supporting area. The clinical manifestation of denture stomatitis appears as small or large areas of smooth or granular type of erythema in the denture bearing areas. The hard palate is the most frequent site for denture stomatitis (Figure 11).[77] The cause of denture stomatitis is multifactorial. Poor oral hygiene can lead to accumulation of plaque on the denture surface that leads to bacterial and fungal infection is the main cause for denture stomatitis. Other factors can also contribute to denture stomatitis as mechanical irritation from poor fitted dentures, thermal burns, allergic reaction, wearing the denture during sleep. The treatment of denture stomatitis include identifying and correction of the irritation cause, improve the oral hygiene, antifungal medication and leaving the denture outside the mouth for longer periods to allow the tissues to rest.[29] Rinsing the mouth and soaking the dentures in 0.8% chlorine dioxide or 0.2% chlorhexidine gluconate has proven efficiency in decreasing the soft tissue inflammation and candida colonization in denture stomatitis patients.[78]

Figure 11: Palatal mucosa with denture stomatitis.[79]

Burning mouth syndrome is an idiopathic complaint of burning sensation in the oral mucosa mostly the tongue, hard palate and lips without medical or dental causes. It is more commonly affecting women (33:1) especially at menopausal age. Several predisposing factors are associated with the burning mouth syndrome such as xerostomia, dysesthesia, altered taste sensation, depression and poor quality of life. The diagnosis of burning mouth syndrome is done by exclusion all other causes that can produce similar burning sensation. These causes include local irritation from the denture, caustic mouthwashes, acidic diet, cheek biting, smoking and candidal infection. Some mucocutaneous diseases such as lichen planus and pemphigus might have similar clinical presentation but they can be excluded by biopsy. Viral infections, nutritional and endocrine disorders and xerostomia may also result in similar symptoms. If all previous causes are ruled out and the patient dose not response to the conventional treatment then the case will be diagnosed as burning mouth syndrome. Several treatment modalities have been investigated such as antidepressants, anticonvulsants, local anesthesia, hormonal replacement therapy and benzydamine hydrochloride oral rinse, but none has proven complete efficiency. Cognitive behavioral therapy has been found to be effective in alleviating the symptoms especially when combined with Alpha-liponic acid. Topical clonazepam

also has been found to be effective in reducing the pain sensation without harmful side effects.[80]

Pain in the temporomandibular joint (TMJ) can be caused by decreased vertical dimension, trauma from occlusion due to improper occlusion or joint arthritis. The vertical dimension needs to be checked first. If it is reduced significantly, the denture needs to be remade with the correct vertical dimension. The occlusion then needs to be checked and corrected accordingly. If the problem still exists, the patient must be referred to a TMJ specialist to evaluate the joint for arthritis or other disorder.[81]

2.3.2.2 Function related complaints:

Denture looseness is one of the most common complaints with complete denture. When the teeth are not occluding, denture looseness can results from overextended borders, loss of posterior palatal seal, underextended borders, tissue dehydration, displaced oral mucosa recoil or inaccurate teeth position. The border extension must be checked using disclosing wax and corrected accordingly. If no border overextension has been found the depth and efficiency of posterior palatal seal area should be checked using green stick compound to verify the seal. If the post dam is deficient, it can be corrected using cold cure acrylic resin. If the post dam was efficient, the borders should be checked for underextention using green stick compound and border molding. If the retention improved and the denture is underextended, the compound should be replaced with acrylic resin.[81] If the denture extensions were correct, the denture looseness might be due to tissue dehydration that result from alcoholism[18] or xerostomia. Lack of adequate amount of saliva reduces the ability to make peripheral seal. Artificial saliva can be prescribed to the patient to

improve the denture retention.[66] Denture looseness might also occurs due to making the final impressions on abused oral mucosa that recoils after the new denture insertion. If that fault occurred, the denture needs to be relined with soft tissue conditioner and left outside the patient's mouth 48-72 hours before taking a new the final impression for the new dentures to reline the denture with heat cured acrylic resin.[39] The teeth position in the denture might also cause denture looseness and should be checked. If the mandibular teeth placed too lingual to the ridge, it will restrict the tongue movement and cause denture lifting by the tongue. The lingual cusps of the mandibular teeth should be removed if possible or reset the teeth to give more space for the tongue movement. If the anterior teeth are placed too labial, excessive pressure from the lips on the anterior part of the dentures can cause denture dislodgment. In this case, the anterior teeth must be reset in the correct position.[66]

Denture looseness when incising the food**,** can be caused by loss of posterior palatal seal, placement of the anterior teeth too labial, presence of flappy tissues in the anterior region of the ridge or bad incising habit.[18] The post dam area should be checked and corrected if necessarily. The anterior teeth position should be checked. If the teeth placed too far labial the denture need to be redone. The presence of flappy tissue should be managed during the final impression phase either by surgical removal or making the final impression with minimal tissue displacement technique.[34] The patient also needs to be instructed not to bite hard food with anterior teeth and cut the food into small pieces first and chew with the posterior teeth bilaterally.

Denture loosening during food chewing can be caused by improper occlusion, lack of relief over the median palatine raphe, presence of flappy tissues on the ridge,

setting the teeth too buccally, disharmony between the centric relation and the centric occlusion[18] or underextended peripheral borders[81]. Malocclusion must be check and interferences must be adjusted with clinical remount procedure as described earlier. The median palatine raphe area must be checked and relieved if necessarily. The presence of flappy tissue, buccal positioned teeth, disharmony between centric relation and centric occlusion and border extensions including the post dam must be checked and managed as discussed earlier.

Difficulty in chewing without denture loosening can be caused by lack of adaptation period, wrong eating habits[81], using non-anatomical denture teeth or using worn denture teeth[66]. Patients with new dentures need 6-8 weeks to learn how to chew with the denture. The patient must be advised to finish the learning period before any denture adjustment is made. Also, the patient must be instructed to chew on both sides simultaneously and start with soft food and then gradually move to harder types of food. If non-anatomical teeth were used, the rationale for using these teeth must be explained to the patient. If the denture teeth severely worn, the denture need to be remade.

Food accumulation under the denture can be caused by lack of adaptation period, decreased vertical dimension or setting the posterior teeth too far lingual to the mandibular ridge that encroaches the tongue space.[81] Patient with new dentures must be advised to finish the learning period (6-8 weeks) before any denture adjustment is made. If the patient using an old dentures, the vertical dimension and mandibular posterior teeth position must be checked and managed as mentioned earlier.

Difficulty in swallowing can be caused by overextension of posterior border of maxillary or mandibular denture, too thick posterior borders of maxillary or mandibular denture, increased vertical dimension, decreased vertical dimension or setting the posterior teeth too far lingual to the mandibular ridge.[18] The posterior borders extension and thickness must be checked and adjusted accordingly. The vertical dimension must be checked and managed as mentioned earlier. The mandibular posterior teeth position must be checked and managed as mentioned earlier. Inability to open the mouth too wide for food can be caused by increased vertical dimension.[66] This complaints usually accompanied with difficulty in speech and facial pain. The vertical dimension must be checked and managed as mentioned earlier.

Teeth clicking during mastication can be caused by increased vertical dimension, dentures looseness or use of porcelain denture teeth.[81] the vertical dimension must be checked and managed as mentioned earlier. Denture looseness causes must be checked and managed accordingly. Acrylic teeth can be used to replace the porcelain teeth to decrease the clicking sounds.

Gagging reflex can occurs immediately after a new denture insertion or delayed two weeks to two months after denture insertion. The immediate gagging reflex can be caused by posterior overextension of maxillary or mandibular denture, too thick maxillary posterior border or too thick distolingual flange of mandibular denture.[81] The borders extension and thickness must be checked and adjusted as indicated earlier. The delayed gagging reflex can be caused by malocclusion causing the denture to loosen and allowing saliva under the denture, or underextention of

denture borders allowing saliva under the denture.[18] The occlusion must be checked and adjusted as described earlier. The border extension must be checked and adjusted accordingly.

2.3.2.3 Esthetics related complaints:

Denture esthetics must be accurately assessed during the trial stage of the denture. The dentist should not proceed to the final denture construction unless ample time is given to the patient and his closed family to assess the denture esthetics. Complaints about the denture teeth such as the shade of the teeth is too light or too dark, the teeth mold is too small or too big after the final denture construction required teeth resetting.[66]

Fullness under the nose can be caused by too long or too thick maxillary labial flange.[81] The labial flange extension and thickness should be evaluated and adjusted accordingly. Distortion of the philtrum and nasolabial sulcus can result from setting the maxillary anterior teeth too far labially. The position of the maxillary anterior teeth must be checked. If the teeth were in incorrect position, the teeth need to be reset. Depressed philtrum or nasolabial sulcus can be caused by too thin or too short maxillary labial flange. The labial flange must be checked and increased in thickness or length if it was deficient.[81] Sunken in upper lip can be result from setting the maxillary anterior teeth too far lingually. The position of the maxillary anterior teeth must be checked. If the teeth were in incorrect position, the teeth need to be reset.

Showing too much of the teeth can be caused by increased vertical dimension, the incisal plane is too low or setting the lateral incisors and canines in too prominent

position.[18] The vertical dimension must be checked and managed as mentioned earlier. The incisal plane must be evaluated by esthetics and phonetics. The maxillary central incisor should show only 2 mm or less in geriatric patients when the patient relax his lip. All maxillary teeth should follow the lip line when the patient smiles. Also, the incisal edges of the maxillary teeth should touch lightly on the vermilion border of the lower lip when the patient pronounced the letter "f". If the incisal plane is placed too far low or the lateral incisors and canines were set in too prominent position, the teeth need to be reset.

Artificial look of the denture can be results from arranging the teeth in too regular alignment, using the same shade for all teeth or unnatural color of the denture base. Rearranging the teeth with some rotations, shortening of some teeth, incisal edge grinding, using darker shade on the canine and posterior teeth can give more natural look to the denture.[81] Selecting the denture base color depends on the patients skin color. With dark skin patients, the denture base color must be darker in order to give the natural look.[66]

2.3.2.4 Phonetics related complaints:

Speech must be assessed carefully during teeth setup and trial stage of the denture construction steps. Difficulty in speech in general can be caused by decreased tongue space due to increased denture base thickness, denture looseness or increased vertical dimension.[81] The denture base thickness must be checked. If the denture base is thicker than 4 mm, it must be reduced and polished. Denture looseness causes must be evaluated and managed accordingly is described earlier. The vertical dimension must be checked and managed as described earlier.

Whistle on “s” sound is caused by presence of narrow air space anteriorly due to undercontoured anterior part of the palate. The contour of the palate can be tested by palatogram using colored indicating material. The indicating material is sprayed on the palatal area of the denture. The denture then inserted in the patient mouth and the patient is asked to pronounce “s” containing word such as “so-so”. After removal of the denture, the area of tongue contact with the palate is evaluated. The normal “s” sound is produced when the tongue lightly touches on the anterior part of the palate. If there is no contact in the anterior area, the air escapes through the space producing a whistle (Figure 12).[82] To prevent the whistle sound, a layer of acrylic resin must be added to the anterior part of the palate to stop the flow of the air.[81] Lisp on “s” sound is caused by presence of overcontoured anterior area of the palate that excessively blocks the airflow during pronouncing the “s” sound. The lisp sound also can be diagnosed by palatogram that shows the excessive contact of the tongue with the anterior part of the palate during pronouncing the “s” sound (Figure 13). To prevent the lisp sound, the thickness of the denture base in the anterior part of the maxilla must be reduced.[82]

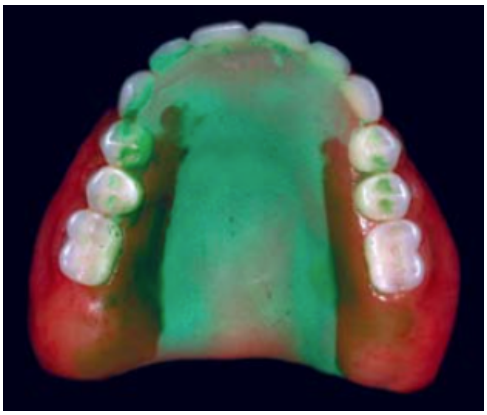

Figure 12: palatogram of undercontoured palate.[82]

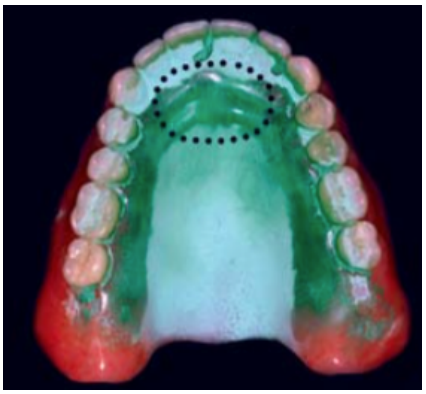

Figure 13: palatogram of overcontoured palate.[82]

Inability to distinct between “Th” and “t” sounds can result from increased vertical dimension. The vertical dimension must be checked and managed as described earlier. Pronouncing the “T” sounds like “Th” can result from setting the anterior teeth too lingually. The maxillary incisors position must be evaluated by esthetics and phonetics. If is set too much lingually, the anterior teeth must be reset more labially. Inability to distinct between “F” and “v” sounds results from improper position of the maxillary incisors vertically or horizontally. The incisal edges of the maxillary teeth should touch lightly on the vermilion border of the lower lip when the patient pronounced the letter “f”. If the anterior teeth in wrong position, the teeth need to be reset in the proper position.[81]

2.4 Clinical Decision Support Systems:

In the healthcare industry, there are three main uses of the information technology and data management. The first use is the data collection tools, which deals with gathering meaningful data from the patients’ electronic health records. The second one is the data sharing tools that allow exchanging the patients’ health data between the health care providers. The third category is the data analysis tools, which

help the healthcare providers in interpreting the patients' data to provide the optimum treatment. An example of this category is the clinical decision support system.[83]

Clinical decision support system (CDSS) is a computer program designed to provide patient related information and recommendation after processing the patients' data and suitable knowledge base. The three main component of any CDSS are (1) the knowledge base, which is collected from the evidence based knowledge and/or experts knowledge, (2) a computer program to integrate the patient's data with the knowledge base and (3) the user interface which allow the healthcare provider to interact with the system in order to gather the needed information for decision making.[84]

In order to evaluate the utility of the CDSSs in healthcare industry, Garg et al conducted a systematic review for all implemented CDSSs until 2004. The review included 97 studies. The results showed that 64% of the systems in general improved the practioners performance. The best improvement was with the reminder systems (76%) while the performance improvement with the diagnosis systems was seen in 40% of the systems.[22] Another review by Kawamoto et al was conducted to evaluate the ability of CDSSs to improve the clinical practice. The review involved seventy implemented CDSSs. The results showed that 68% of the systems showed significant improvement in the clinical performance. The author also conducted a multiple regression in order to identify the key features for the successful CDSS. The results showed that four common features to predict the success of the CDSSs are:

- The system is computer based.

- The system is part of the clinician workflow and provides automatic decision support.
- The system provides suggestions to solve the problem and not only assessment.
- The system provides the support at the time and location where the decision is needed.[85]

There are two categories of CDSS, active and passive systems. Active systems process the patient's information and automatically generate an alert to clinicians when intervention is needed. It is very helpful to the busy clinicians because they don't have to enter any patients' information to get the advice. Examples of these systems are the systems that monitor the adverse drug reaction and laboratory test result. The passive system requires the clinicians to seek for advice when they need it. These systems are usually used for diagnosis and critiquing decisions.[86] An example of the passive system is the clinical decision support system for diagnosis and management of complete denture complaints.

CDSSs can be classified into several types according to the functions provided. The event monitor systems usually integrated with the patients' electronic health records. Any entered clinical data and lab results are analyzed by the system using the information in the knowledge base. The system then sends alerts to the healthcare providers if any abnormality is detected. Another type of CDSSs is the consultation systems. In this system the healthcare provider enter the patients data that include demographics, medical history, clinical examination findings and lab results into the system. The system then processes the information and provides the user with

a list of differential diagnoses for the case and/or suggest the needed action or treatment modalities that need to be done.[87]

Multiple requirements are needed in order to develop a successful CDSS. The CDSS has to be user friendly and easy to use in order to make the job easier and not more complicated for the clinicians. Also, the knowledge base has to be updated always and provide the most current reference for the user. The successful CDSS has to be patient-specific and provide different advice for every patient and not a general advice for everyone. The system also has to accept feedback immediately and apply the change on all the other similar cases. CDSS has to overcome the difficulties associated with widely implementation of these systems like the cost of the implementation and increase risk of liability.[86]

2.4.1 Use of clinical decision support systems in dentistry:

The effort for developing CDSSs in dentistry started in 1970s with the main aim was to improve the patients care quality. These systems can have several advantages for the dentists and patients as well. Most of the systems provide the knowledge of the experts combined with the evidence-based knowledge from the literature. The singe clinician cannot combine all these knowledge and experience by himself early in his practical life. So, using the CDSSs enable the general dentists to understand and practice the dentistry on the expert level that leads to improvement of patient care. Also, using the CDSSs can help in reducing the unwanted complications for the patients that might leads to threatening the patient's life, increase hospital stay and increase the treatment cost.[88]

Applications of CDSSs in dentistry can be integrated into the electronic health records or they can standalone. Examples of the CDSSs functions that is integrated in the patients electronic health records include:

- Generating alerts about the risk of drug allergy if the dentist prescribed a new medications for the patients.
- Generate alerts about the need of prophylactic antibiotic premedication as in case of bacterial endocarditis patients.
- Alerts the dentist for the need for ferrule oral cancer screening in case of smoking patients.
- Alerts the dentist for the need of periodontal examination in case of diabetic patients since they are at high risk of developing periodontal disease.[87]

Several standalone CDSSs were developed since 1970s in almost all branches of dentistry. White conducted an extensive literature review on dental CDSSs categorized it into six areas. These areas are dental emergencies, orofacial pain, oral medicine, radiology, orthodontics and restorative dentistry.[88] Examples of CDSSs will be provided in each of these dental areas. In the area of dental emergencies, Hyman et al introduced a dental trauma diagnostic system in 1983. The program was designed to advise the clinician in the primary care facilities on the correct diagnosis and initial care of dental injuries.[89] In the same year, Hyman et al also introduced the computerized endodontic diagnosis system to aid the clinician in pulpal diagnosis. The system analyses the patient symptoms and the clinical tests results to provide the correct pulpal diagnosis. The author reported that 87% of the diagnosed cases by the system were in agreement with the clinicians' diagnosis.[90] In 1986, Ralls et al

introduced a system for diagnosis of dental emergencies. The system uses a decision tree to analyze the patients' symptoms and provide on of thirty-five different diagnoses. The author reports 88% agreement between the system and the experts' diagnosis.[91]

In the area of the orofacial pain, Matsumura et al introduced the RHINOS (Rule-based Headache and facial pain INformation Organizing System) for diagnosis of headache and orofacial pain in 1986. The system is rule-based and provides a differential diagnosis for headache and orofacial pain according to the patient' symptoms and clinical examination results.[92] In 1987, Fricton et al developed IMPATH system to assess the psychological and behavioral factors associated with temporomandibular dysfunction. The system require the patient to answers several questions and assign a score to each answer in order to identify the factors causing the patients complaints.[93] In 1991, Zusman introduced an expert system for diagnosis of orofacial pain and locating its source. The system was rule-based and depends on analyzing the pain attributes like the intensity, type duration, etc. in order to identify the source of the orofacial pain.[94]

In the area of oral medicine, Caine et al developed a CDSS for diagnosis of soft tissue lesions in 1990. The system called Differential Diagnostic Assistant for Soft Tissues. It provides differential diagnosis for the lesion out of 192 lesions stored in the system's knowledge base.[95] In 1991, Wagner developed an image-based CDSS for diagnosis of oral mucosal lesions. The clinician first enters the lesion specification such as the location, color and texture into the system. Then system displays the possible lesions that match the specifications. The clinician then selects the most

similar lesion that matches the patient's lesion to reach to the diagnosis. The system also provides additional information about the management of the diagnosed lesion.[96] In 1994, Rudin developed DART (Diagnostic Aid and Resource Tool) system for diagnosis and management of more than 600 oral diseases. The clinician interact with the system during the medical history the clinical examination. The system can request additional details and laboratory tests if needed to come up with a differential diagnosis for the disease.[97]

In the area of radiology, Wiener et al developed Odontogenic Cysts and Tumors system for diagnosis of lesions from dental origin in 1986. The system contains information about twelve lesions, four cysts and eight tumors and uses Bayesian mechanism to differentiate between them.[98] In 1987, Abbey developed an expert system called Periapical Radiolucency. First, the clinician enters all the patient's signs and symptoms in the system. Then the system compares theses observations with all the possible observations already stored in the system's knowledge base using algorithmic mechanism to provide a differential diagnosis for the lesion.[99] In 1989, White developed the ORAD system for interpretation of radiographic lesions. The system first inquires the clinician using questions about the lesion characteristics. Then it uses a Bayesian mechanism to provide a differential diagnosis for the lesion with a probability of each diagnosis. The system's knowledge base contains information about 140 lesions that can be diagnosed from the radiographs.[100] in 1993, Siegel et al developed the CAREOP (Computer Assisted Radiographic Evaluation of Oral Pathology) system for differential diagnosis of oral bony tumors. The system uses Bayesian mechanism to differentiate between 20 tumors than occurs in the maxillary and mandibular jaws.[101]

In the area of orthodontics, several CDSSs have been used to aid in orthodontic treatment. In 1988 Slavicek developed a CDSS for orthodontic diagnosis and treatment planning.[102] The system utilizes the information from the patient's data, cephalometric analysis and stone models in order to provide its outcome. In 1989, Wilkoff et al developed the MacCeph system for cephalometric radiograph tracing and analysis of facial growth.[103] In 1991, Pass et al developed a CDSS for automatic identification of landmarks on the cephalometric radiograph.[104] Also in 1991, Mackin et al developed an expert system to help general dentists in orthodontic treatment planning and the necessity of referral to specialists.[105] The system utilizes a rule-based mechanism to evaluate the extent of crowding of mandibular incisors teeth and suggest the need for orthodontic fixed appliances and premolars extraction. The system suggests either a simple treatment plan for the simple cases that can be treated by general dentists or suggest referral to an orthodontist for the complicated cases.

In the area of restorative dentistry, Hammond et al developed the RaPiD system to aid the clinician in the design of removable partial dentures.[106] The system is rule-based and requires the clinician to enter the missing teeth and the location of rest seats on the abutment teeth. Then the system designs the denture and can send it directly to the laboratory. The system also has a critique mode if the dentist wants to design the denture. If the design is not ideal, the system suggests changes and guides the clinician to the optimal design. In 1990, Wicks et al developed a patient-specific CDSS for removable partial denture design.[107] This system uses an algorithmic mechanism with a decision tree structure. The system inquires the clinician about patient specific information such as the missing teeth, the periodontal condition, occlusion, soft tissue attachments and esthetic requirements. Then the system

provides the denture design that can be modified by the clinician if needed and send it to the laboratory after approval. In 2012, Mago et al developed a CDSS to help dentists in developing a treatment plan for broken teeth.[108] This system uses the fuzzy logic mechanism to process the patient's signs and symptoms such as pain, amount of remaining tooth structure and tooth mobility. The system then provides the clinician with the treatment plan(s) for the tooth such as medication, filling, extraction and root canal treatment. The system suggested treatment were compared with dentists suggested treatment for the same cases. The results indicated that there was no significant difference between the two treatments suggestions. In 2013, Polaskova et al developed a CDSS to help dentists in treatment planning for implants.[109] The system is rule-based and available as a web application for easy access from any electronic device but it requires access to the Internet. The clinician first enters a number of clinical examination data in the system such as the tooth position, distance between the adjacent teeth, amount of available bone in the site of interest. The system then provides the recommendation for treatment based on the knowledge base data with three outcomes: implantation only, augmentation with implant or augmentation- implantation from 6-9 months. In 2014, Sadighpour et al developed a CDSS for implant treatment planning of edentulous maxilla.[110] The system uses artificial neural network mechanism that is trained from actual clinical scenarios to simulate expert treatment decisions. The clinician first enters ten input factors that affect the implant treatment planning such as number of implants in each region of the maxilla, the esthetic consideration and the inter-occlusal distance. The system then processes the data and provides the user with one of five treatment modalities: removable prosthesis with bar attachment, with ball attachment or with bar or ball attachments, Fixed hybrid prosthesis or Fixed PFM prosthesis. The system results

were compared with the experts' opinions about the treatment of 12 new cases. The results showed that the system recommendations were similar to the experts in 83% of the cases. In 2015, Prejmerean et al developed a CDSS to help in color matching in shade selection.[111] The system software receives the digital image of the tooth that and analyzes the colors and provide the matching color tab according to the 3D Vita shade guide. Testing the system by taking images for the shade guide tabs revealed good accuracy in matching the shade. The literature review did not revealed any CDSS used for troubleshooting and management of complete denture complaints. Therefore, it will be introduced in this study.

CHAPTER III: SYSTEM DESIGN AND DEVELOPMENT

3.1 Overview on system architecture:

The diagnosis and management of complete denture complaints are one of the difficult areas in clinical dentistry. They require a lot of knowledge and experience in order to identify the exact cause of the complaint. Each complaint can be caused by several causes that need to be checked in a systematic way. Treating the wrong cause can leads to another problem in the denture rather than solving the previous one. Therefore, a clinical decision support system is in need in this area of dentistry. The clinical decision support system for diagnosis and management of complete denture complaints is designed mainly to provide the inexperienced clinicians and general dentists with the required knowledge in order to easily diagnose and treat their patients in an efficient way. The system takes the user in a step-by-step process starting from asking the user to enter the patient's complaint to the final step of proposing the suitable management for the complaint. During the process, the system will ask the user to check all the possible causes for the complaint in order starting from the most common cause to the least common one. Also, the system provides the user with the methodology of how to the check each causes and what material is best to be used in order to diagnose the complaint efficiently.

Figure 14 shows the flow chart of the system in diagnosis and management the complete denture complaints. Figure 15 shows an example of the flow chart in diagnosis and management of the cheek biting patient's complaint. As shown in the example, the system asks the user to check the first possible cause for the patient's complaint with providing the methodology for that. Then, the system receives the feedback from the user if the cause is the reason for the patient's complaint or not. If

the first cause is the reason for the complaint, the system will provide the user with the methodology for how to manage the cause. If the cause is not the reason for the complaint, the system will ask the user to check the second possible cause and so on. The clinical decision support system for diagnosis and management of complete denture complaint is an expert system and developed using the Exsys Corvid Core framework (Exsys Inc. version 1.0.9). The system basic features will be explained in the next section.

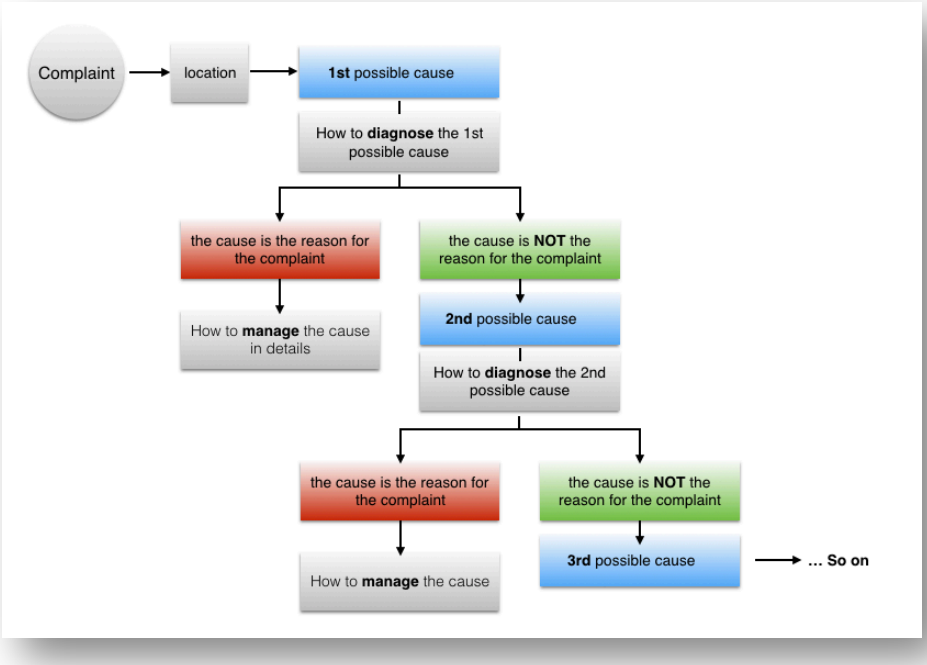

Figure14: The flow chart for the CDSS for diagnosis and management of complete denture complaints.

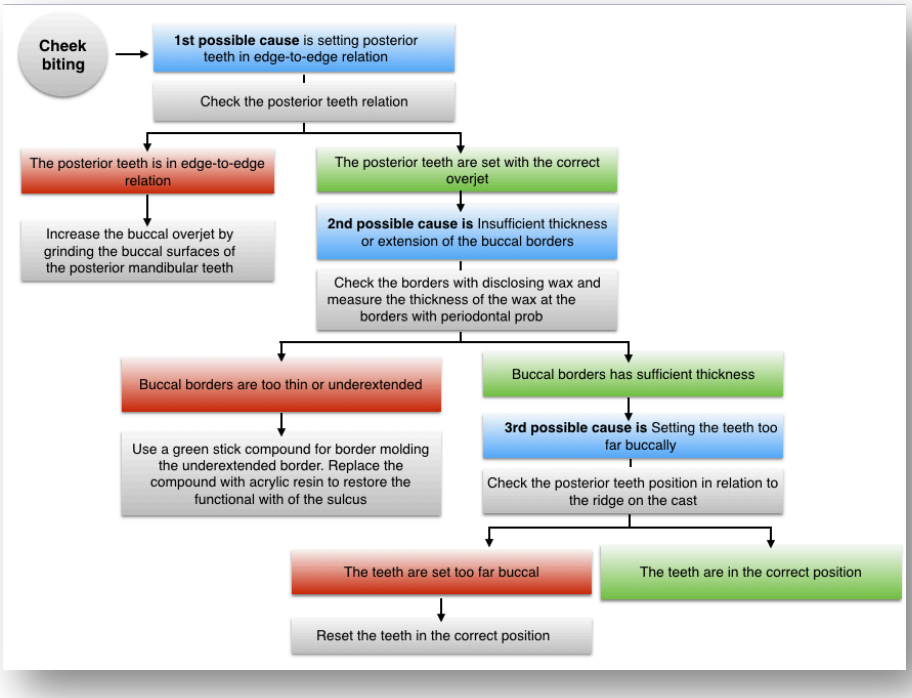

Figure 15: Example of the system flow chart in diagnosis and management of cheek biting complaint.

3.2 Exsys Corvid Core software basic features:

Exsys Corvid Core is a tool for development and deploying online expert systems that help the user in solving the difficult decision needed problems. It is called expert systems because it simulates the conversation that is done with the human experts in order to get the advice to solve certain problem. Exsys Corvid Core system can do this conversation online through the user's web browser and provide the expert advice using the built in knowledge base.[112]

There are three components for Exsys Corvid Core system: the user interface, the knowledge base and the inference engine. The user interface provides the users with online access to the decision support system and allows them to interact with it through any web browser. It also allows the user to view the final system outcome

and get the advice. The second component is the knowledge base that contains all the knowledge needed for the decision-making. This knowledge is built in the system in the form of heuristic rules that are defined by the programmer. The third component is the inference engine, which analyses the heuristic rules from the knowledge base and produces the advice for the decision-making problem.

There are two inference methods that are used in running any decision support system: the backward chaining and the forward chaining. The backward chaining is a goal driven method that starts from the goal and works backward. It is usually used when the system is intended to test if a certain goal is true or not by testing all the rules starting from the goal and moves backward. In the other hand, the forward chaining is a data-driven inference method. It starts with the data entered by the user and use the logic to extract more data from the built in rules or from the user input in order to reach to the conclusion that solve the problem. The forward chaining inference method has advantage over the backward chaining if the needed data is available upfront. This will allow the system to test the following rules and easily produce the conclusion.

The main building blocks in the Corvid core system are variables, logic block and command block (figure 16). The knowledge base rules are set in the system using IF/THEN statements. The variables are the fundamental components that are used to set these statements. Both ends of the IF/THEN statement are stored in the system as variables. The logic block is used to connect all the variables to produce a true IF/THEN statement that is executed by the command block. The command block also

control the method of running the inference engine of either forward or backward chaining method.

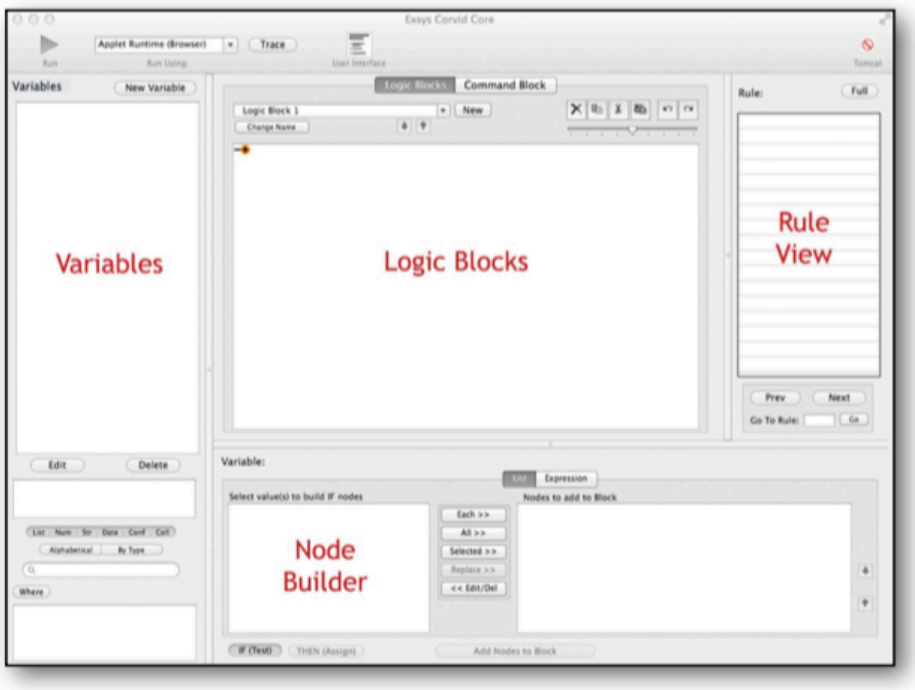

Figure 16: The main building blocks in Exsys Corvid Core[112]

3.3 System development:

The CDSS for diagnosis and management of complete denture complaints was developed using the forward chaining inference method. The variable section of the system contains all the possible patients' complaints, the diagnostic method for each complaint and the management of each complaint. The logic block of the system connects between the different variables to produce a large decision tree. This tree contains 123 rules that cover all possibilities to diagnose and manage 48 patients' complaints. The knowledge base of the system is derived from the evidence-based literature presented earlier in section 2.3. A summary of all patients' complaints with diagnosis and management that is used to formulate the system rules are presented in table 1- 4.

Table 1: Pain and discomfort related complete denture complaints.

Complaint	Location	How to diagnose	How to manage
I. Localized Sore spot	A. In the vestibule	1. Check the borders manually for the presence of **sharp or rough denture border**	Smooth the borders with acrylic burs and polish.
		2. Check if the **borders are overextended** in width and length with disclosing wax. **METHOD:** Dry the denture border; apply disclosing wax on one segment at a time, warm in water bath for 5 sec. Insert the denture, ask the patient to do all border-molding movements. Remove the denture and observe any wiped off wax which indicates border overextension.	Adjust any area wiped off from the border using acrylic burs and polish.
	B. In the distal border of maxillary denture	1. Check if the **maxillary distal border is overextended**. The distal border should end at the "Ah" line. **METHOD:** The ideal location of the PPS area is between the blow line anteriorly and the vibrating line (“Ah” line) posteriorly and extend from one humular notch to the other one. To locate the blow line, ask the patient to blow out from the nose while his nostrils are closed. Mark the line caused by downward expansion of the soft palate using Thompson stick. To locate the "Ah" line, ask the patient to say “Ah” repeatedly and mark the line on the moving tissue of the soft palate using Thompson stick.	Shorten the overextended distal border. If the posterior palatal seal is completely eliminated, roughen the intaglio surface and add reline acrylic to the area of the new PPS.
		2. Check manually if the **posterior palatal seal (PPS) area is sharp or too deep**. **METHOD**: The ideal depth of the PPS is 0.5 mm at the humular notch, 1.5 mm between the humular notch and the midline and 1 mm at the midline.	Smooth or reduce the thickness of the posterior palatal seal by acrylic burs, polish.
	C. Over the ridge	**1.** Check the ridge manually for the **presence of bone spicules**. Also, check for the **presence of knife edged ridge** with pressure indicating paste.	If a bone spicule is present, remove it under local anesthesia. If a knife edge ridge is present, relief the denture in the area as indicated by PIP using acrylic bur.

Table 1: Pain and discomfort related complete denture complaints (continue).

Complaint	Location	How to diagnose	How to manage
I. Localized Sore spot	C. Over the ridge (cont.)	2. Check the oral mucosa visually for any **ulcer** due to **acrylic bubble or pressure area** from the denture base. Mark the ulcer with indelible pencil to transfer it to the denture base	Relief the denture in the marked area using acrylic bur.
		3. Check the occlusion for the presence of **occlusal interference or prematurity** in centric or eccentric movements using occlusal indicator wax or articulating paper	Make a new inter-occlusal record, remount the denture on a semi-adjustable articulator. Adjust the occlusion by selective grinding according to the following rules: Check the occlusion with horseshoe articulating paper with the blue color for centric contacts and the red color for excursive movements. The vertical dimension should not be altered. Reducing the palatal cusps of the upper teeth and buccal cusps of the lower teeth will decrease the vertical dimension. **FOR CENTRIC OCCLUSION ADJUSTMENTS:** Reduce interceptive occlusal contacts: If the cusp high in centric and eccentric, reduce the cusp tips. Otherwise, deepen the fossa. If the mandible must be retruded farther, use the MUDL rule in which the mesial inclines of maxillary teeth and distal inclines of the mandibular teeth are reduced. Adjust the teeth until uniform contacts exist on all posterior teeth with no anterior teeth contacts. **FOR WORKING SIDE INTERFERENCE**: Use the BULL rule in which the lingual inclines of upper buccal cusps or the buccal inclines of the lower lingual cusps are reduced. **FOR BALANCING SIDE INTERFERENCE:** use the LUBL rule in which the buccal inclines of the upper lingual cusps and the lingual inclines of the lower buccal cusps are reduced. **FOR PROTRUSIVE INTERFERENCE:** if the anterior teeth contact with no contact between the posterior teeth, reduce the lower anterior teeth. If the posterior teeth contact with no contact between the anterior teeth, use the DUML rule in which the distal inclines of the upper teeth and the mesial inclines of the lower teeth are reduced.

Table 1: Pain and discomfort related complete denture complaints (continue).

Complaint	Location	How to diagnose	How to manage
I. Localized Sore spot	D. Under the lingual flange of mandibular denture	1. Check if the **lingual flange is overextended** using disclosing wax. **METHOD**: As described earlier in Table 1-I-A-2	Adjust any area wiped off from the border with acrylic burs, polish.
		2. Check if there **disharmony between the centric relation (CR) and the centric occlusion (CO)** driving the denture forward. **METHOD**: Check the centric relation position using bimanual manipulation method. Place your fingers at the right angles of the mandible with upward pressure and place the thumbs on the chin with downward pressure. Then, manipulate the mandible to pure hinge movement into the centric relation position. If the teeth cusps dose not interdigitate, the centric relation dose not coincide with the centric occlusion.	Take a new CR record and remount the denture. If the error is less than half width of the cusp, adjust the occlusion. If the error is greater, reset the teeth on at least one denture.
		Check the occlusion for the presence of **occlusal interference or prematurity** in centric or eccentric movements using occlusal indicator wax or articulating paper	As described earlier in Table 1-I-C-3
	E. Under the labial flange of mandibular denture	1. Check if the **labial flange is overextended** using disclosing wax. **METHOD:** As described earlier in Table 1-I-A-2	Adjust any area wiped off from the border with acrylic burs, polish.
		2. Check if the patient has a **habit of chewing in protrusive position.**	Educate the patient to chew on the posterior teeth bilaterally.
	F. In posterior aspect of the maxillary denture on opening	Check if the **buccal flange is too thick at the buccal aspect of the tuberosity** that interferes with the coronoid process movement.	Reduce the thickness by acrylic burs, polish.

Table 1: Pain and discomfort related complete denture complaints (continue).

Complaint	How to diagnose	How to manage
II. Generalized soreness over the ridge	1. Check if the **vertical dimension is increased** using Pleasure points. **METHOD**: Mark two points in the face, one on the nose and one on the chin. Take the denture outside the patient's mouth. Ask the patient to say " Emma" and relax his mandible with the lips in light contact. Measure the distance between the two points to calculate the rest vertical dimension (VDR). Insert the denture in the patient's mouth and ask the patient to occlude. Measure the distance between the two points to calculate the occluding vertical dimension (VDO). The VDO should be less than the VDR by 2-3 mm, which is called the freeway space. If the freeway space is less than 2 mm, the vertical dimension is increased.	If the vertical dimension increase is less than 1.5 mm, reduce the vertical dimension by occlusal grinding. If the vertical dimension increase is more than 1.5 mm, reset the mandibular teeth at the correct vertical dimension
	2. Check the **denture base adaptation** using pressure indicating paste. **METHOD**: As described earlier in Table 1-I-C-1	Reline the denture.
	3. The complaint's cause is not related to the denture and could be related to oral manifestation of a systemic disease	

Table 1: Pain and discomfort related complete denture complaints (continue).

Complaint	Location	How to diagnose	How to manage
III. Burning sensation	A. In the anterior hard palate, upper lip and anterior alveolar ridge	1. Check for **pressure area over the anterior palatine foramen** (located under the incisive papilla) using pressure indicating paste. **METHOD**: As described earlier in Table 1-I-C-1	Relief the denture in the pressure area using acrylic bur.
		2. The burning sensation could be due to **Burning Mouth Syndrome.** Diagnosis is As described in Table 1-VIII	As described in Table 1-VIII
	B. In the maxillary premolars to molars area	1. Check for **pressure area over the greater palatine foramen** (located medial to the third molar region and 1.6 cm from the median palatine suture) using pressure indicating paste. **METHOD**: As described earlier in Table 1-I-C-1	Relief the denture in the pressure area using acrylic bur.
		2. The burning sensation could be due to **Burning Mouth Syndrome.** Diagnosis is As described in Table 1-VIII	As described in Table 1-VIII
	C. In the mandibular anterior ridge	1. Check for **pressure area over the mental foramen** (located 28 mm from the midline of the mandible and 15 mm from the inferior border of the mandible) using pressure indicating paste. **METHOD**: As described earlier in Table 1-I-C-1	Relief the denture in the pressure area using acrylic bur.
		2. The burning sensation could be due to **Burning Mouth Syndrome.** Diagnosis is As described in Table 1-VIII	As described in Table 1-VIII
IV. Generalized redness	A. In all tissues contacted by the denture including the cheeks and the tongue	The patient is **allergic** to the denture base acrylic resin. Confirm the allergy using the patch test.	Remake the denture using all-metal denture base. **Figure 4**
	B. In the denture bearing area	1. Check the **denture base adaptation** using pressure indicating paste. **METHOD**: As described earlier in Table 1-I-C-1	Reline the denture.
		2. Refer the patient to his physician to check for **vitamin deficiency** especially vitamin B	The patient must use the vitamin supplements and improve his diet

Table 1: Pain and discomfort related complete denture complaints (continue).

Complaint	How to diagnose	How to manage
V. Tongue biting	1. Check if the **vertical dimension is decreased** using pleasure points. **METHOD**: As described in Table 1-II-1. If the freeway space is more than 4 mm, the vertical dimension is decreased.	Reset all mandibular teeth or remake the mandibular denture.
	2. Check if the **posterior teeth were set too lingual** to the mandibular ridge. **METHOD:** Place a wax knife in the intaglio surface of the denture and notice the mandibular teeth position. The central fossae of the teeth should lie over the blade of the wax knife.	Remove the lingual surface of posterior teeth. If severe modification is needed, reset the teeth
	3. Check of the **palatal/lingual cusps were set in edge-to-edge relation** with no horizontal overlap.	Increase the horizontal overlap by grinding the palatal surfaces of posterior maxillary teeth.
	4. Check intraorally if the patient has a **large tongue**	Reset the teeth in posterior crossbite relation using a narrow teeth mold
VI. Cheek Biting	1. Check if the **posterior teeth were set in edge-to-edge relation** with no horizontal overlap.	Increase the buccal overjet by grinding the buccal surfaces of the posterior mandibular teeth or reset one posterior arch.
	2. Check if the **vertical dimension is decreased** using pleasure points. **METHOD**: As described earlier in Table 1-V-1	Reset all mandibular teeth or remake the mandibular denture.
	3. Check if the **buccal borders have insufficient thickness or extension** with disclosing wax. **METHOD**: First, dry the denture border then apply the disclosing wax on one segment in a time and warm it up in a water bath for five seconds. Insert the denture carefully into the patient's mouth and ask the patient to do all border-molding movements. After that, remove the denture carefully and measure the thickness of the wax at the borders with periodontal probe. If the wax thickness over the borders exceeds 1 mm, the borders are underextended.	Use a green stick compound for border molding the underextended border. Replace the compound with acrylic resin to restore the functional with of the sulcus.
	4. Check if the **posterior teeth were set too far buccally**. **METHOD**: Check the teeth position by placing a wax knife in the in the intaglio surface of the denture and observing the mandibular teeth position. The central fossae of the teeth should lie over the blade of the knife.	Reset the maxillary and mandibular teeth in the correct position or Remake both dentures.
	5. Check if the **cuspid/bicuspid teeth were set too far labial**.	Reset the cuspid/bicuspid maxillary and mandibular teeth in the correct position.

Table 1: Pain and discomfort related complete denture complaints (continue).

Complaint	How to diagnose	How to manage
VII. **Denture stomatitis**: appears as small or large areas of smooth or granular type of erythema in the denture bearing mucosa, mainly the hard palate	**The cause** of denture stomatitis is multifactorial. The main cause is poor oral hygiene that leads to accumulation of plaque on the denture surface resulting in bacterial and/or fungal infection. **Other contributing factors** are mechanical irritation, thermal burns, allergic reaction and wearing the denture during sleep.	**Management** of denture stomatitis include the identifying and correction of the irritation cause, improvement of oral hygiene, antifungal medication and patient instruction to leave the denture out of mouth for longer periods to allow the tissues to rest. Rinsing the mouth and soaking the dentures in 0.8% chlorine dioxide or 0.2% chlorhexidine gluconate has proven effective in decreasing the soft tissue inflammation and candida colonization.
	References: Gendreau L, Loewy ZG. Epidemiology and etiology of denture stomatitis. J Prosthodont. 2011;20(4):251-260. Uludamar A, Ozyesil AG, Ozkan YK. Clinical and microbiological efficacy of three different treatment methods in the management of denture stomatitis. Gerodontology. 2011;28(2):104-110.	
VIII. **Burning mouth syndrome**: Burning sensation in the oral mucosa mostly tongue, hard palate and lips. It is mainly affecting women at the menopause age.	**The cause** is Idiopathic. Several predisposing factors such as xerostomia, dysesthesia, altered taste sensation; depression and poor quality of life are associated with the disease. **Diagnosis** is done by exclusion of all other causes that can produce similar burning sensation such as local denture irritation, caustic mouthwashes, acidic diet, cheek biting, smoking, candidal infection, Some mucocutaneous such as lichen planus and pemphigus, viral infections, nutritional disorders, endocrine disorders and xerostomia	**Management** is done by cognitive behavioral therapy combined with Alpha-liponic acid to alleviate the symptoms. Topical clonazepam is also effective in reducing the pain sensation.
	Reference: Mock D, Chugh D. Burning mouth syndrome. International journal of oral science. 2010;2(1):1.	

Table 1: Pain and discomfort related complete denture complaints (continue).

Complaint	Type of denture	How to diagnose	How to manage
IX Pain in the TMJ	**A. New** denture	1. Check if the **vertical dimension is increased** using Pleasure points. **METHOD**: As described earlier in Table 1-II-1	As described earlier in Table 1-II-1
		2. Check if the **vertical dimension is decreased** using Pleasure points. **METHOD**: As described earlier in Table 1-V-1	Reset all mandibular teeth or remake the mandibular denture.
		3. Check the occlusion for the presence of **occlusal interference or prematurity** in centric or eccentric movements using occlusal indicator wax or articulating paper	As described earlier in Table 1-I-C-3
		4. Refer the patient to a TMJ specialist to evaluate the temporomandibular joint for arthritis or other TMJ disorders	
	B. Old denture	1. Check if the **vertical dimension is decreased** using Pleasure points. **METHOD**: As described earlier in Table 1-V-1	• Reset all mandibular teeth or remake the mandibular denture. • **If the TMJ pain does not improve,** refer the patient to a TMJ specialist to evaluate the temporomandibular joint for arthritis or other TMJ disorders.
		2. Check the occlusion for the presence of **occlusal interference or prematurity** in centric or eccentric movements using occlusal indicator wax or articulating paper	• As described earlier in Table 1-I-C-3 • **If the TMJ pain does not improve,** refer the patient to a TMJ specialist to evaluate the temporomandibular joint for arthritis or other TMJ disorders.
		3. Refer the patient to a TMJ specialist to evaluate the temporomandibular joint for arthritis or other TMJ disorders	

Table 2: Function related complete denture complaints.

Complaint	Type of denture	Type of complaint	How to diagnose	How to manage
I. Denture looseness	**New denture**	A. Maxillary denture **looseness at initial placement**	1. Check if the **borders are overextended** with disclosing wax. **METHOD**: As described earlier in Table 1-I-A-2	As described earlier in Table 1-I-A-2
			2. Check if the posterior palatal seal **(PPS) is excessive or insufficient** in extension and depth. **METHOD**: As described earlier in Table 1-B-1,2	As described earlier in Table 1-B-1,2
			3. Check if the **peripheral seal is insufficient** due to **borders underextention** with disclosing wax. **METHOD**: As described in Table 1-VI-3	As described in Table 1-VI-3
			4. Check if the **tissues are dehydrated** due to alcoholism or xerostomia that interfere with the proper peripheral seal. **METHOD:** Review if the patient is alcoholic, has salivary gland disease, taking medications with xerostomia as adverse reaction or received radiation therapy to the head and neck region.	Identify and treat the underlying cause. Prescribe artificial saliva and medications to stimulate the saliva. Instruct the patient to increase the water intake frequency during the day.
			5. Check the **denture base adaptation** using pressure indicating paste. Ill fitting base can result from inaccurate impression. **METHOD**: As described earlier in Table 1-I-C-1	Reline The denture
			6. **Lack of alveolar ridge height**.	If there is severe ridge resorption, advice the patient to place dental implants or uses a denture adhesive.
		B. Maxillary denture **drops on opening** at the initial placement	1. Check if the **labial border is overextended** with disclosing wax. **METHOD**: As described earlier in Table 1-I-A-2	As described earlier in Table 1-I-A-2

Table 2: Function related complete denture complaints (continue).

Complaint	Type of denture	Type of complaint	How to diagnose	How to manage
I. Denture looseness (cont.)	**New denture (cont.)**	B. Maxillary denture **drops on opening** at the initial placement (cont.)	2. Check if the **buccal frenum is inadequately relieved** with disclosing wax. **METHOD**: As described earlier in Table 1-I-A-2	As described earlier in Table 1-I-A-2
			3. Check if the **maxillary anterior teeth were set too labial**. This will cause excessive lip pressure on the dentures.	Reset the anterior teeth in the correct position.
		C. Maxillary denture looseness after 24 hours of delivery	Check if the final impressions were made on **abused oral mucosa** that recoils after the denture insertion.	Lytle suggested six steps for management of the abused tissues. First, correct the denture occlusion and other faults that caused denture instability. Second, locate and correct the pressure areas on the intaglio surface of the denture. Third, reline the denture with soft tissue conditioning material and remove and repeat the relining every few days. Forth, instruct the patient to use soft diet and remove the denture during sleep to minimize the stresses. Fifth, instruct the patient to massage the soft tissue to stimulate the mucosa to return to the normal condition. Sixth, before taking the final impression, instruct the patient to leave the denture outside his mouth for 48 to 72 hours. After restoring the mucosal health, reline the denture with heat-cured acrylic resin. Reference: Lytle RB. The management of abused oral tissues in complete denture construction. The Journal of Prosthetic Dentistry. 1957;7(1):27-42

Table 2: Function related complete denture complaints (continue).

Complaint	Type of denture	Type of complaint	How to diagnose	How to manage
I. Denture looseness (cont.)	**New denture (cont.)**	D. Mandibular denture rise when talking	1. **Lack of alveolar ridge height**.	Advice the patient to place dental implants or uses a denture adhesive.
			2. Check for **borders overextension** in width and length with disclosing wax. **METHOD**: As described earlier in Table 1-I-A-2	Adjust any area wiped off from the border using acrylic burs, polish.
			3. Check if the **posterior teeth were set too lingual** to the mandibular ridge. **METHOD:** As described in Table 1-V-2	Remove the lingual surface of posterior teeth. Or reset the teeth
			4. Check if the **mandibular anterior teeth were set too labial**. This will cause excessive lip pressure on the dentures.	Remake the denture.
		E. Mandibular denture rise when eating	1. Check the patient **chews unilaterally**	Instruct the patient to chew on both sides simultaneously.
			2. Check the **denture base adaptation** using pressure indicating paste. Ill fitting base can result from inaccurate impression. **METHOD**: As described earlier in Table 1-I-C-1	Reline the denture
			3. **Lack of alveolar ridge height**.	If there is severe ridge resorption, advice the patient to place dental implants or uses a denture adhesive.
			4. Check if the **occlusal plane is too high**. **METHOD:** the occlusal plane should bisect or at 2/3 the height of the retromolar pad	Reset all posterior teeth or remake the denture
			5. Check if the **posterior teeth were set too far buccally**. METHOD: As described in table 1-VI-4	Reset all the posterior teeth
			6. Check for **borders overextension** in width and length with disclosing wax. **METHOD**: As described earlier in Table 1-I-A-2	Adjust any area wiped off from the border using acrylic burs, polish.

Table 2: Function related complete denture complaints (continue).

Complaint	Type of denture	Type of complaint	How to diagnose	How to manage
I. Denture looseness (cont.)	**New denture (cont.)**	F. Denture looseness when incising the food	Check if the **patient incise the food with the anterior teeth**	Instruct the patient to incise the food with cuspid/bicuspid teeth or cut the food in the plate and place it in mouth
		G. Maxillary denture looseness when eating	1. Check the occlusion for the presence of **occlusal interference or prematurity** in centric or eccentric movements using occlusal indicator wax or articulating paper	As described earlier in Table 1-I-C-3
			2. **Lack of alveolar ridge height**.	If there is severe ridge resorption, advice the patient to place implants or uses a denture adhesive.
			Check the patient **chews unilaterally**	Instruct the patient to chew on both sides simultaneously.
	Old denture		1. Check the **denture base adaptation** using pressure indicating paste. **METHOD**: As described earlier in Table 1-I-C-1	Reline the denture
			2. Check if the **peripheral seal is insufficient** due to **borders underextention** with disclosing wax. **METHOD**: As described in Table 1-VI-3	As described in Table 1-VI-3
			3. **Lack of alveolar ridge height**.	If there is severe ridge resorption, advice the patient to place implants or uses a denture adhesive.

Table 2: Function related complete denture complaints (continue).

Complaint	How to diagnose	How to manage
II. Lack of stability	1. Check for the **presence of flappy tissues** in the anterior region of the ridge that are not managed during the final impression stage. **METHOD:** Use a blunt instrument to evaluate the mobility of the tissues.	• Remove of the flappy tissues or augment the ridge surgically and reline the denture. • If surgery is contraindicated, remake the denture with mucostatic final impression technique.
	2. Check the **denture base adaptation** using pressure indicating paste. Ill fitting base can result from **inaccurate impression or tissue change**. **METHOD**: As described earlier in Table 1-I-C-1	Reline the denture
	Check the occlusion for the presence of **occlusal interference or prematurity** in centric or eccentric movements using occlusal indicator wax or articulating paper	As described earlier in Table 1-I-C-3
III. Food Accumulation under the denture	1. Check for maxillary or mandibular **denture looseness.** As described in Table 2-I	As described in table 2-I
	2. Check the **denture base adaptation** using pressure indicating paste. Ill fitting base can result from **inaccurate impression or tissue change**. **METHOD**: As described earlier in Table 1-I-C-1	Reline the denture
	3. Check if the **peripheral seal is insufficient** due to **borders underextention** with disclosing wax. **METHOD**: As described in Table 1-VI-3	As described in Table 1-VI-3
	4. Check the occlusion for the presence of **occlusal interference or prematurity** in centric or eccentric movements using occlusal indicator wax or articulating paper	As described earlier in Table 1-I-C-3
IV. Teeth clicking	1. Check for maxillary or mandibular **denture looseness.** As described in Table 2-I	As described earlier in Table 1-II-1
	2. Check if the **vertical dimension is increased** using Pleasure points. **METHOD**: As described earlier in Table 1-II-1	As described in table 2-I
	3. Check if **porcelain teeth** were used	Replace the porcelain denture teeth with acrylic denture teeth

Table 2: Function related complete denture complaints (continue).

Complaint	Type of denture	How to diagnose	How to manage
V. Difficulty in chewing	**New denture**	1. Patients with new dentures need an **adaptation period** of 6-8 weeks to learn how to chew with the denture.	Advise the patient to finish the learning period before making any denture adjustments.
		2. Check if the patient has **muscle soreness or fatigue** due to **increased vertical dimension** **METHOD**: As described earlier in Table 1-II-1	As described earlier in Table 1-II-1
		3. Check if the patient has **muscle soreness or fatigue** due to **decreased vertical dimension** **METHOD:** As described earlier in Table 1-V-1	As described earlier in Table 1-V-1
	Old denture	1. Check if the denture **teeth are severely worn** after using the denture for long time. It is usually accompanied with decreased VDO.	Remake the denture
		2. Check if the patient has **muscle soreness or fatigue** due to **decreased vertical dimension** **METHOD:** As described earlier in Table 1-V-1	As described earlier in Table 1-V-1
VI. Difficulty in Swallowing		1. Check if the **maxillary distal border is overextended**. **METHOD**: As described earlier in Table1-1-B-1	As described earlier in Table1-1-B-1
		2. Check if the **mandibular distolingual flange** is **overextended in the retromylohyoid space.**	Shorten the flange and polish.
		3. Check if the **vertical dimension is increased** using Pleasure points. **METHOD**: As described earlier in Table 1-II-1	As described earlier in Table 1-II-1

Table 2: Function related complete denture complaints (continue).

Complaint	Timing	How to diagnose	How to manage
VII. Gaging reflex	**Immediate:** occurs immediately after new denture delivery	1. Check if the **maxillary distal border is overextended**. **METHOD**: As described earlier in Table1-1-B-1	As described earlier in Table1-1-B-1
		2. Check if the maxillary **posterior borders is too thick**	Adjust the thick borders with acrylic burs and polish.
		3. Check for maxillary or mandibular **denture looseness.** As described in Table 2-I	As described in table 2-I
		4. Check if the **vertical dimension is increased** using Pleasure points. **METHOD**: As described earlier in Table 1-II-1	As described earlier in Table 1-II-1
		5. Check if the **mandibular distolingual flange** is **overextended in the retromylohyoid space.**	Shorten the flange and polish.
		6. Check if the patient has **hyperactive gaging reflex** before the new denture delivery	Identify, Aversion therapy counseling and conditioning
		7. Check if the gaging reflex is just **psychological** reflex.	Identify, Aversion therapy counseling and conditioning
	Delayed: occurs two weeks to two months after denture delivery	1. Check for maxillary or mandibular **denture looseness.** As described in Table 2-I	As described in table 2-I
		2. Check the occlusion for the presence of **occlusal interference or prematurity** in centric or eccentric movements using occlusal indicator wax or articulating paper	As described earlier in Table 1-I-C-3

Table 3: Esthetic related complete denture complaints.

Complaint	How to diagnose	How to manage
I. The teeth shade is too light or too dark	This complaint results from the failure to give the patient and his family ample time to evaluate the denture esthetics during the teeth try-in stage. Have the patient examine the denture set up standing in front of the mirror, not under the dentist light.	Reset the teeth.
II. The teeth are too small or too large	• This complaint results from the failure to give the patient and his family ample time to evaluate the denture esthetics during the teeth the try in stage. Have the patient examine the denture set up standing in front of the mirror, not under the dentist light. • Differentiate between what is meant by the complaint. If posterior teeth are moved forward, patient complaints of teeth are too large when in fact the teeth are too small.	Reset the teeth.
III. Fullness under the nose	Check if the maxillary **labial flange is overextended or too thick** using disclosing wax. **METHOD:** As described earlier in Table 1-I-A-2	As described earlier in Table 1-I-A-2
IV. Distortion of the philtrum or nasolabial sulcus	Check if the **anterior teeth were set too labial or flared up**. **METHOD:** As described in Table 2-I-B-3	Reset the anterior teeth in the correct position.
V. Depression of the philtrum or nasolabial sulcus	Check if the maxillary **labial flange is too short or too thin** using disclosing wax. **METHOD:** Dry the denture border, apply the disclosing wax on one segment at time, warm in water bath for 5 sec. Insert the denture, ask the patient to do all border-molding movements. Remove the denture, measure the thickness of the wax at the borders with periodontal probe. If the wax thickness over the borders exceeds 1 mm, the borders are underextended. Border mold the deficient areas with green stick compound to verify if the depression improved	Replace the green stick compound with heat-cured acrylic resin.
VI. Sunken in upper lip	Check if the **anterior teeth were set too lingual**. The mid facial surface of anterior teeth supports the lip **METHOD:** As described in Table 2-I-B-3	Reset the anterior teeth in the correct position.

Table 3: Esthetic related complete denture complaints (continue).

Complaint	How to diagnose	How to manage
VII. Showing too much of the teeth	1. Check if the **vertical dimension is increased** using Pleasure points. **METHOD**: As described earlier in Table 1-II-1	As described earlier in Table 1-II-1
	2. Check if the incisal plane was set too low. **METHOD:** Check if the maxillary central incisor is showing more than 2 mm when the patient relaxes his lip. Check if all maxillary teeth follow the lip line when the patient smiles. Check if the incisal edges of the maxillary teeth touch lightly on the vermilion border of the lower lip when the patient pronounced the letter "f".	Reset the teeth in the correct incisal plane
	3. Check if the **lateral incisors and canines were set in too prominent** position.	Reset the teeth in the normal position.
	4. Check if the **teeth mold is too big or too narrow** that shows too much teeth.	Reset the teeth with the suitable mold.
	5. Check if the teeth were set with **no buccal corridor**	Reset the teeth with buccal corridor.
VIII. The denture looks too artificial	1. Check if the teeth were set in **too regular alignment**	Reset the teeth with some rotations, shortening of some teeth, incisal edge grinding.
	2. Check if the **same shade was used for all teeth.**	Reset the teeth using darker shade for the canines and posterior teeth
	3. Check if **unnatural color was used for the denture base**. The denture base color should match with the patient's skin color. With dark skin patients, the denture base color should be darker.	Rebase the denture with suitable denture base color.

Table 4: Phonetics related complete denture complaints.

Complaint	How to diagnose	How to manage
I. Difficulty in speech in general	1. Check if the **lingual flanges are too thick** that leads to decreased tongue space using disclosing wax. **METHOD**: As described earlier in Table 1-I-A-2	As described earlier in Table 1-I-A-2
	2. Check if the **vertical dimension is increased** using Pleasure points. **METHOD**: As described earlier in Table 1-II-1	As described earlier in Table 1-II-1
	3. Check if the **denture is too thick**	Reduce the thick areas and polish.
	4. Check for maxillary or mandibular **denture looseness.** As described in Table 2-I	As described in table 2-I
II. Whistle on "s" sound	1. Check if there is **too narrow space in the bicuspid area**	Grind the palatal surfaces of the maxillary bicuspid teeth.
	2. Check if the anterior part of the palate is undercontoured causing **narrow air space anteriorly**. **METHOD:** Test the contour of the palate by palatogram using colored indicating material. If there is no tongue contact in the anterior area during pronouncing the "s" sound, the air escapes through the space producing a whistle.	Add a layer of acrylic resin to the anterior part of the palate to stop the flow of the air.
	3. Ask the patient if he had whistling with his natural teeth before. Also, ask the patient to speak without denture or with the previous denture.	The whistling can be a normal habit for the patient. No denture adjustment needed

Table 4: Phonetics related complete denture complaints (continue).

Complaint	How to diagnose	How to manage
III. Lisp on "s" sound	1. Check if the anterior area of the palate is overcontoured that excessively blocks the airflow during pronouncing the "s" sound. **METHOD:** Test the contour of the palate by palatogram using colored indicating material. Check If there is an excessive tongue contact with the anterior part of the palate during pronouncing the "s" sound.	Reduce the thickness of the denture base in the anterior part of the maxilla
	2. Ask the patient if he had lisp with his natural teeth before. Also, ask the patient to speak without denture or with the previous denture.	The lisping can be a normal habit for the patient. No denture adjustment needed
IV. Inability to distinct between "Th" and "t" sounds	Check if the **vertical dimension is increased** using Pleasure points. **METHOD**: As described earlier in Table 1-II-1	As described earlier in Table 1-II-1
V. Pronouncing the "T" sounds like "Th"	Check if the maxillary **anterior teeth were set too far lingually**. **METHOD:** As described in Table 2-I-B-3	Reset the anterior teeth in the correct position.
VI. Inability to distinct between "F" and "v" sounds	Check if the **vertical position of the maxillary incisors** is correct. • If "F" sounds like "V": Maxillary anterior teeth are too long. • If "V" sounds like "F": Maxillary anterior teeth are too short. **METHOD:** As described in Table 3-VII-2	Reset the teeth in the correct position

In order to program the rules in the Corvid Core software, the heuristic rules need to be entered as IF/THEN statements. For example, the decision tree rules in the example in figure 15 about the cheek biting complaints can be converted to IF/THEN rules that is stored in the logic block of Corvid Core system and retrieved by the inference engine as response to the user interaction with the system as shown in figure 17. When the user selects the complaints categories "pain and discomfort complaint" and selects one of the pain complaints, which is for this example "cheek biting", the system will present the first possible cause for this complaint and the method to diagnose it. The rule is stored in the system as follows:

IF:
The complaints category = pain and discomfort complaints.
AND
The pain complaints = cheek biting.
THEN:
Check if the posterior teeth were set in edge-to-edge relation.

Then the user has to check the teeth relation intraorally and then respond to the system by selecting one of two choices:

1. The posterior teeth were set in edge-to-edge relation.
2. The posterior teeth were set in normal overjet relation.

If the user selects the option that make the first possible cause true, the system will presents the user with the management protocol to solve the patient's problem. The rule is stored in the system as:

IF:

The posterior teeth were set in edge-to-edge relation.

THEN:

Increase the buccal overjet by grinding the buccal surfaces of the posterior mandibular teeth.

If the user selects the option that make the first possible cause not true, the system will display the second possible cause for the complaint along with the diagnostic method. The rule is stored in the system as:

IF:

The posterior teeth were set in normal overjet relation.

THEN:

Check if the vertical dimension is decreased using pleasure points.

METHOD: Mark two points in the face, one on the nose and one on the chin. Take the denture outside the patient's mouth. Ask the patient to say "Emma" and relax the mandible with the lips in light contact. Measure the distance between the two points to calculate the rest vertical dimension (VDR). Insert the denture in the patient's mouth and ask the patient to occlude. Measure the distance between the two points to calculate the occluding vertical dimension (VDO). The VDO should be less than the VDR by 2-3 mm, which is called the freeway space. If the freeway space is more than 4 mm, the vertical dimension is decreased.

Then the user has to check the vertical dimension using the method provided and then respond to the system by selecting one of two choices that showed if the cause is true or not and so on.

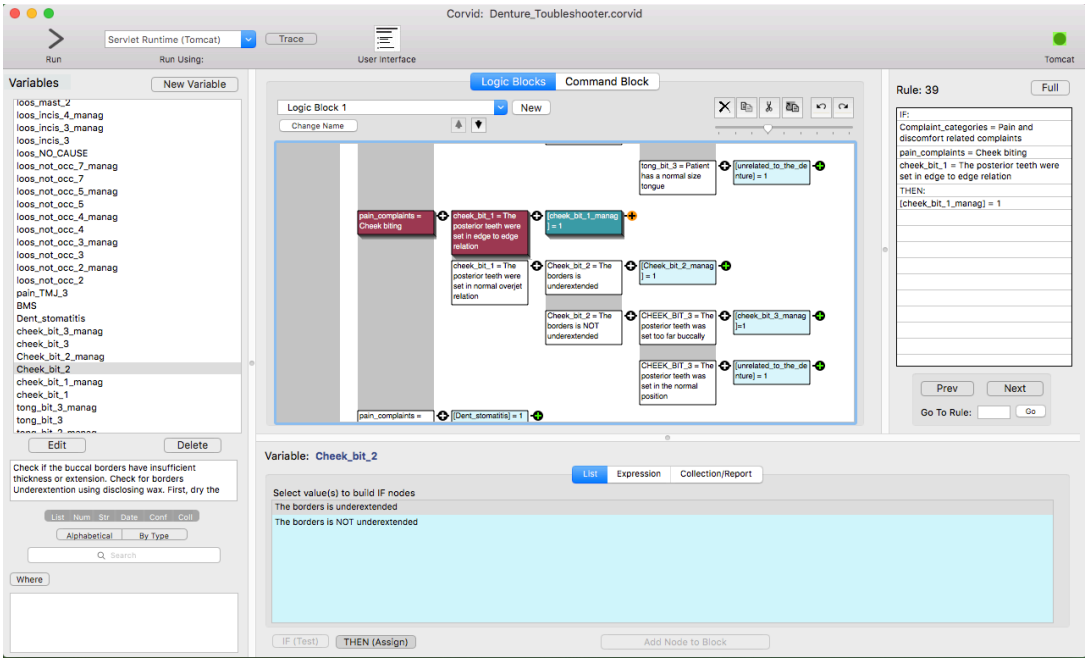

Figure 17: The heuristic rules for diagnosis and management of cheek biting complaint.

3.3 System validation:

After system development, the system cannot be launched online until validation. The system validation ensures that the system was developed correctly and included all possible patients' complaints, all possible causes for each complaint and the best management protocol for each complaint. The clinical decision support system for diagnosis and management of complete denture complaints is validated by ten expert prosthodontists. All prosthodontists are faculty members in the School of Dental Medicine, Rutgers University, Newark, New Jersey. The prosthodontists reviewed the actual system on the computer and reviewed all the rules in the system. After that, the prosthodontists gave their opinion about the system and the rules that need to be modified, added or removed from the system. Also, the prosthodontists

filled a questionnaire about their impression about the system and the degree of agreement with the system rules (Appendix A), The questionnaire contains ten questions that have a 5-point Likert scale from "strongly disagree" to "strongly agree".

The survey questions are:

1. Due to complexity of diagnosis and management of complete denture complaints for inexperienced clinicians, there is a need to develop such system.
2. The system is user friendly.
3. It is better for the system to be available online as a web page than to be stand-alone desktop application.
4. The system is a good tool to assist the general dentists to manage the complete denture complaints at the point of care.
5. The system is a good tool for training the undergraduate students.
6. The system is a good tool for continuing dental education courses.
7. The system contains most of the possible patients' complaints from complete denture.
8. The system provides most of the possible causes for each patient's complaint.
9. The system provides the best management protocol for each patient's complaints.
10. Your overall agreement with the system

The questionnaire items were statistically analyzed using IBM® SPSS Statistics software (Version 24). The reliability and internal consistency of the questionnaire items was assessed using Cronbach's Alpha test.

CHAPTER IV: RESULTS

1.1 System execution:

The clinical decision support system for diagnosis and management of complete denture complains was successfully developed and programed using the Exsys Corvid Core software. The system was named " Complete Denture Complaints Troubleshooter". 48 possible patient's complaints along with their methods of diagnosis and management were incorporated into the system. The system contains 123 rules that will be retrieved according the user interaction with the system. The front page of the system's user interface contains a simple description of the system and the general flow chart for the system in order to aid the user to understand how to use the system (figure 18).

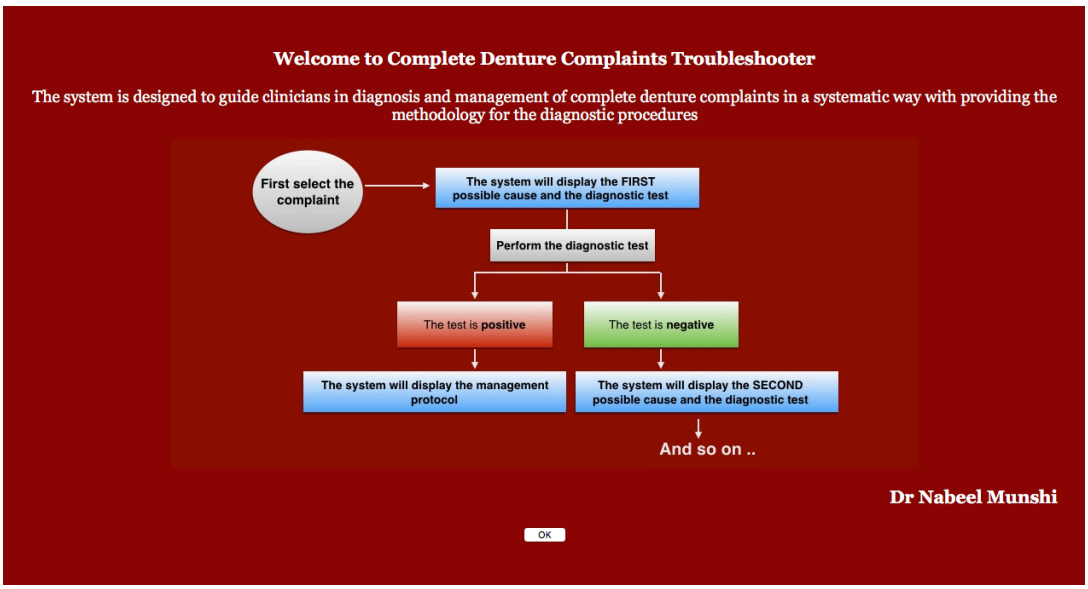

Figure 18: The front page of the system's user interface.

Two case examples of the system use for diagnosis and management of complete denture complaints are provided in the following screenshots from the system to explain how the system works:

Case example 1: The patient complains from sore spot over the ridge when he uses the denture:

The clinician must take the full history of the patient's complaints and do a full mouth examination in order to determine the nature and characteristics of the complaint. After that, the clinician starts using the system. The first step for the clinician is to select the main category of the patient's complaint "pain and discomfort related complaints" category and then selects "OK" (figure 19).

Figure 19: Screenshot 1 for case example 1

On the next screen, the clinician selects the complaint "Localized sore spot" and selects "OK" (figure 20).

Figure 20: screen shot 2 for case example 1

On the next screen the clinician selects the location of the sore spot " Over the ridge" and selects "OK" (figure 21).

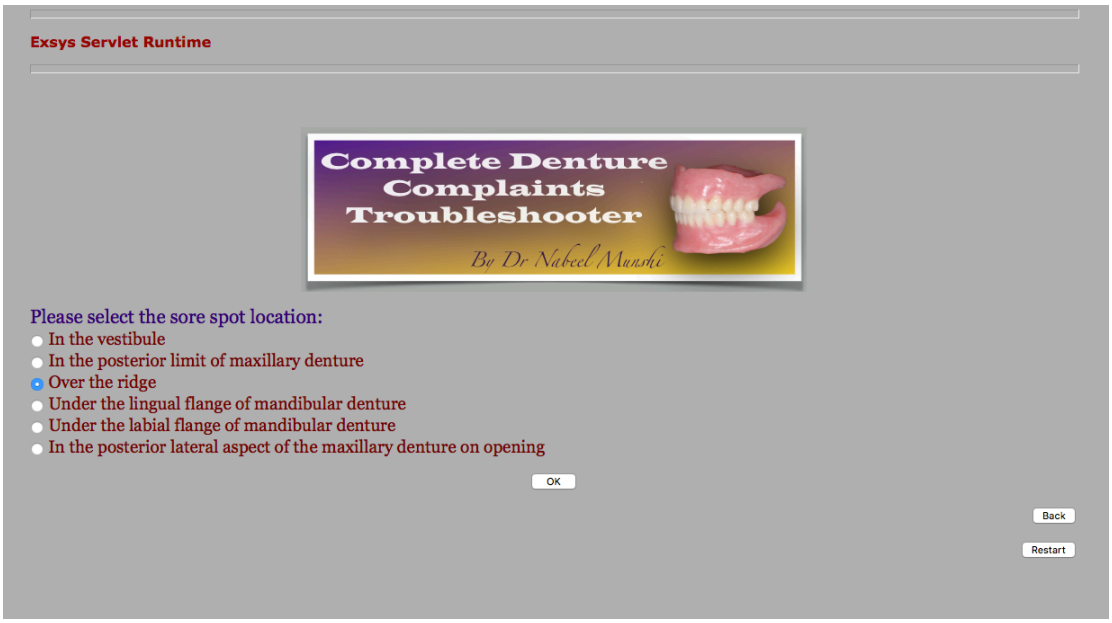

Figure 21: screen shot 3 for case example 1

The system will display the first possible cause for the patient's complaints and the detailed method to diagnose it. The system also will display a picture demonstrating how the diagnostic test should be done correctly (figure 22).

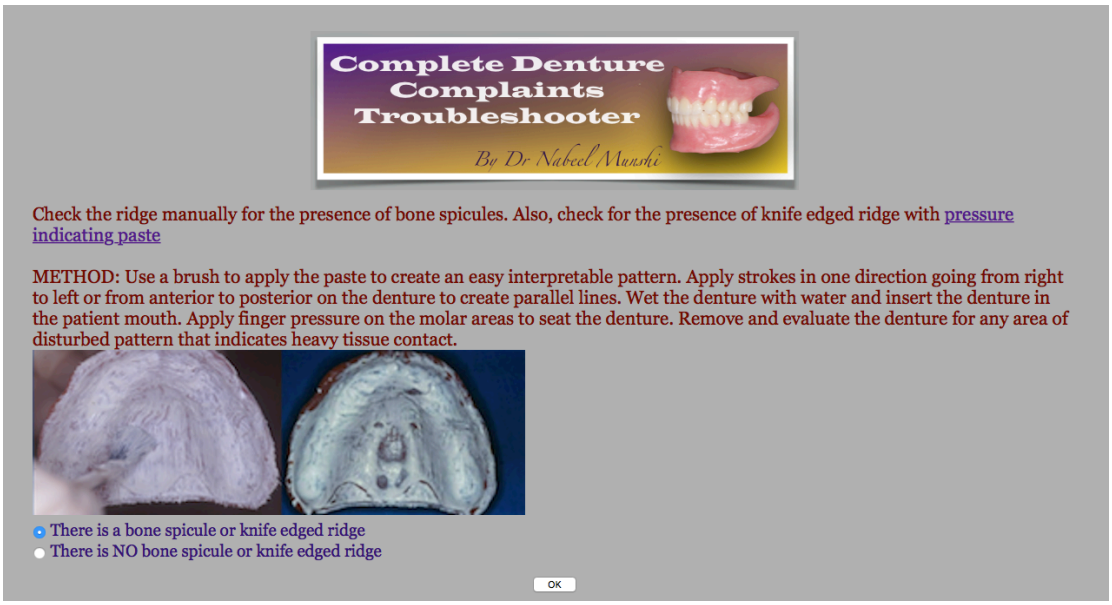

Figure 22: screen shot 4 for case example 1

If the clinician is not familiar with the material that need to be used to perform the diagnostic test, clicking on the hyperlinked material's name will open a new webpage on Google images so to learn more about the material and how to use it. For this case, if the clinician clicks on "pressure indicating paste" the following screen will appear (figure 23).

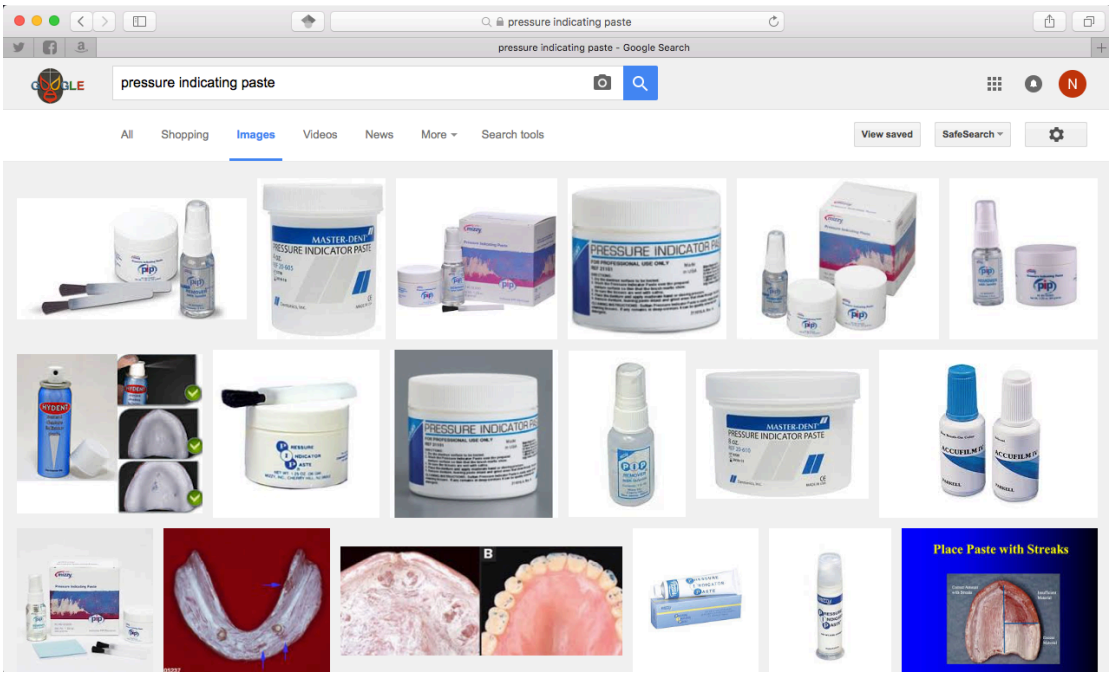

Figure 23: screen shot 5 for case example 1

The clinician then performs the diagnostic test on the patient and returns back to the system and chooses one of two options. If the clinician found the diagnostic test was positive, selects the first option “There is a bone spicule or knife edged ridge” and then “OK” (figure 22). On the next screen, the system then will display the management protocol for the selected complaint (figure 24).

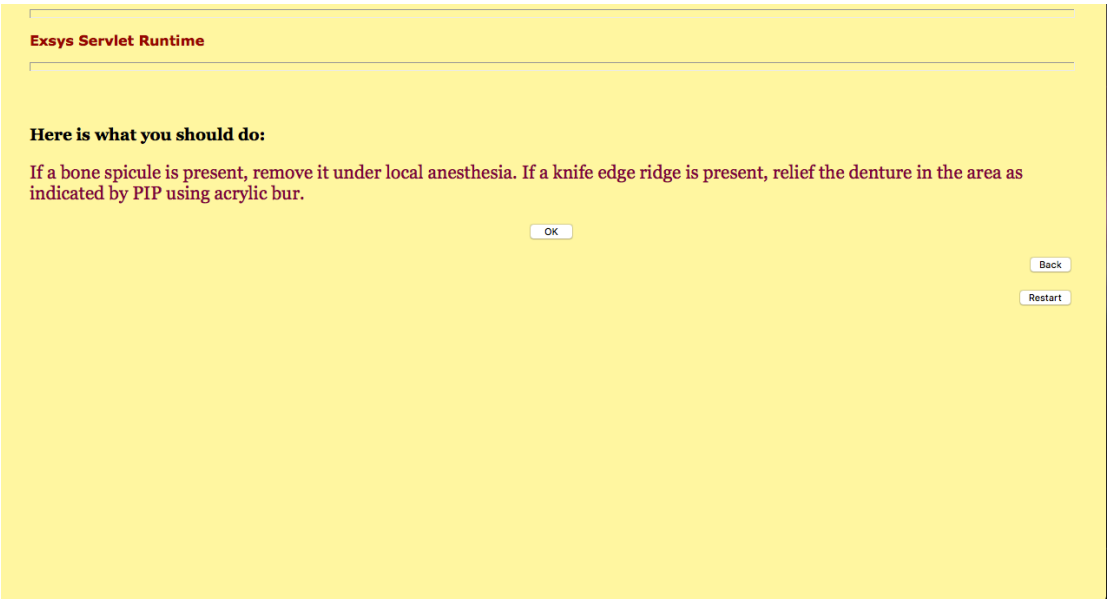

Figure 24: screen shot 6 for case example 1

After viewing the management protocol the clinicians clicks on “OK”. On the next screen and after each complaint’s management screen, the system will displays a list of recommended reference for diagnosis and management of complete denture complaints. These references are useful if the clinician or the student needs further reading about the topic. After the reference page, the system ends (figure 25).

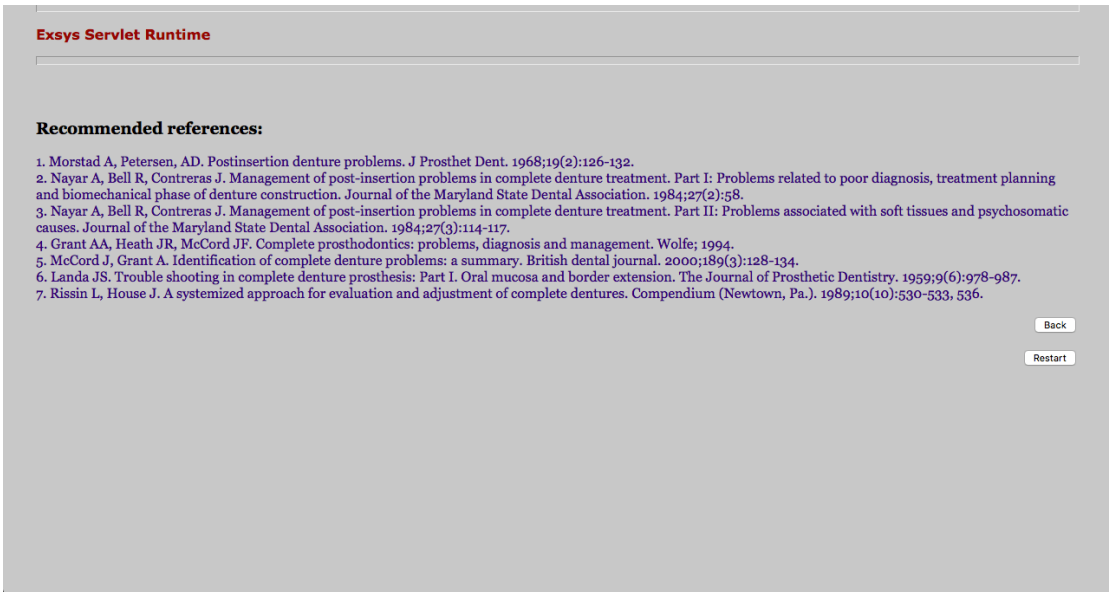

Figure 25: screen shot 7 for case example 1

If the diagnostic test for the first possible cause was negative, the clinician selects the second option “There is NO bone spicule or knife edged ridge” and then “ OK” (figure 22). On the next screen, the system will display the second possible cause for the patient’s complaints and the method to diagnose it (Figure 26). The clinician then performs the diagnostic test and accordingly chooses one of the two options. If the diagnostic test was positive, the clinician chooses the first option. The system will display the management protocol for the second possible cause (figure 27). If the diagnostic test was negative, the clinician chooses the second option. The system will display the third possible cause for the patient’s complaint (figure 28). Since this

cause is the last possible cause, the system displays only one option to display the management protocol for the third possible cause (figure 29). When the clinician clicks on “OK” the system will display the references screen (figure 25) and the system ends. If the patient has another complaint, the clinician clicks on “Restart” to select the other patient’s complaint.

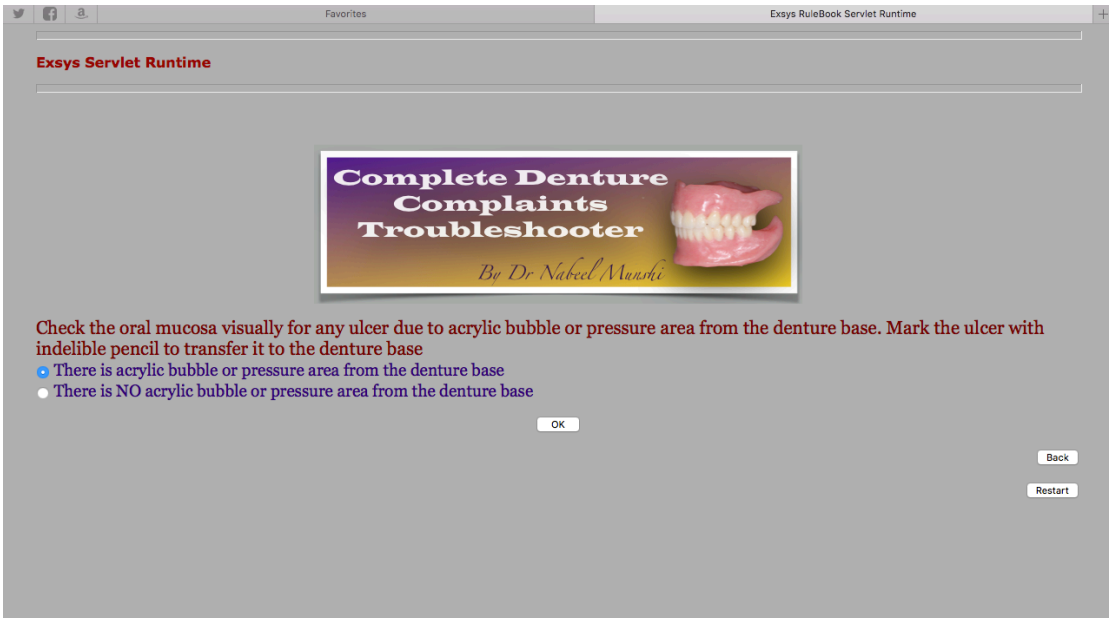

Figure 26: screen shot 8 for case example 1

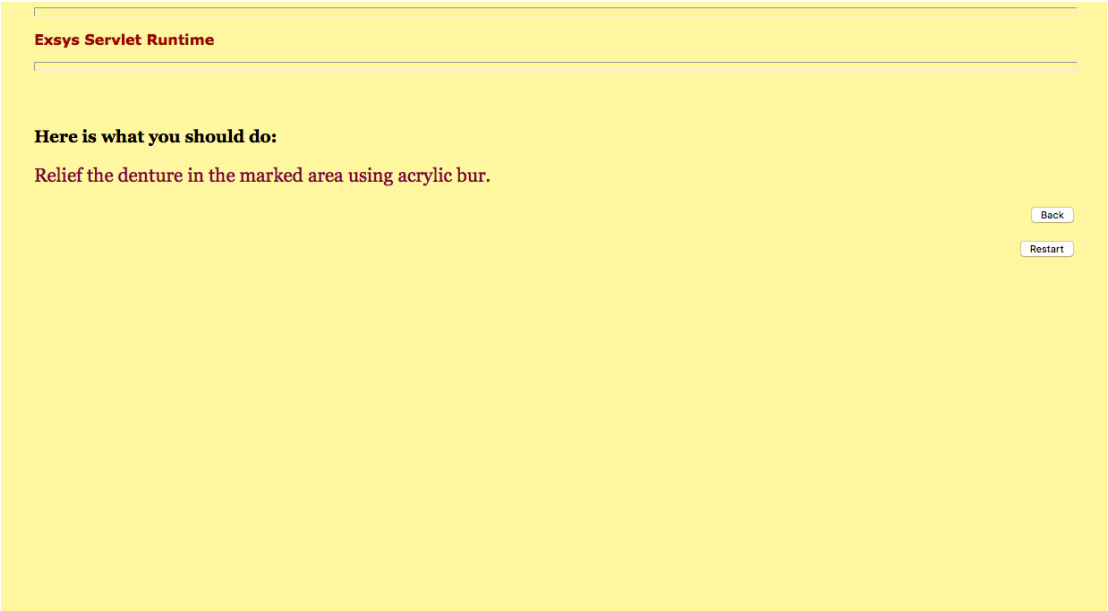

Figure 27: screen shot 9 for case example 1

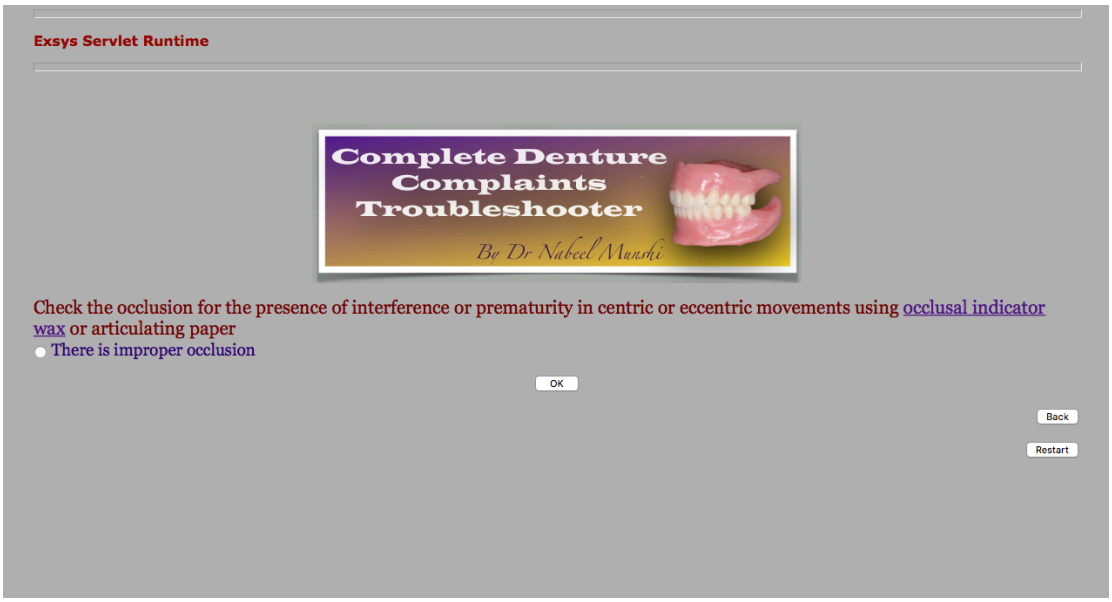

Figure 28: screen shot 10 for case example 1

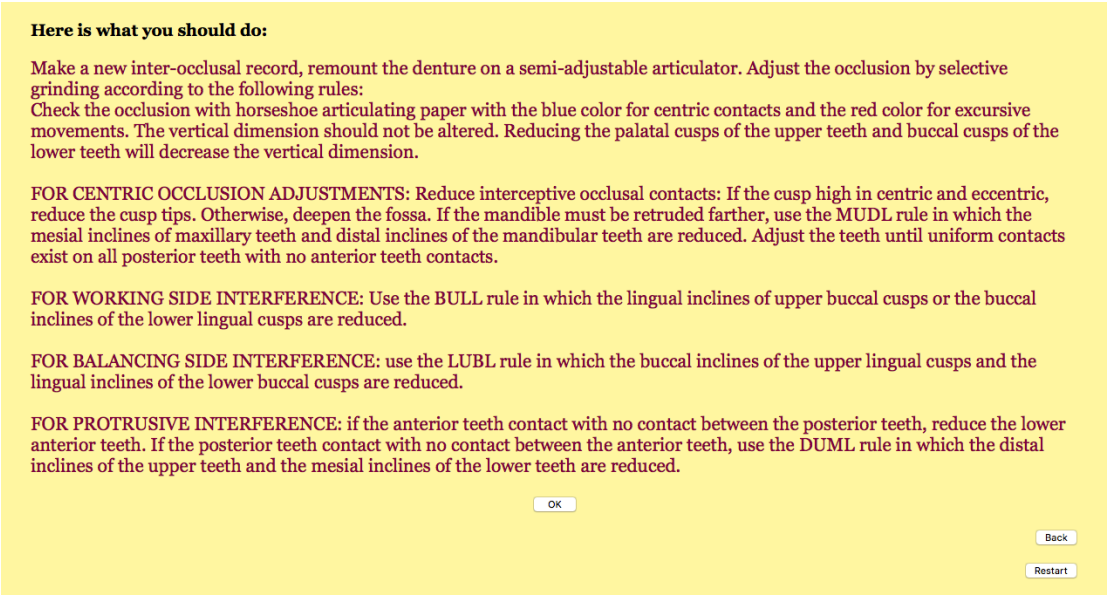

Figure 29: screen shot 11 for case example 1

Case example 2: The patient complains from lisping when he pronouncing the "s" letter when he uses the denture:

After examining the patient, the clinician starts using the system. The first step for the clinician is to select the main category of the patient's complaint "Phonetics related complaints" category and then selects "OK" (figure 30).

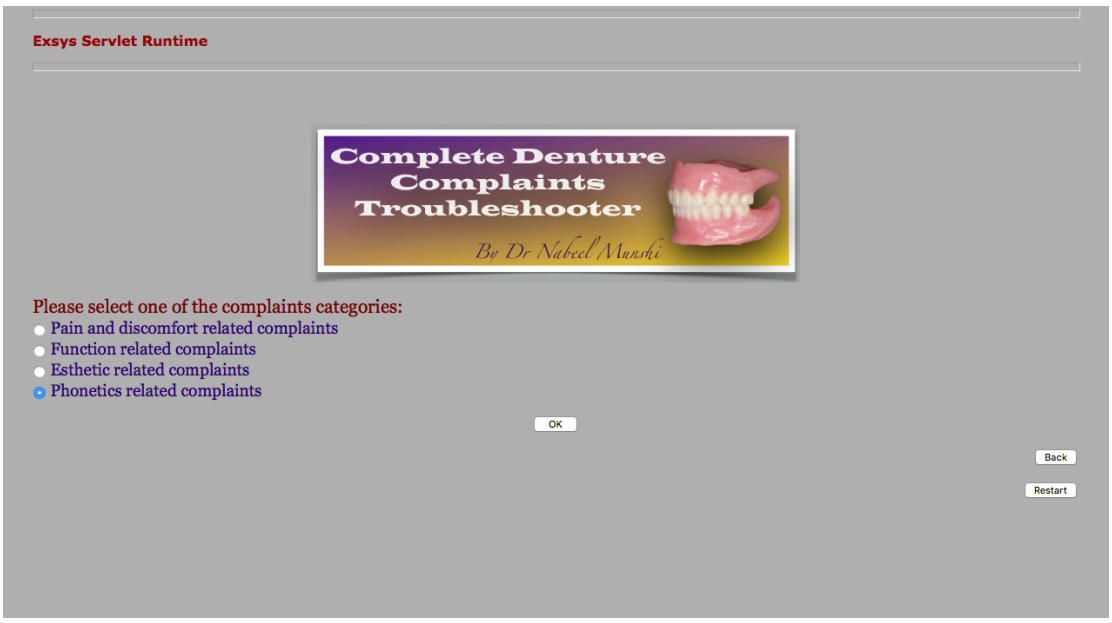

Figure 30: screen shot 1 for case example 2

On the next screen, the clinician selects the complaint "Lisp on "s" sound" and selects "OK" (figure 31).

Figure 31: screen shot 2 for case example 2

The system will display the first possible cause for the patient's complaints and the detailed method to diagnose it. The system also will display a picture demonstrating how the denture will appear if the diagnostic test was positive (figure 32).

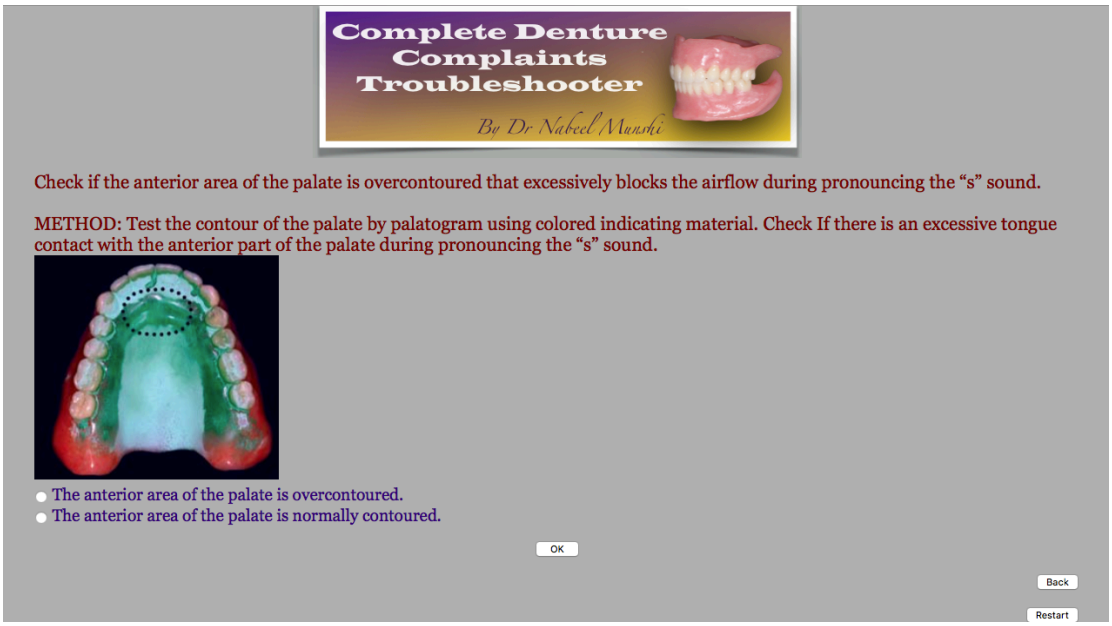

Figure 32: screen shot 3 for case example 2

The clinician then performs the diagnostic test on the patient and comes back to the system and chooses one of two options. If the diagnostic test was positive, the clinician selects the first option “The anterior area of the palate is overcontoured” and then “OK” (figure 32). On the next screen, the system then will display the management protocol for the selected complaint along with a picture to show how the denture needs to look like after correction. Also, the system will display the specific hyperlinked reference for management of this patient’s complaint (figure 33). Clicking on the reference will open a new webpage showing the original reference article in the Journal of Prosthetic Dentistry website. The clinician can review the whole article to get further information about the diagnostic or management method for the patient’s complaint (figure 34).

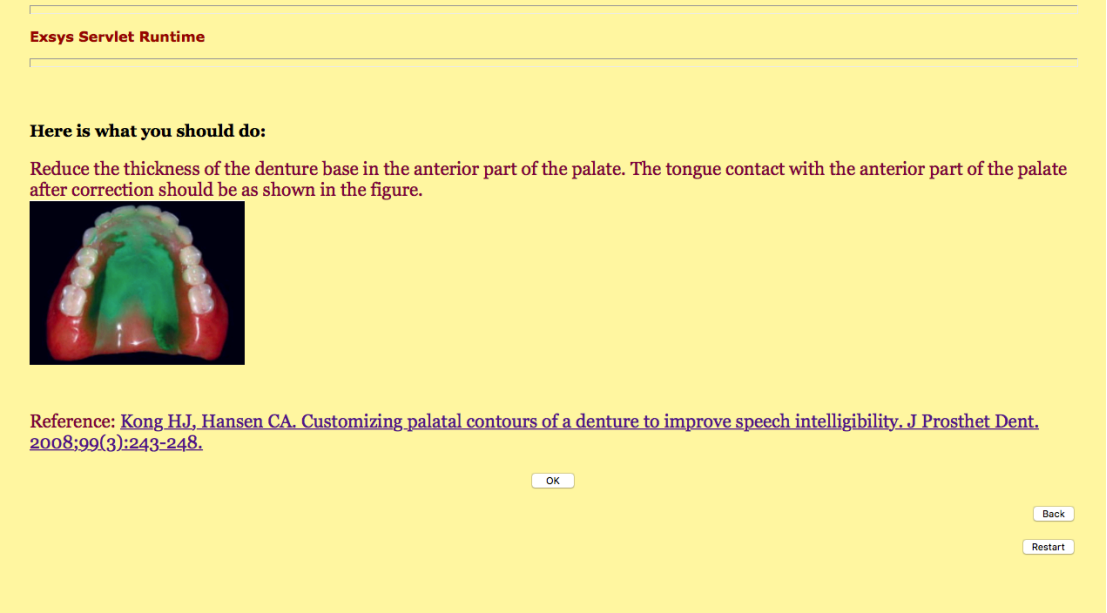

Figure 33: screen shot 4 for case example 2

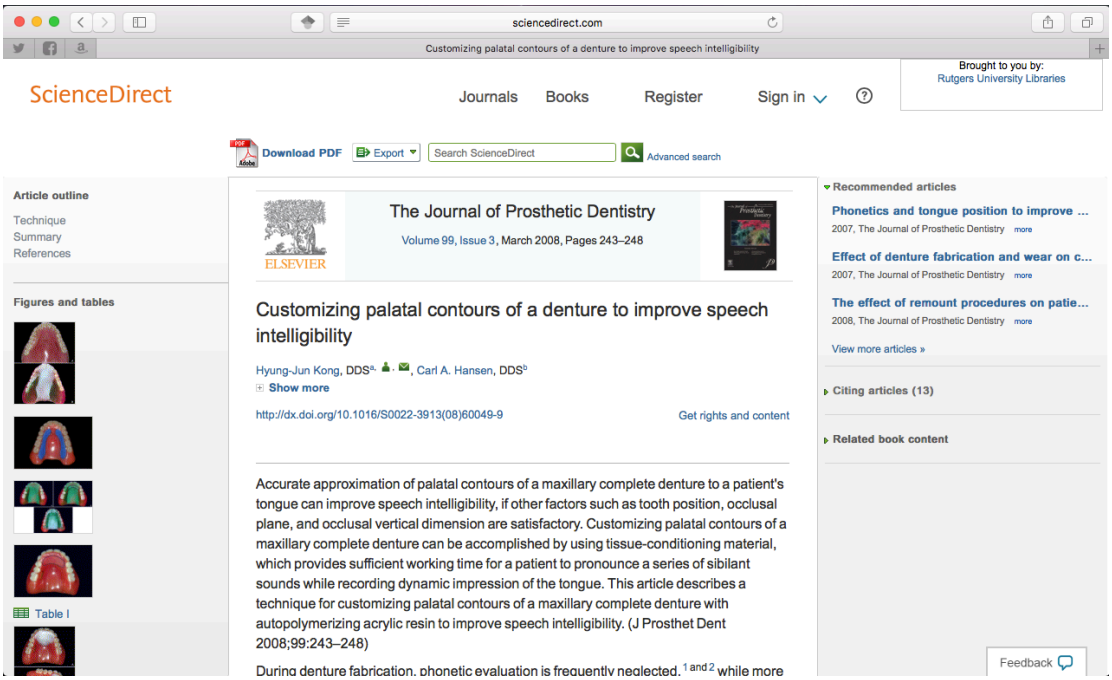

Figure 34: screen shot 5 for case example 2

If the diagnostic test for the first possible cause was negative, the clinician selects the second option “The anterior area of the palate is overcontoured” and then “ OK” (figure 32). On the next screen, the system will display the second possible cause for the patient’s complaints and the method to diagnose it (Figure 35).

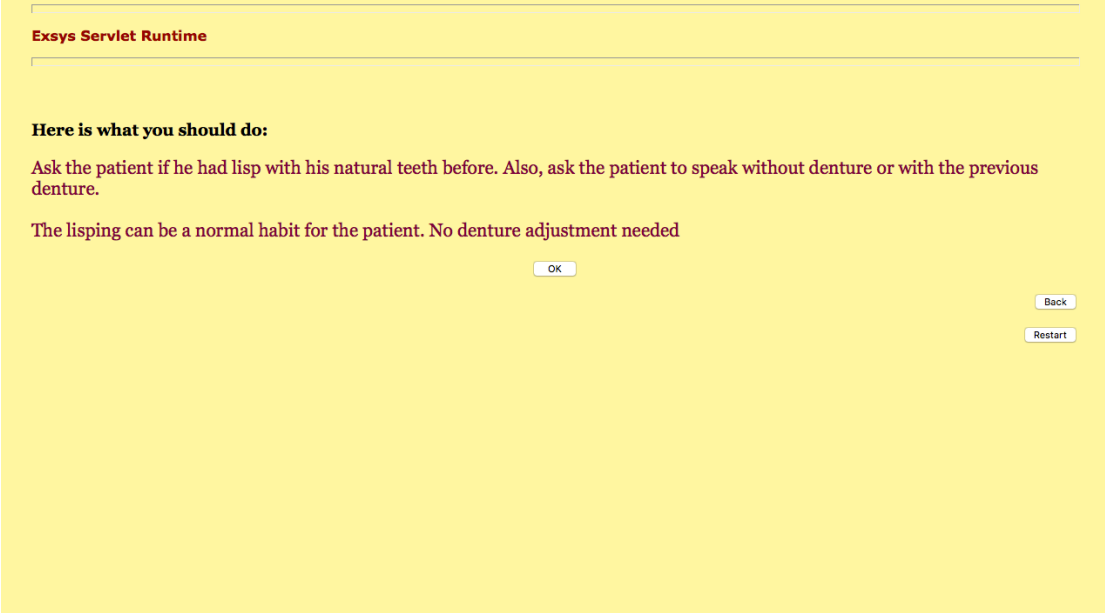

Figure 35: screen shot 6 for case example 2

When the clinician clicks on “OK” the system will display the general reference screen (figure 25) and the system ends. If the patient has another complaint, the clinician clicks on “Restart” to select the other patient’s complaint.

1.2 System validation results:

The internal consistency and reliability of the validation questionnaire items were tested using Cronbach's Alpha test. The results of Cronbach's Alpha test for are shown in Table 5. The Cronbach's Alpha reliability coefficient was 0.847, which is considered within the reasonable range of internal consistency as suggested by Gliem and Gliem.[113]

Table 5. The results of Cronbach's Alpha test for the questionnaire items.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.847	.860	10

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Q1	39.4000	22.489	.543	.	.837
Q2	39.6000	22.711	.442	.	.842
Q3	40.0000	19.333	.482	.	.847
Q4	39.3000	23.789	.303	.	.850
Q5	39.8000	18.400	.726	.	.814
Q6	39.8000	19.511	.691	.	.819
Q7	39.7000	19.122	.610	.	.828
Q8	39.8000	20.178	.485	.	.841
Q9	39.9000	20.544	.744	.	.819
Q10	39.6000	21.600	.680	.	.828

The Validation questionnaire was distributed to ten expert prosthodontists. All of them returned the questionnaire completed with a response rate of 100%. The distribution and percentages of the expert prosthodontist response according to the Likert scale are shown in table 6. All evaluators agreed on the importance to develop the clinical decision support system for diagnosis and management of complete denture complaints due to the complexity of the topic. The evaluators also agreed that the system is user friendly and easy to use. 70% of the evaluators agreed that the system is better available online rather than desktop application.

All evaluators agreed that the system must be implemented in the dental offices to help the general dentists in diagnosis and management of complete denture complaints at the point of care with 80% of them strongly agree on that. 90% of the evaluators found the system as a good tool in undergraduate student training during the complete denture curriculum course while 80% of them found it a good tool for continuing education courses.

Evaluation of the knowledge base of the system showed that 90% of the evaluators agreed that the system contains most of the complete denture complaints, most of the causes for the complaints and the best management protocol for each patient's complaint. The overall agreement of the expert prosthodontists with the system was 100%, which indicates that the system was successfully developed.

Table 6: Distribution and percentages of the evaluators' response to the questionnaire's questions.

Questionnaire question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Q1: Due to complexity of diagnosis and management of complete denture complaints for inexperienced clinicians, there is a need to develop such system.	7 (70%)	3 (30%)	0 (0%)	0 (0%)	0 (0%)
Q2: The system is user friendly	5 (50%)	5 (50%)	0 (0%)	0 (0%)	0 (0%)
Q3: It is better for the system to be available online as a web page than to be stand-alone desktop application.	5 (50%)	2 (20%)	2 (20%)	1 (10%)	0 (0%)
Q4: The system is a good tool to assist the general dentists to manage the complete denture complaints at the point of care.	8 (80%)	2 (20%)	0 (0%)	0 (0%)	0 (0%)
Q5: The system is a good tool for training the undergraduate students	5 (50%)	4 (40%)	0 (0%)	1 (10%)	0 (0%)
Q6: The system is a good tool for continuing dental education courses.	5 (50%)	3 (30%)	2 (20%)	0 (0%)	0 (0%)
Q7: The system contains most of the possible patients' complaints from complete denture	6 (60%)	3 (30%)	0 (0%)	1 (10%)	0 (0%)
Q8: The system provides most of the possible causes for each patient's complaint.	5 (50%)	4 (40%)	0 (0%)	1 (10%)	0 (0%)
Q9: The system provides the best management protocol for each patient's complaints.	3 (30%)	6 (60%)	1 (10%)	0 (0%)	0 (0%)
Q10: Your overall agreement with the system	5 (50%)	5 (50%)	0 (0%)	0 (0%)	0 (0%)

CHAPTER V: DISCUSSION

Diagnosis of complete denture complaints is very complex topic. There are too many complaints and too many causes for these complaints. One patient might have two or three complaints that are caused by only one cause. On the other hand, one patient's complaint might have more than one cause. Failure to diagnose these complaints by general dentists will be very frustrating. This will leave them with two options. The first one is to refer the patient to specialist and lose the patient's confidence and the financial benefit behind him. Brunello et al reported that more than 500 complete denture patients were referred to specialty dental clinic from general dentist because they were unable to diagnose their denture complaints.[19] The other option is to replace the denture with a new one that is unethical for the dentist and add unnecessary cost to the patient. Therefore, it is important to address this problem to find a solution for general dentists and patients.

One of the solutions for the problem is to provide the general dentist with a knowledge resource that is easy accessible at the point of care. To meet this need, the clinical decision support system for diagnosis and management of complete denture complaints was developed in this study. In order to validate the new system, a survey questionnaire was distributed to ten expert prosthodontists with long experience in complete denture treatment (appendix A).

The questionnaire results were statistically analyzed using Cronbach's Alpha test. This test is used to measure the reliability and internal consistency of the

questionnaire items. The coefficient of Cronbach's Alpha ranges between 0 and 1 and it is calculated using the following equation:

$$\alpha = \frac{n}{n-1}\left(1 - \frac{\Sigma Vi}{Vtest}\right)$$

- n = number of questions
- Vi = variance of scores on each question
- Vtest = total variance of overall scores on the entire test

The higher the alpha coefficient means that the questionnaire items have good internal consistency. The rule of thumb in interpreting the Cronbach's alpha coefficient is:

- Excellent when alpha is equal to or more than 0.9
- Good when alpha is equal to or more than 0.8
- Acceptable when alpha is equal to or more than 0.7
- Questionable when alpha is equal to or more than 0.6
- Poor when alpha is equal to or more than 0.5
- Unacceptable when alpha is less than 0.5[113]

In this study, the Cronbach's alpha coefficient for the validation questionnaire was 0.847, which represent good internal consistency of the questionnaire items.

The results of the validation questionnaire showed that all prosthodontists agreed on the need to develop such system for diagnosis and management of complete denture complaints due to the complexity of the procedure. All of the ten prosthodontists agreed that the system is user friendly and easy to use after they navigate through the original system in computer. The diagnosis and management of complete denture complaints need be done in systematic way because adjusting the denture in the wrong spot can complicate the situation and add another problem in the denture. The new clinical decision support system will ensure that the diagnostic procedure is done in step-by-step method. To ensure the systematic approach for

diagnosis procedure, the system display only one cause in a time and dose not display all the causes for the each patient's complaint. The causes are organized in the system heuristic knowledge base so that the system displays the most common cause for the complaint first followed by the less common causes. The system also displays the detailed diagnostic method with figures illustrated how to do each test. The dental material that needs to be used is hyperlinked to easily transfer the dentist to a website that shows how the material looks like and how to use it. This will helps the inexperienced general dentists to perform the diagnostic test in the correct way to avoid the misdiagnosis.

The validation questionnaire response showed a variation in agreement weather the system should be available online or as a stand-alone desktop application. Utilizing the system online require the availability of Internet access in the general dentist office. An investigation by Schleyer showed that 94% of general dentists in the United States have access to the Internet in their offices.[114] Therefore, the new system will be available online to be easy accessible from the dentist's mobile phone or desktop computer. The new system can also integrated in the electronic health record software or it can be available as a mobile application in order to facilitate the accessibility.

As reported earlier, there is a concern about the competency and level of skills of the undergraduate students in mastering the complete denture skills due to limited exposure to denture cases. One of the goals of the new system is to serve as a training tool for the undergraduate students during the complete denture course. The validation questionnaire response showed that 90% of the evaluators found the system

as a good tool in undergraduate student training during the complete denture curriculum course. The system will help the students to learn how construct a successful complete denture in a reverse way. Knowing the patients complaints and their causes will help the students to avoid these complaints during the complete denture construction. The availability of the system online allow the students to access it anywhere and not only during the school hours.

Regarding the knowledge base of the system, 90% of the evaluators agreed that the system contains most of the complete denture complaints, most of the causes for the complaints and the best management protocol for each patient's complaint. Most of the evaluators provided some modifications to the system knowledge base either by adding new rules or modifying the existed ones. These modifications are very important to sculpture the system knowledge since the evaluators have great and long experience in treating complete denture patients.

The Exsys Corvid Core shell was used for the development of the clinical decision support system for diagnosis and management of complete denture complaints. There are several commercially available Expert Systems Shells that can be used to develop clinical decision support systems. These shells differ from each other in several aspects such as end user interface, programmer interface, inference engine, knowledge representation, programing complexity and cost. Salim et al compared between three commonly used shells for developing clinical decision support systems. The three shells are MP2 Professional, Exsys Corvid and Art Enterprise. The results showed that the MP2 Professional shell has the highest functional performance but it is also the most complex one in programming. The

Exsys Corvid and Art Enterprise were in the same rank. They showed less functional performance but they were much easier in programming than MP2 Professional shell.[115] The Exsys Corvid shell was selected for this project for its good performance, ease of programing and reasonable cost.

The future direction of this research is to do a pilot implementation of the system in general dentists' clinics. The general dentists will use the system in diagnosis and management of complete denture complaints at the point of care. After using the system for sufficient time, the general dentists feedback will be collected in a form of survey questionnaire. This feedback will be helpful to improve the system before launching online.

CHAPTER VI: SUMMARY AND CONCLUSION:

The clinical decision support and training system for diagnosis and management of complete denture complaints was successfully developed using Exsys Corvid Core software. The software was very convenient and easy to program without need of pervious background on computer programing. It is also possess a lot of good functions that make it suitable for programing other clinical decision support systems in other branches in dentistry.

The first goal for the system is to help the general dentists and inexperienced clinicians in diagnosis and management of complete denture complaints at the point of care. The failure in solving the patients' complaints and wasting multiple visits until reach the patients' satisfaction could affect the dentist practice. It will decrease the patients' confidence in their dentists that might lead them to switch to another dentist. Also, it will affect the dentist practice by decreases the patients' referrals. The satisfied patient is the best advertising tool for the dentist and lead to more referrals from the patients' family and friends.

The second goal is to be used as a training tool for the undergraduate students improve their skills in diagnosis and management of complete denture complaints. The new clinical decision support system can be used for training the students even in the absence of patients as part of the dental students electronic curriculum. Knowing the complaint and what are the possible causes for each complaint will help the students to avoid that complaint during the denture construction to provide more efficient treatment for the complete denture patients.

The system was validated by ten expert prosthodontists using a survey questionnaire. The questionnaire results were statistically evaluated using the Cronbach's Alpha test. The test result showed good internal consistency and reliability of the validation questionnaire. All prosthodontists agreed with the need of such system in order to aid the general dentists in diagnosis and management of complete denture complaints due to the complexity of the topic. Most of the prosthodontist agreed with the knowledge base of the system and provided their recommendation that were used to further improve the system before launching it online. The overall agreement with the system was 100% that indicate that the system was successfully developed and ready to be used.

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Appendix A: The Distributed Validation Questionnaire

Dear Doctor,

I am inviting you to take part in evaluation of my PhD degree project entitled "Clinical Decision Support System for Diagnosis and Management of Complete Denture Complaints". I am working on my project under the supervision of Dr Shankar Srinivasan and Dr Mohammed Kamel.

The goal of the project is to develop a computer software that will be available online to help inexperienced clinicians and dental students in diagnosis and management of complete denture complaints in a systematic way and using an evidence based knowledge.

Please review the systems knowledge base rules. I appreciate any suggestion and recommendation to add or remove patient's complaints, complaint's causes or modifying the diagnostic or management protocol in order to improve the system. After reviewing the rules, please fill out the included questionnaire about your degree of agreement with the system's rules, as your valuable opinion is important to me.

If you have any question regarding the system please contact me on my e-mail munshinm@shp.rutgers.edu. Or Phone number 2039797597.

Yours faithfully

Nabeel Munshi
PhD student in Biomedical informatics department
School of Health Professions, Rutgers University

Question 1: Due to complexity of diagnosis and management of complete denture complaints for inexperienced clinicians, there is a need to develop such system.

5	4	3	2	1
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Question 2: The system is user friendly.

5	4	3	2	1
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Question 3: It is better for the system to be available online as a web page than to be stand-alone desktop application.

5	4	3	2	1
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Question 4: The system is a good tool to assist the general dentists to manage the complete denture complaints at the point of care.

5	4	3	2	1
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Question 5: The system is a good tool for training the undergraduate students.

5	4	3	2	1
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Question 6: The system is a good tool for continuing dental education courses.

5	4	3	2	1
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Question 7: The system contains most of the possible patients' complaints from complete denture

5	4	3	2	1
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Question 8: The system provides most of the possible causes for each patient's complaint.

5	4	3	2	1
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Question 9: The system provides the best management protocol for each patient's complaints.

5	4	3	2	1
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Question 10: Your overall agreement with the system.

5	4	3	2	1
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Please provide any suggestions or recommendation in order to improves the system: