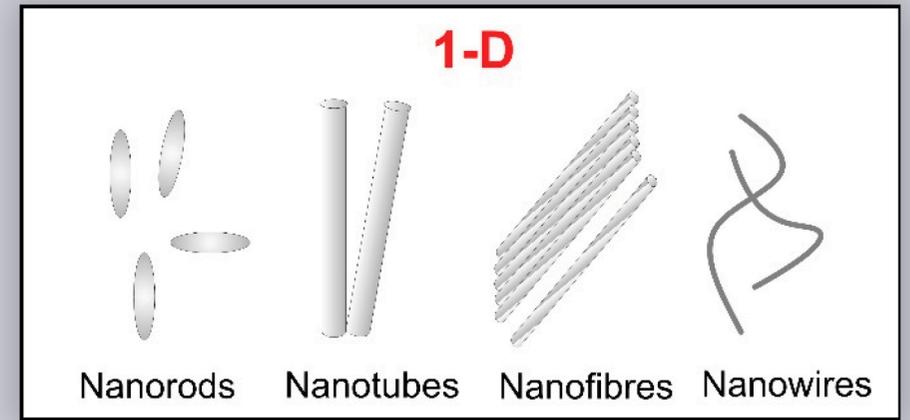


# DENTISTRY RESEARCH

Theory, Method and Practice



Editor

Prof. Dr. Övül Kümbüloğlu



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DENTISTRY

# **Dentistry Research**

**Theory, Method and Practice**

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# **PREFACE**

Books are great resources for improving ourselves in terms of both therotically and practically. This book consists of numerous sections, written by highly valuable researchers of various branches of Dentistry. The editor appreciates all these authors for their contributions and wishes the reader would enjoy being informed, enlightened and encouraged for further investigations on those matters.

Prof. Dr. Ovul Kumbuloglu  
Editor



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# CHAPTER 1

## DETERMINATION OF INTER-ARCH RELATIONSHIP AT ALL POINTS

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### **1. Introduction**

**A**n accurate dental impression is one of the primary essentials for functionally or esthetically successful prosthetic restorations. Subsequent to the impression-making, the inter-arch relationship of the patient has to be determined. The inter-occlusal relationship has to be recorded precisely due to being the other essential for success in any prosthetic rehabilitation. The accuracy of the occlusal records is as significant as a well-obtained dental impression since the patients and the clinician are often willing to reduce the number and the duration of the dental appointments. A possible error in this process may result in spending hours on correcting the deviation of the occlusion<sup>1</sup>. An accurately registered tooth-to-tooth or arch-to-arch relationship is very critical for the success of fixed and removable prosthetic restorations<sup>2</sup>.

The materials and methods for the registration of the inter-arch relationship may differ according to the patient being dentate, edentulous or partially dentate and type of the prosthesis planned. The possible methods are reviewed in this book chapter.

## 2. The Historical and General Perspective on Inter-Arch Recording

E. J. Dunning introduced the Impression Plaster in 1844 which is named as Tip 1 Plaster of Paris gypsum as well. This material is known as to be the first inter-occlusal registration medium. The Modelling Compound was introduced by Charles Thomas Stent in 1856 which is a thermoplastic material recording details difficultly. Both of the materials had some drawbacks unfortunately and needed some modifiers to be added in order to improve their physical properties. Modelling wax, the most common inter-occlusal registration material, was released on the market in late 1920's having both advantages and disadvantages. It is an easy material to be used but has a risk of distortion since the coefficient of thermal expansion is high and the internal stresses are released. In 1930's, Kelly and Ward introduced Zinc oxide eugenol for the first time having an acceptable rigidity for an inter-occlusal registration medium. The brittleness of this material and the dimensional instability due to the evaporation of the by-products are the two main disadvantages of ZOE. In 1961, Chase introduced Acrylic resins as an alternative for inter-occlusal registration materials. Acrylic resins have a drawback because of the polymerization shrinkage, however, the material is a good alternative when the record should be stored for some time. Elastomers were released on the market which were known as to be dimensionally stable than the acrylic resins. In 1969, Polyether was firstly patented having a major advantage of high accuracy and an ability of excellent recovery in case of a deformation<sup>1</sup>.

Phillip Pfaff was the dentist of Fredrick the Great in Germany and he described the technique of "taking a bite" in 1756 for the first time<sup>1</sup>. Natural waxes were the material he preferred to use<sup>3-5</sup>. Till the end of the 19<sup>th</sup> century, this technique was frequently used for the bite registration. Then, Brown suggested the repeated closure using softened wax rims in 1954. Greene preferred to make his patients hold their mandible apart from their maxilla for some seconds in order to fatigue the mandibular muscles and break the muscle engram. Eventually, these methods have evolved into the ones that are routinely used today<sup>1</sup>.

In the past, "Squash Bite", "Biscuit Bite" or "Mush Bite" technique was commonly used in order to determine the centric relation in which the patient bit onto a thermoplastic material such as modeling wax or impression compound placed between the occlusal rims<sup>1</sup>.

In general point of view, the inter-occlusal records can be classified into:

- Centric inter-occlusal records
  - ✓ Maximum intercuspation position records: The inter-occlusal relationship determined at maximum intercuspation of the existing teeth

- ✓ Retruded centric position records: The inter-occlusal relationship determined when the mandible is at the centric relation. RCP is recommended when there is a need of an alteration in the occlusal vertical dimension and a usage of face-bow is indicated
- Eccentric inter-occlusal records
  - ✓ Lateral excursive inter-occlusal records: This registration should be performed with no occlusal contact and the record is taken in lateral excursive movement of the mandible.
  - ✓ Protrusive inter-occlusal records: The record is registered when the mandible is protruded<sup>1</sup>.

Till the beginning era of the dentistry, ZOE and dental waxes can be stated as the base materials among all the inter-arch registration medium due to being affordable and easy to manipulate<sup>6</sup>.

As a general classification, the materials commonly used for inter-occlusal recording can be listed as:

- zinc oxide eugenol paste
- acrylic resin
- modelling wax
- elastomeric impression materials
- impression plaster
- modelling compound<sup>1</sup>.

Polyether bite registration paste (Ramitec, 3M ESPE Dental Products, USA) and polyvinyl siloxane bite registration material (Imprint, 3M ESPE, Canada, Correct Plus Bite Superfast, Pentron Clinical, Orange, CA, USA, Jet Bite, Coltene Whaledent, Switzerland) can be given as examples for up-to-date elastomeric registration materials<sup>2,6</sup>. Other than the materials, there are different ways of making a record of inter-occlusal relationship:

- Graphic method
- Functional method
- Cephalometric analysis
- Inter-occlusal bite registration

Proprioception of the patient, direct visualization and the tactile sense of the clinician is very important for an accurate inter-occlusal record<sup>1</sup>.

The inter-occlusal registration materials can be evaluated according to their physical and chemical properties. The basic requirements for an ideal inter-occlusal registration material can be listed as:

- ❖ dimensional stability upon setting
- ❖ compression resistance
- ❖ surface hardness
- ❖ compressibility
- ❖ no displacement of the teeth at intercuspation
- ❖ ease of use
- ❖ biocompatibility
- ❖ preserving rigidity after setting
- ❖ exhibiting the records of the occlusal and incisal surfaces clearly<sup>1,2</sup>.

There is no doubt that the dimensional stability of the inter-occlusal record medium is the most significant physical property since there may be an error or a delay in the laboratory process during the cast modelling, mounting or transferring<sup>2</sup>. A dimensionally unstable registration material may cause an incorrect inter-arch relationship on the articulator and this may conclude with misleading occlusal contacts dissimilar to the original jaw relationship<sup>7</sup>. In addition, cast models seated improperly on the inter-occlusal registration medium may also end up with varied occlusal contacts<sup>1</sup>.

In their study, Dwivedi et al. suggested that 24 to 48 hours is the ideal time for the usage of the polyether registration material. Same researchers advised that the polyvinyl siloxane registration materials should be used in less than 24 hours and the ideal time for the bite registration wax is founded to be 1 hour. According to the conclusion of the study, the most accurate inter-occlusal record medium was polyvinyl siloxane<sup>2</sup>.

Similar to the study of Dwivedi et al, Tejo et al. stated that the polyether records should be articulated within 48 hours and polyvinyl siloxane records should be articulated within 24 hours. According to the researchers, The ZOE inter-occlusal records should be articulated within 1 hour<sup>6</sup>.

According to Suzuki et al., no matter what the inter-occlusal recording material is, 0.5 mm of a vertical discrepancy is observed while mounting the casts on the articulator<sup>8</sup>. In order to eliminate this situation, double-arch closed mouth impression technique is advised since the inter-occlusal relationship can be determined correctly in single step at the same time when the impressions are obtained. However, it is a disadvantage that the stock trays of this type of impression technique are not rigid and the impressions can easily be deformed<sup>9</sup>.

### **3. The Appropriate Terminology**

The term of 'bite registration' is not a very convenient way to describe the inter-occlusal recording stage since the patient does not bite into anything. Due to the

fact that there is a possibility to make an uncontrolled mandibular movement dissimilar to the Centric Relation, “Biting into something” is not a trustworthy action for the determination of inter-occlusal relationship<sup>10</sup>. For instance, the term of bite registration may be used for dentate patients but using this term for partially edentulous or edentulous patients is not proper since there is actually “no bite” in that circumstance.

According to Glossary of Prosthodontic Terms, an inter-occlusal record is defined as: “the registration of the positional relationship of the opposing teeth or the jaws to each other”<sup>11</sup>.

The most recent description of Centric Relation is as follows: “The maxilla-mandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective discs, with the complex in the anterior-superior position against the slopes of the articular eminences. This position is independent of tooth contact. It is restricted to a purely rotary movement about the transverse horizontal axis”<sup>12</sup>.

Retruded Contact Position (RCP) is the reproducible and repeatable mandibular position which is stated as a reference point for the dental rehabilitation of edentulous or dentate patients. This position is a beginning point for the excursive mandibular movements as well<sup>12</sup>. This position can also be named as terminal hinge position, ligamentous position, premature contact in centric relation and centric relation contact position<sup>13</sup>. In 1952, Posselt stated that the RCP and ICP was at the same point in %10 of dentate people. For the majority, the RCP is at the posterior of ICP<sup>14</sup>.

#### **4. An Example for an Inter-Occlusal Registration Method**

“Functional Bite Impression Technique” consists of the impressions taken under the occlusal loading and functionally generated path (FGP) recording in the determination of the maxillo-mandibular relationship. The prosthetic restorations usually need a very little amount of occlusal adjustment with the help of this technique. The FBI technique is stated as to be used for the fabrication of implant prosthesis, complete dentures or a single restoration. The stages of FBI can be listed as:

- The fabrication of a double-arch custom impression tray with a FGP table
- The trial and adjustment of the FBI custom tray
- The recording of the FGP with an inter-occlusal registration medium
- Double-arch impression
- Pouring of the casts
- Fabrication of the restoration<sup>9</sup>

By means of FBI technique, the cast models can be mounted on the articulator without the removal of the impression material. Less amount of impression material is used and this is equal to less shrinkage of the impression material and less expansion of the dental stone. In their study, Shimizu et al. found out that the inter-occlusal record was more accurate in FBI technique providing an appropriate occlusal height and scheme when compared to conventional technique<sup>9</sup>. For this reason, the researchers recommend the FBI technique especially in cases of single-unit fixed restorations or unilateral removable partial dentures, but this technique has to be clinically and scientifically verified more<sup>9</sup>.

## 5. Inter-Arch Relationship in Edentulous Patients

### 5.1. Vertical Jaw Relations: The Determination of Vertical Dimension...

According to Glossary of Prosthodontic Terms, vertical dimension is defined as: the distance between two selected anatomic and marked points (usually one on the tip of the nose and other upon the chin) one on a fixed and one on the movable member". There are two possible measurements for the vertical dimension:

- Vertical Dimension at Rest
- Occlusal Vertical Dimension

Occlusal vertical dimension is the measurement of the height of the two points on the lower face when the teeth (for dentate patients) or wax rims (for the edentulous patients) are occluded. Prior to any treatment, the possible loss in the occlusal vertical dimension should be determined. The loss in OVD can be seen in partially dentate patients as well because of the posterior teeth loss, so that no dental stop exists. Due to enamel abrasion, a loss in OVD can be observed in dentate patients as well. If there is a need for the determination of occlusal vertical dimension, this stage must be followed carefully during the occlusal registration regardless of the treatment.

Inter-occlusal rest space or freeway space is the difference between the vertical dimension at rest and the occlusal vertical dimension. This space should be determined carefully in order not to cause high OVD. If there is no inter-occlusal rest space, the mandibular jaw muscles will not have their rest at neutral and unpressurized position of the condyles. Thus, the equilibrium will be damaged<sup>15</sup>.

The methods for measuring the occlusal vertical dimension in edentulous patients are classified as:

- Pre-Extraction Methods: These methods are appropriate to be used for the dentate patients only when the OVD of the patient is convenient and the occlusion of the patient is stable.
  - Measurements of Intraoral Dimensions
  - Profile Tracing
  - Cephalometric Approach
  - Pre-extraction Phonetics
  - Pre-extraction Photographs
  - Orofacial Device
- Post-Extraction Methods
  - Physiologic Rest Position and Inter-Occlusal Distance
  - Facial Esthetic Appearance
  - Deglutition/Swallowing
  - Craniofacial Landmarks Measurements
  - Cephalometric Radiographs
  - Post-Extraction Phonetics
  - Measurement of the Former Denture
  - Fingers Length
  - Tactile Sense
  - Biting Force
  - Open-Rest Method
  - Magnetic Plates<sup>16</sup>

## 5.2. *Horizontal Jaw Relations*

This relation is defined as the position of the mandible according to the maxilla in horizontal plane and can be classified into:

- Centric Relation
- Protrusive Relation
- Lateral Relation<sup>15</sup>

There are several methods used for the horizontal inter-arch relationship. The registration of the RCP can be made either patient-guided or operator-guided<sup>13</sup>.

The Patient-Guided Inter-Occlusal Relationship Registration Methods are:

- ❖ Schuyler Technique<sup>17</sup>: An appropriate technique for dentate patients. A piece of horseshoe shaped softened wax is placed between the upper and lower arch teeth. The patient has to touch his/her palate with the tip of the tongue and bite into the wax. This technique can be applied to the edentulous patients as well with the help of wax rims.

- ❖ Physiological Technique: Appropriate for the edentulous patients. Cones of wax are softened and placed in the posterior region. Patient has to swallow several times in order to fatigue the muscles so that the mandible can achieve the retrusion<sup>18</sup>.
- ❖ Gothic-Arch: This technique can be used either extra-orally or intra-orally and proper for edentulous or dentate patients. System consists of upper and lower wax rims, a metal plate and a mandibular pin. As the patient moves the mandible, an arrowhead is scribed and the intersection point of the arrows is the RCP<sup>19,20</sup>.
- ❖ Myo-monitor: An electronic device which provides the determination of the retral contact position with the stimulations for the jaw-closer muscles<sup>21,22</sup>.

The Operator-Guided Inter-Occlusal Relationship Registration Methods are:

- ❖ Chin-point Guidance Method: The clinician puts the thumb and index finger on the chin-point of the patient. There is a risk of over-retrusion<sup>23</sup>.
- ❖ Three finger Chin-point Guidance: Not appropriate for the edentulous patients since the operator may cause a displacement of the denture bases<sup>24</sup>.
- ❖ Bimanual Manipulation Method: Reliability for the condyles to be placed antero-superiorly in the glenoid fossa<sup>25</sup>.
- ❖ Power-centric registration: Clinician applies a posteriorly directed force on the chin. There is a risk of over-retrusion of the condyles<sup>26</sup>.

Retentive lower and upper denture bases are essential for these methods.

## 6. The Role of Face-Bow

The face-bow is a useful accessory for the mounting of the maxillary cast model on the semi-adjustable articulators. By means of the face-bow, the maxillary and mandibular cast models can be mounted on the articulators approximate to the patient's terminal hinge axis. As a result, the occlusal scheme will be accurate in centric relation and eccentric movements.

In their review article, Farias-Neto et al. stated that the use of face-bow can be acceptable in complete dentures or occlusal splint but it is not essential to use it in fixed restorations or removable partial dentures<sup>27</sup>

## 7. Occlusal Registration of the Dentate Patients

Before the beginning of any dental treatment, the current occlusion of the patient has to be recorded in order not to cause any unnecessary and undesirable changes in the occlusion. However, it is also very significant to evaluate the pre-treatment occlusion of the patient based on the criteria of the "ideal occlusion".

The occlusion of the patient may not be close to an ideal occlusion occasionally and this situation may result in various symptoms of temporomandibular joint disorders. In such cases, it is possible that a “re-organization” in the occlusion may be a need even with an increased occlusal vertical dimension<sup>10</sup>. An occlusal diagnostic splint which can be stated as a provisional rehabilitative prosthesis or a definitive hybrid prosthesis (overdentures) can be given as examples for prosthesis with a “re-constructed” occlusion. Unlike these exceptions, the occlusion of the dentate patients should be conformed<sup>10</sup>. In case of maintaining the vertical dimension of the occlusion and the pre-treatment inter-cuspal relationship, the cast models should be mounted on the articulator similar to the jaws’ original relationship<sup>28</sup>

The patient’s occlusion with a tooth-supported removable partial denture or a short span fixed partial restoration is borne by teeth which consists of proprioceptors located within the periodontal membrane. Thus, any possible undesired primary contact and instability in the restoration can easily be felt by the patient since the proprioceptors have the mission of sensing the occlusal loads<sup>10</sup>.

The examination stage of the pre-treatment occlusion is very important in order to plan the prosthetic design. For instance, the removable partial dentures may be tooth supported, tissue and tooth supported or mucosa supported. Since the deformation under occlusal loading and amount of the displacement is different in tooth and mucosa, the sharing of the loading between the tissues has to be adjusted. Hence, “Altered cast technique” described by Applegate is recommended in such cases. On the other hand, at the delivery stage of the prosthesis, the occlusion should be checked carefully regardless of the restoration type, whether there is an unnecessary alteration in the static and dynamic occlusion or the occlusion is conformed successfully<sup>10</sup>.

If the patient is dentate, and there is no loss in the occlusal vertical dimension, bite registration will be enough. If the inter-cuspal position of the patient is comfortable and stable, this means that there is no need for a reconstruction in the occlusion. It would be a wise decision to make ICP coincident to RCP when a reorganization in the occlusion is needed (Wilson-British Dental Journal). RCP is a significant position not only for edentulous patients but for dentate patients as well while mounting the models on the articulator and when there is a need for a re-organization in the occlusion with a new occlusal vertical dimension. In addition, in case of an occlusal splint therapy, RCP is the reliable position to be used<sup>13</sup>.

The inter-occlusal registration methods for the dentate patients are not distinctive from the methods used for the edentulous patients. Various operator-guided methods for the dentate patients will be discussed in the following part:

- ❖ Anterior Guidance by a Lucia Jig<sup>29</sup>
- ❖ Anterior Guidance by a tongue blade<sup>30</sup>
- ❖ Anterior Guidance by a Leaf Gauge<sup>31</sup>
- ❖ Anterior Guidance by OSU Woelfel Gauge<sup>32</sup>

These four methods intend to provide an anterior reference point during the registration of the RCP and maintain the disclusion of the posterior teeth. After the application of these auxiliary tools, the proprioception and the muscle engram is broken so that the registration of the RCP can be achieved easily. Lucia Jig is prepared from self-cured acrylic resin intra-orally or extra-orally on the cast model. The intra-oral preparation of the jig is not recommended due to the exothermic reaction and thermal trauma. The jig is prepared with a 40-60° angle slope in superior-posterior direction. The patient should perform antero-posterior and lateral movements<sup>29</sup>. The posterior teeth should never occlude during this process since these tools provide a training for the teeth and try to deprogram the system. 10-20 minutes of usage is enough for achieving an accurate RCP. Consequent to the determination of the correct anterior guidance, a registration medium can be used in order to register the inter-arch relationship. In case of the usage of leaf gauge and the OSU Woelfel Gauge, a registration support wafer can be used for the registration material to achieve an easy record. If tongue blade or leaf gauge is used as the anterior guidance tool, the number of the wooden spatulas or the thickness of the leaves can alter in order to provide the disclusion in the posterior teeth.

In general, usage of an anterior jig, well-performed chin-point guidance and bimanual manipulation methods can be recommended<sup>13</sup>.

If the restoration is a crown or a bridge where there are appropriate number of standing teeth as well, the occlusion will be preserved and the restoration will be prepared in maximum intercuspation. In this case, it will be enough to record the quadrant of the prepared teeth. Full-arch registration materials are not recommended since the total closure of the teeth can be prevented by the material<sup>33</sup>. An inter-occlusal record may not be required if the teeth have stable intercuspation providing a tripod in occlusal contacts. Inter-occlusal registration is essential when the arches lack horizontal stability in their intercuspation<sup>34</sup>

## 8. Methods of Occlusal Analysis

Occlusal analysis can be made in two ways: Qualitative method or Quantitative method. Qualitative methods are not reliable since they are stated as conventional and cannot measure the amount of the load. Articulating papers,

shim stock, waxes and silicone impressions can be given as examples for the qualitative occlusal analysis methods. Photo-occlusion and T-Scan systems are the quantitative methods which determine the density of the occlusal contacts<sup>35</sup>

## 9. Digitalization in Inter-Arch Relationship

Currently, a totally digital workflow can be preferred while preparing prosthetic restorations. By means of the improvement in the resolution of the intraoral scanners (IOS) and the addition of the tooth color, a real-like image of the teeth can be obtained easily. In the digital workflow, the buccal bite is registered and scanned by the IOS and the static inter-cuspal position is recorded digitally. The occlusal contacts are shown in distinctive colors. Well-obtained digital impressions of the both arches and an accurate digital inter-occlusal record are the essentials for the digital workflow<sup>36</sup>.

The following steps should be taken care in the digital workflow:

- Digital impression of maxilla and mandible
- Inter-occlusal record of static occlusion and excursive mandibular movements
- Transferring the maxilla in relation to the patient's skull
- Mounting the virtual models on the virtual articulator<sup>37</sup>

Virtual face-bows can be used in order to mount the maxillary digital model on the virtual articulator according to the reference planes<sup>37</sup>.

Determining the occlusal contacts with colors by using the articulating papers is recommended before any digital scanning of jaws' relation<sup>38</sup>.

## 10. Conclusion

Inter-occlusal registration is the most essential step for the preparation of the prosthetic restorations following the impression-making process in order to simulate real-like occlusal scheme. Since the beginning era of the dentistry, there are various methods and materials used for the determination of the inter-occlusal relationship. The methods and the materials can be preferred according to the restoration type and the situation of the case being edentulous or dentate. Some of the conventional methods and materials are stated recommended as gold standards, thus, it would be better for the clinician to make a good decision in relation to the case. However, digital inter-occlusal records have guaranteed their places in dental practice and it is also comprehensible that there is no escape from the digital technology in the near future.

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## CHAPTER 2

# POSSIBLE COMPLICATIONS AFTER DELIVERY OF REMOVABLE DENTURES

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### 1. Introduction

Removable dentures are still the most common form of treatment of the reduced, seriously compromised dentition. One treatment goal, in addition to restoring the patient's function and esthetics, is to prevent further damage to the masticatory system. Although it is not a viable tissue, a prosthesis is compatible when accepted by the oral environment. Character, age, neuromuscular adaptation capability, and expectations of the patient make it sometimes very difficult to adapt to the new denture.<sup>1</sup> Thus, the patient should be informed of the possible discomfort in the first few days, e.g., soreness, difficulty with phonetics, discomfort, and gagging.<sup>2,3</sup> Patients mostly like to know that these difficulties can be solved easily in the control appointments. It is vital to inform the patients about the importance of periodic recalls.<sup>4</sup>

## 2. Complications

Problems that may occur after the delivery of removable prosthesis can basically be examined in two groups.<sup>4,5,6</sup>

### 2.1. *Early Period Complications (after 24 hours):*

Most common early period complications are;

- a) Sore spots: Painful areas with erythema in the mucosa located at the tip or slope of the crest, vestibul flange and on frenulum. Pressure areas may be caused from premature tooth contacts and also the impaired base plates as well. Pressure indicator paste for the detection of hit points or marking with an indelible pencil methods can be used.

Pain on denture bearing areas can be caused by acrylic residues remaining on the inner surface of the denture and the sharp edges. Internal surface is checked with finger, pressure areas should be determined and corrected.

The cause of the generalized pain on denture bearing areas may be the short boundaries of the denture base or over correction of the impression surface during adjustment of the prosthesis. Underextended denture base of removable denture may be elongated by relining or rebasing with a suitable functional impression method.<sup>1, 4, 7, 8</sup>

- b) Difficulty in seating or removing the denture: Soft tissue undercuts may create problems if any component of a removable denture passes over them during insertion or removal of the prosthesis. These problems usually involve pain and discomfort due to injuries of these soft tissues. These soft tissue undercuts should be surgically corrected prior to definitive treatment but if they appear after the treatment, the RPDs may be rebased, relined, or remade according to the extent of the surgical procedure.<sup>9, 10</sup>

Patient-related factors may be inability to manipulate or distortion of the RPD after usage. Elder RPD users may have systemic neurologic disorders. It is very important to show the patient how to insert and remove the prosthesis and ask him/her to manipulate with the practitioner in the first and the following early appointments.<sup>2, 6, 11</sup>

- c) Difficulty in chewing: Patients should be advised not to eat tough and sticky food during the early period of adjustment. The occlusal surfaces of the artificial teeth should be examined with an articulating paper, and the occlusal prematurities should be eliminated or the artificial teeth of one or both sides should be reset where an occlusal adjustment is not adequate to

overcome occlusal problems, or if some artificial teeth lack occluding the opposing arch.<sup>12, 13</sup>

Pain on the prosthesis edge mostly accompanied by pain in masseter and temporal muscles is also one of the most common problems. The reason is that the occlusal vertical dimension is more than the tolerable level for the patient. If it is less than 1.5 mm, corrections may be done to provide free way space. If more than 1.5 mm, interocclusal records and vertical relationship of the jaws should be determined again and teeth arrangement should be renewed.<sup>14, 15, 16</sup>

- d) Biting cheeks and tongue: The cause of cheek and tongue biting may be the inadequate functional width of the sulcus, low vertical height, teeth arrangement localized out of the crest line, inadequate interalveolar distance and inadequate horizontal overlap at molar region. In order to overcome these problems, functional width of the sulcus is provided, teeth alignment should be rearranged, tuber region should be thinned and edges at retromolar region should be shortened, lower buccal tubercles should be abraded from vestibule surface respectively.<sup>15, 17, 18</sup>
- e) Pain /soreness in the throat, difficulty in swallowing: The reason of this complaints may be, high vertical dimension of prosthesis, long edges at retromylohyoid region or ulcerations due to deep modelling of the post dam area. Vertical height should be decreased, relining may be applied and edges may be shortened.<sup>6, 8, 19</sup>
- f) Prosthesis with insufficient retention: This problem may be caused of many different reasons. The major one may be the lack of peripheral sealing. The sulcular edges of the prosthesis may be short and thin. The borders should be reshaped by the functional movements of the patient to obtain accurate hermetic sealing and the impression should be renewed. Relineing may be applied as a temporary solution. The premature occlusal contacts can also cause rotation of the dentures and deteriorate the retention. Occlusion should be rechecked and premature contacts must be eliminated. Xerostomia, decrease in salivary secretion, also reduces the retention of the prosthesis. The direct results of decreased salivary secretions, decrease in the resistance of the mucosal tissues against mechanical irritations, decrease in the retention of prosthetic restorations. In order to decrease the complications of denture usage in patients with xerostomia, the oral hygiene which will be provided by mouthwashes with chlorhexidine and daily artificial saliva makers is very important. Even so, complications can

be expected and if possible, the use of dentures continuously should be limited. <sup>14, 20, 21, 22, 23</sup>

Excessive displacement forces can also cause retention problems. If the buccal flanges at tubers are long, then it makes the denture move when the mouth opens and if the lingual flange is thick, the tongue replaces the mandibular denture during movement. The excessive long margins should be shortened to normal mucosa. If the upper prosthesis dislodges when yawning or when the mouth is excessively opened, the flanges at posterior region may be too thick or the border at homular notch is too long. <sup>6, 22</sup>

Dislodging of upper prosthesis during chewing may be due to non flexible areas at the median palatal raphe that requires relief and inaccurate teeth setting.

If the prosthesis suddenly loses its retention, the reason is often a mechanical problem. The lower prosthesis may be displaced as a result of modiolus contraction, the edges of prosthesis are not well contoured. Excessive long or short flanges at masseter area and external oblique line can cause the removal of lower denture. Again for the lower prosthesis, if the occlusal plane is very high, the tongue applies firm pressure to the lingual surfaces of the lower denture and replaces it. <sup>22, 24</sup>

- g) Noise raised from teeth during chewing: This problem may be caused by high vertical dimension, lack of stability in prostheses, porcelain tooth, insufficient overjet and problems with lateral movements. <sup>21, 22, 25</sup>
- h) Phonation disorders: Labially or lingually localized anterior teeth and high and low vertical dimension of dentures are the main reasons of these problems. Rearrangement of teeth is required to overcome such problems. <sup>25</sup>
- i) Feeling nauseous: Incompatibility with the tissue, a gap at the post dam region, thickness of palatal plate, excessive posterior borders, long distolingual borders, inadequate space for tongue, occlusal disorders are the reasons related to dentures for feeling nauseous. However, the psychological side of this situation should be kept in mind after checking all these possibilities related to dentures fabrication process <sup>4, 10, 17</sup>
- j) Reduced sense of taste: This situation is not related to the prosthesis. The dorsum part of the tongue should be brushed. It must be told the patient that it is a psychological effect. <sup>13, 17</sup>

- k) Food impaction under prosthesis: This problem can be caused by the lack of stability and incorrect impression of the dentures. <sup>21, 22</sup>
- l) Increase in saliva rate: Salivary glands react against the new prosthesis as a foreign material and release more secretion. This situation is temporary and will be over by the time as the patient gets used to his own denture. The patient should also be informed about this. <sup>10,11,17</sup>
- m) Aesthetic problems: The patients can complain about plump or collapsed appearance on the lips, wrinkles on the lips and more or less visibility of teeth during speech and smiling. If the teeth arrangement is localized to palatinally, lip commissures hangs down, upper lip gets shortened and the nasolabial sulcus is deepened. If the teeth arrangement is localized labially, then lips tighten, filtrum becomes shallower and the nasolabial sulcus is erased. <sup>1, 2, 10, 11</sup>

## ***2.2. Late Period Complications:***

Most common late period complications are;

- a) Sore spots: Sore spots can be detected at borders of dentures localized especially at lower canine region due to tissue changes and resorption by the time. <sup>1, 5, 6, 7</sup>
- b) Loosening of prosthesis: It usually depends on resorption. Therefore, patients should be told that prostheses should be renewed every five years. <sup>7, 8, 18</sup>
- c) Halitosis: The reason is mainly poor oral hygiene and systemic disorders. <sup>26</sup>
- d) Burning sensation on tongue and palate: The pressure over the incisive papilla and mental foramen may cause paraesthesia, pain, burning sensation and similar complaints. <sup>17, 23, 27</sup>
- e) Collapse in facial appearance: Due to atrophy, the lips and the submucosa are thin and collapse through the mouth. The vermilion border is converted into a single line, and the mouth opening is reduced. <sup>8, 10, 18</sup>
- f) Cheilitis in the corners of the mouth: Saliva accumulates in the corners of the lips, and infection can develop together with tissue injury. These painful fissures develop through the sides and inferiorly on the skin and create a condition known as angular cheilitis. Angular cheilitis is seen in the corners of the mouth can be caused by decreased vertical dimension and *Candida albicans* coming from saliva contaminated by stomatitis. For the treatment of angular stomatitis, if the vertical dimension is low, a new denture should

be made, and if candida infection is present, antifungal pomades should be used.<sup>21, 26</sup>

- g) Irritations in sub-prosthetic tissues: Denture hyperplasia begins with the irritation of the denture flanges at first, and a hyperemia is observed in the tissues. Fibrous hyperplasia can be observed when a specific point in the lower or upper jaw is exposed to excessive force for a long period and when mucosal atrophy cannot follow bone atrophy. If there is a worn and inadaptable denture, depending on the length of time, and if the mucous membrane covering the bone is too thick, the movement of the denture during function will create distortion that causes damage to the tissues. In patients who have severe irritation from their old dentures, soft tissue surgery can be required, which could be a result of major mistakes of denture or bone resorption that cannot be compensated by modifying the inner surface of the ill-fitting denture.<sup>9, 20, 21, 22</sup>
- h) Ear ache: The reason may be high vertical dimension and premature contacts creating pain in temporomandibular joint.
- i) Denture fractures: Fractures may occur when dropped by the patient or breaks in the mouth during use. Fractures due to use may be a result of inadaptable denture bases, tight contacts in the anterior area, occlusal disorders and excessive forces from antagonist natural dentition. Denture fractures are sometimes due to anatomical structures such as torus palatinus, labial frenulum extending to crest tip and tissue undercuts. In order to avoid from fractures a metal mesh substructure is recommended to increase the fracture resistance of dentures during fabrication process.<sup>28</sup>

### 3. Conclusion

Removable dentures usually requires periodic recalls and can create new complications for the patient that has never been existed before. It should be kept in mind that the surrounding tissue is dynamic and changes by the time thus, occlusal re arrangements and relining may be needed. The important thing is to solve the problem before it grows.

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## CHAPTER 3

# AN OVERVIEW OF ANTIMICROBIAL METAL AND METAL OXIDE NANOPARTICLES IN DENTISTRY

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### 1. Introduction

Nanotechnology is based on the idea of creating functional structures by individually controlling atoms and molecules. In general, nanotechnology term is translated as “the science of the little ones”. However, in addition to creating small structures, nanotechnology also includes developing devices and materials with different biological, chemical and physical properties from large-scale structures (1). The term nanotechnology was first expressed by Taniguchi as “material processing, separation, joining and degradation at the atomic or molecular level” (2). Today, the usage areas of nanotechnology related to the field of health can be grouped under various headings such as the production and transport of drugs, the creation of biomaterials, tissue engineering, in vivo imaging, in vivo / in vitro diagnosis and treatment of diseases (3,4,5).

Nanotechnology is used to obtain nano-sized materials. These nanomaterials also referred as nanostructures, can be categorized according to their size. While nanoparticles are zero-dimensional nanostructures, nanotubes and nanofibres are one-dimensional nanostructures (6). Nanoparticles, nano-sized materials between approximately 1-100 nm, have different morphologies such as prism, rod, cube, sphere (7). The physicochemical properties of these materials including ultra-small dimensions, enhanced chemical reactivity and wide surface area-to-volume ratio have increased the use of nanomaterials in

antibacterial treatments (8). In this context; sizes, structures and surface properties of nanoparticles cause them to be accepted as effective antibacterial agents (9). There is an inverse relationship between the size and antimicrobial activity of nanoparticles. Nanoparticles between 1-10 nm show the highest biocidal effect against bacteria (10,11). The smaller the particle, the greater the ratio of surface area to volume, increasing biological activity and chemical reactivity. The high chemical reactivity of nanomaterials increases the formation of free radical-containing reactive oxygen species (ROS) (12). Among the nanomaterials with antibacterial properties, metallic nanoparticles such as gold, silver, copper and metal oxide nanoparticles such as zinc oxide, copper oxide, and titanium dioxide are the most effective ones. And nanotechnology with metal oxide nanoparticles exhibits a way to enhance the activity of inorganic antibacterial agents (9).

## 2. Nanotechnology

Nanotechnology is one of the most interesting and topical areas of science. This technology is based on the idea of creating nanostructures in the size range of 0.1–100 nanometers by controlling atoms and molecules. This discipline includes the formation, characterization, and application of materials at nanoscale dimensions. This technology will also give us the ability to arrange the atoms as we wish and achieve effective and complete control of the structure of matter (1,13,14).

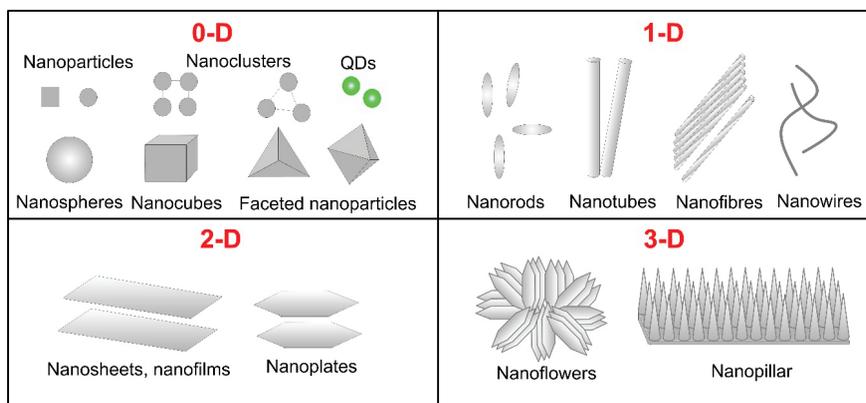
There are two approaches for obtaining nanoscale materials. These are top-down and bottom-up approaches. In the bottom up strategy (e.g. sol-gel method), the production of material is from atoms and molecules and the material increases in size until this continuous change is limited. In this case, the parameter of interest is the size of the object, not the number of atoms it contains. Better control of particle size can be achieved with a bottom-up strategy. In the top down strategy (e.g. conventional milling processes), it deals with improvements in the properties of a sample that gradually decreases from macroscopic to nanometric sizes by breaking the material down (6,13,15).

Materials at the nanoscale have new properties that are very different from the molecular properties of the material. Compared to bulk materials, nanomaterials have a much higher surface area than their total volume. The large surface area affects the interaction of elements and nanoparticles with each other (16). And also large surface area/volume ratio allows nanomaterials to expose different biomedical activities compared to normal sized materials. Conductivity, uniformity and special optical properties are the other unique physical properties of nanomaterials and these properties make them more advantageous in biology

and materials science (14). Several nanostructures with unique properties have been developed by nanotechnology for biomedical applications (17). Today, health-related uses of nanotechnology can be grouped under various headings such as drug delivery, creation of biomaterials, in vivo imaging, in vitro diagnosis, creation of active implants and treatment of diseases (18).

### 3. Nanoparticles

Nanostructures are classified according to their morphologies, such as nanoparticles, nanotubes, nanocrystals, and nanofibers. Nanoparticles are a zero-dimensional structure that has a spherical shape, nanotubes, nanorods and nanofibers are one-dimensional hollow structure (19).



**Figure 1.** Scheme of nanostructured materials with different morphologies. 0-D, 1-D, 2-D, and 3-D indicate zero-, one-, two- and three-dimensional nanoparticles (20).

In general, powders of 100 nm or less are called nanoparticles. According to the European Union (EU), nanoparticles have one or more external dimensions in the size range from 1 to 100 nm. The larger surface area/volume ratio of nanoparticles than bulk materials makes nanoparticles much more reactive compared to larger particles with the same composition. This can also increase the elution/release of potentially toxic substances (21). The wide surface area of nanoparticles is relevant to mass and heat transfer between particles and their surroundings, and is important for properties such as reactivity, solubility, sintering performance, which affect particle surface and internal properties. When atoms and molecules on the particle surface become effective in the nanometer arrangement, the material's melting point is lower than the bulk material's melting point, as they tend to move easily at low temperatures. The reduced melting point of

very small particles is due to a unique property of nanoparticles associated with deposition and particle growth. Since the nanoparticles are smaller than the visible wavelength, light scattering is neglected and higher transparency can be achieved than conventional pigments. Nanoparticles generally show common properties. Therefore, the environmental conditions and dispersion of the particles are important as well as their physical properties. The nanoparticles aggregate due to adhesion and in many cases they show binding due to this high adhesion throughout the manufacturing process (22). Unfortunately, one of the biggest challenges in the application of nanotechnology in restorative materials is the agglomeration of nanoparticles. The high surface-free energy concentration leads to nanoparticles to bind strongly to other materials and to each other. When particles are weakly bound by Van der Waals forces, they are referred to as “agglomerates”, while “aggregates” are referred to as particles bound together by solid bridges (13).

The main factors that determine the behavior of nanoparticles are their size, shape and surface (23). The fact that the sizes of nanoparticles are smaller than the critical lengths that define many physical phenomena gives them unique properties (1). These unique properties provide many benefits in dental applications. The nanoparticles can provide large surface area, prevent white spot lesions and biofilm formation by antimicrobial, antiviral, and antifungal properties, enhance the mechanical properties of dental materials, enhance the bond strength between dentin and material (24). Nanoparticles exhibit effective antimicrobial functions through large surface areas that provide more contact with microorganisms (25). Enhanced antimicrobial activity occurs when the high positive charge and large surface area of the nanoparticles interact more with the negatively charged surface of the bacterial cells (26,27).

The concentration, shape, size, surface chemistry of nanoparticles and also environmental factors are factors that affect the antibacterial activity of nanoparticles. It has been stated that the surface size of nanoparticles, as well as their potential to infiltrate the bacterial wall, are effective on the ability of nanoparticles to bind to bacteria and on irreversible cell damage. The larger surface area of the smaller nanoparticles makes it possible to interact more effectively with bacteria, resulting in increased bactericidal activity (28). Nanoparticles can adhere to the cell walls of both Gram positive and Gram negative bacteria and penetrate into the cell, impairing cell function with releasing relevant ions. Therefore, it can be concluded that nanoparticles are favorable in inhibition of biofilm formation and the treatment of diseases induced by drug-resistant microorganisms. Although the specific mechanism of action is not yet clear,

the antibacterial mechanism of nanoparticles can be defined in three categories. Firstly; interaction with the cell wall and membrane of peptidoglycan, causing cell lysis; secondly, interaction with bacterial proteins and disruption of protein synthesis; the third is interaction with DNA of bacteria and inhibition of DNA replication (27).

#### **4. Antimicrobial Metal Nanoparticles**

Metal and metal oxide nanoparticles are applied in various fields of dentistry due to their broad spectrum bactericidal properties (27). Nanoparticles can show their antibacterial properties in the oral cavity in two ways, the first is to combine dental materials with these nanoparticles, and the second is to cover the surface of the materials with nanoparticles with the aim of reducing biofilm formation by preventing microbial adhesion (29,30). The high surface/volume ratio and size of metallic nanoparticles lead to them to react with microbial membranes, resulting in an additional antimicrobial effect as well as the release of metal ions (30). However metal nanoparticles are also low cost, easy to use and highly stable (31).

The reaction of positively charged nanoparticles with the negatively charged surface of microorganisms causes the accumulation of nanoparticles on the surface of bacterial cell. These positively charged nanoparticles bind effectively to the cell membrane and lead to disruption of the cell wall framework, resulting in a rise in cell permeability, allowing more nanoparticles to enter the bacteria, concluding leakage of cellular contents. An irreversible damage that results in delayed growth or killing of microbes is result from too many metal nanoparticles. Metal nanoparticles penetrate the microorganism's cell membrane, lead to the release of reactive oxygen species and generate oxidative stress in the cell. This leads to decreased respiration and ATP production and degradation of the cell membrane. ROS induced by a metal oxide is generated by the active redox cycle and the pro-oxidant functional group on the metal oxide nanoparticle interface (26).

In dentistry, importance has been given to the study of metal nanoparticles. The most common metal nanoparticles used in dental materials are silver, titanium, copper, gold, zinc. These nanoparticles, showing improved mechanical, antimicrobial and regenerative properties, have been incorporated into composite resins, restorative cements, adhesives, endodontic materials, acrylic denture base resins, orthodontic brackets and dental implants. In terms of antimicrobial effect, silver and gold are used in their pure forms, while metal oxide form of titanium, zinc and copper are used (32).

#### **4.1. Copper nanoparticles (Cu)**

The lower cost of copper than silver or gold gives it a better cost-benefit ratio. Copper nano particles have been exhibited to be efficient against Gram positive and Gram negative bacteria and viruses as influenza and as human coronavirus on materials surfaces (6,28,33). Copper may exhibit a similar mechanism of action to silver. Like silver, copper is thought to act by combining with -SH groups of key microbial enzymes (30). Copper ions released into the cell can degrade nucleic acid and key enzymes (34). In the presence of 1 mg/mL nanocopper, Gram positive and Gram negative bacteria were reported to decrease by 68% and 65%, respectively, within 2 hours (35).

Copper nanoparticles appear to be a potent inhibitor of dentin MMP-2 (metalloprotease-2) and stimulate secretion of tissue inhibitors of MMPs, resulting in a lower degradation pattern at the resin/dentin interface. It has been reported that the copper nanoparticles addition to adhesive systems at concentrations of up to 0.1% by weight ensure antimicrobial characteristics and maintains adhesion to dentin after 1 and 2 years of water storage without affecting the mechanical performance of adhesive systems (33).

#### **4.2. Gold nanoparticles (Au)**

The unique properties such as non-toxicity, ease of synthesis, optical-electronic properties, biocompatibility, and surface modification make the gold to be frequently used particles among the other metal nanoparticles (36). These nanoparticles can vary in size, volume, shape (rod or spherical), squares, stars and triangles etc. Gold is used in periodontology, tissue engineering, restorative dentistry, dental implants and cancer diagnosis due to distinctive properties such as a wider surface area. The large surface area of nano-sized gold nanoparticles allows them to interact more with inorganic and organic molecules.

And the increased surface/volume ratio provides additional effective impact for improved antibacterial and antifungal action. Gold nanoparticles exhibit antibacterial activity against gram positive and gram negative bacteria at different solution concentrations. Antifungal activity of gold nanoparticles depends on the shape and size. Gold nanoparticles increase the killing effect of low-temperature plasma of *Streptococcus mutans*. Adding gold nanoparticles to the material can help increasing the material's antibacterial activity and decreasing the potentiality of secondary caries (37).

Gold's excellent binding properties make it suitable for the addition of ligands in the enhancement of biomolecular interactions. Gold nanoparticles display intense color and strong contrast in the visible range for imaging

with electron microscopy. In spite of these features, gold exhibits lower antimicrobial effect compared to copper and silver (30). It has also been reported that these nanoparticles prevent the formation of biofilm and therefore can be used as preventive therapy in periodontology. The biocompatibility and cell differentiation effect of gold nanoparticles have also enabled them to be used in stem cell technology and to have great potential in tissue engineering. Gold nanoparticles have also been reported to have a positive effect on the mechanical properties of adhesive systems used in restorative dentistry (37).

#### **4.3. Silver nanoparticles (Ag)**

Silver nanoparticles are one of the most studied particles in scientific research among metallic nanoparticles. The silver nanoparticle synthesis can be biological, chemical or physical. The chemical route is the most common synthesis in dentistry. Silver nanoparticles synthesis is based on the chemical reduction of  $Ag^+1$  to  $Ag^0$  (25). Silver nanoparticles have been studied for use in various fields of dentistry including preventive dentistry, endodontics, periodontics, restorative materials, orthodontics, oral microbiology, dental prosthesis and implants. The inclusion of silver nanoparticles reduces microbial colonization on tooth and improves oral health (25,38). Non-toxicity, biocompatibility, long-lasting antibacterial activity, and low bacterial resistance are advantages of silver nanoparticles (38). Discoloration is one of the disadvantages of silver nanoparticles in the anterior teeth treatment in endodontic. When silver nanoparticles are added to restorative materials, the polymerization process of resin-based materials may be disrupted, resulting in increased release of monomers (21,26).

Due to their small size, silver nanoparticles can easily penetrate to the cell membrane of bacteria, resulting in fast bactericidal activity (26,38). Silver can interfere with proteins and DNA by interacting with SH groups and can also cause bacterial death by altering DNA uncoupling, cell wall synthesis, respiration processes and base pairing (13,38). Induction of reactive oxygen species production is one of the most important mechanisms of silver nanoparticles. These reactive oxygen species, together with dissolved silver ions, increase cellular oxidative stress in microorganisms. The main species responsible for this oxidative damage are hydroxyl radicals. It also damages cell walls and membranes, interferes with the respiratory chain, depletes intracellular ATP levels and breaks down nucleic acids. Silver nanoparticles hold on to the bacteria and infiltrate into the bacterial cell wall, followed by electrostatic attraction between the silver nanoparticles and the functional groups of nitrogen, sulfur or

oxygen on the cell membrane, causing the damage of physical membrane and cellular leakage (25,39,40).

Silver is a safe metal that is non-toxic to animal cell and seriously toxic and lethal to bacterial cell. The addition of silver nanoparticles into the resin composites increases the contact angle on the surface of the materials, thereby limiting the binding and proliferation of bacterial pathogens (13). It has been reported that silver has an inhibitory effect against oral bacteria when placed in glass ionomer cements (41). The positive charge in  $Ag^+$  ions is crucial for antimicrobial function, providing electrostatic interaction between the negatively charged bacterial cell membrane and the positively charged nanoparticles. Bacterial cells in contact with silver nanoparticles receive  $Ag^+$  ions, respiratory enzymes are inhibited, and cell membranes are damaged by the formation of free radicals (42). The antimicrobial function of silver against cariogenic *Streptococcus mutans*, *Enterococcus faecalis*, gram positive and negative bacteria, protozoa, antibiotic-resistant strains, and fungi is known (26,29). Silver nanomaterials have been reported to be effective in preventing coronavirus-mediated cell infection as a virucidal agent or a viral entry inhibitor. These findings may ensure new perspectives about the the antiviral treatment of coronavirus infections (6).

The results of in vitro researches demonstrate the perfect antimicrobial action of silver nanoparticles when along with adhesives, resin co-monomers, intracanal drugs, acrylic resins, and implant coatings to combat microbial infections (6). Silver nanoparticles are included into restorative materials to prevent secondary caries, into adhesives and orthodontic brackets to prevent enamel caries. Consequently, the usage of silver nanoparticles against dental caries, containing prevention of biofilm formation and regulation of the balance of demineralization and remineralization, is a hopeful aspect for the treatment and prevention of dental caries (14).

## 5. Antimicrobial Metal Oxide Nanoparticles

Metal oxides play an important role in many fields of materials science, physics and chemistry. Metal elements can create a wide variety of oxide compounds. Metal oxide nanoparticles can represent unique physical, chemical and antimicrobial properties due to their wide surface area and different crystal morphology, including a large number of ends, corners and potential reactive areas. Bulk oxides are generally durable and stable systems with well-defined crystallographic structures. However, with the reduction of particle size, surface free energy and stress become issues that need extra consideration. Low

surface free energy is a requirement for a nanoparticle to exhibit mechanical or structural stability. As a result of this requirement, phases with low stability in bulk materials can become very stable in nanostructures (43,44).

Metal oxides can also represent metallic, semiconducting or insulating features due to their structure. The energy structures of nanoparticles are characterized by the band gap values providing the semiconductor properties of these materials. These materials can have very good photocatalytic, antibacterial, antifungal, and photoluminescent properties (36).

### ***5.1. Copper oxide nanoparticles (CuO)***

Copper oxide is the simplest member of the family of copper compounds. It is stable in physical and chemical properties, mixed easily with polymers and polarized liquids, and cheap. Copper oxide is a monoclinic semiconductor. Electron correlation effects, high-temperature superconductivity, and spin dynamics are the beneficial properties of copper oxide. Copper oxide nanoparticles have been characterized chemically and physically for potential antimicrobial applications (30,35).

Copper oxide nanoparticles have been prepared chemically by methods such as hydrothermal, sol-gel, co-precipitation, monochemical, spray pyrolysis. The accumulation between copper oxide nanoparticles can be prevented by applying surface coatings with stabilizing agents that control size and morphology (23). Nanoscale copper oxide produced by thermal plasma technology was found to show particle sizes in the range of 20-95 nm with an average surface area of 15.7 m<sup>2</sup>/g (30).

Copper oxide nanoparticles are effective against a variety of bacterial pathogens, including Gram positive and Gram negative bacteria, *E. coli* (26,30). It has been reported that coating the tooth surface with copper oxide nanoparticles inhibits the formation of *S. mutans* biofilm (45).

### ***5.2. Zinc Oxide nanoparticles (ZnO)***

Zinc is an essential trace element in the human body. Zinc oxide is a frequently used compound in the biomedical field because it is stable under harsh processing conditions and is also considered safe, biocompatible, low-toxicity, high stability and low-cost. The superior antibacterial, antifungal, electrical, chemical and optical properties of zinc oxide nanoparticles have made them be included in more researches. Zinc oxide nanoparticles can be prepared by various methods such as solvent-based ultrasonic irradiation, solvothermal, hydrothermal, solgel, thermal evaporation, microemulsion, arc plasma, physical

vapor deposition. Various nanostructures of zinc oxide have been developed such as nanotubes, nanorods, nanopowders, thin films/nanoparticles, quantum dots, and capped nanoparticles that can be used for antimicrobial application (30,46). The antibacterial action mechanism of zinc oxide nanoparticles occurs by the formation of reactive oxygen species and the interaction of the nanoparticle with the intracellular content by damaging the cell membrane. Zinc oxide nanoparticles have the ability to produce reactive oxygen species more easily owing to their photocatalytic properties. The fact that zinc oxide nanoparticles have a positive surface charge allows them to easily interact with negatively charged bacterial membranes and penetrate cells more easily, allowing cells to be destroyed. These properties have allowed these materials to be used as excellent additives for bactericides used in dental products (30,36).

Reactive oxygen species produced by zinc oxide nanoparticles under UV illumination are hydrogen peroxide ( $H_2O_2$ ), hydroxyl radicals ( $HO\bullet$ ), and superoxide ( $O_2^-$ ). The negative charges of superoxide and hydroxyl radicals keep them on the outer surface of the bacteria. Hydrogen peroxide molecules can also pass through the wall of cell and create oxidative damage in cellular structures. The uptake of toxic dissolved zinc ions depletes intracellular ATP production and impairs DNA replication (39).

It has been reported that zinc oxide nanoparticles have cytotoxic effects on bactericidal cells and non-toxic effects on human cells at the same concentration. Zinc oxide nanoparticles have been reported to represent greater toxic effects on bacterial cells than other metal oxide nanoparticles because of ion-shedding ability of zinc oxide. The key factors in determining the toxicity and antibacterial effects of zinc oxide nanoparticles are shape, surface charges, size, dissolution, concentration, and aggregation. As the surface area increases, its antibacterial properties also increase. These nanoparticles have also been shown bactericidal properties for the broad range of bacteria (Gram positive and Gram negative) and fungi, including *S. aureus*, *E. coli*, *A. hydrophila*, *E. faecalis*, *S. pyogenes*, *B. subtilis*, *S. typhimurium*, *K. pneumoniae*, *S. enteritidis*, and *P. aeruginosa*, etc (46).

### **5.3. Titanium Dioxide Nanoparticles ( $TiO_2$ )**

Titanium dioxide is the most well-known titanium compound. Titanium dioxide nanoparticles, is chemically inert, semiconductor, low-cost and non-toxic to animals and humans in micro sizes, antibacterial in various spectrums by having a photocatalytic effect with superior efficiency in the presence of light with energy equal to or greater than the band-gap energy. And also these nanoparticles have properties such as corrosion resistance and high hardness.

Due to these features it has attracted great interest in recent years and offers a wide variety of applications in dentistry (47, 48, 49, 50,51, 52).

Titanium dioxide nanoparticles have three different modifications as anatase, rutile and brookite (53). The rutile crystallographic form of titanium dioxide has a high optical refractive index, and thus grinding it into a fine powder scatters light highly. The rutile structure is chemically inert and is the most stable form of titanium dioxide (54). While the rutile crystallographic structure is known as the stable form; the anatase and brookite crystallographic forms are metastable and can be converted to the rutile structure when heated (55,56,57). The anatase form is generally known as the most active phase and is therefore widely used in a variety of photocatalytic applications. The anatase form shows high activity, is photochemically stable, and is inexpensive compared to others (58).

Being a self-cleaning material makes it widely used in many applications. Titanium dioxide has also been successfully used as an inhibitory agent for bacterial growth. When titanium dioxide particles are exposed to radiation while in close contact with microbes; the microbial surface first becomes the primary target of oxidative attack. During photocatalysis, hydrogen ions ( $H^+$ ) and electrons ( $e^-$ ) are formed on the titanium dioxide surface.  $H^+$  can oxidize and kill bacteria (59). Titanium dioxide, like other metal oxide nanoparticles, causes oxidative stress associated with the formation of reactive oxygen species. Its lipid peroxidation property makes the titanium oxide have an excellent membrane fluidity and cell membrane disruption (26). The anatase form and UV light stimulation for titanium dioxide nanoparticles are necessary to provide maximum antimicrobial activity. In this way, photocatalysis can promote peroxidation of the polyunsaturated phospholipid component of the microbial lipid membrane, causing the loss of respiratory activity and eliciting cell death (30).

## 6. Conclusion

Nanotechnology is predicted to have a major impact in dental research and the development of current treatment methodologies, leading to excellent oral health care in the future. Metal oxide nanoparticles have wide applications in endodontics, orthodontics, restorative dentistry, implantology, dental prostheses, and other dental fields. These nanoparticles have a perfect antibacterial effect, but their antibacterial properties are affected by the type, concentration, shape, size of nanoparticles and other factors. Further studies are required in order to determine all the mechanisms involved in the bactericidal effect of metallic nanoparticles.

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## CHAPTER 4

# REGENERATIVE ENDODONTIC THERAPY

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### 1. Introduction

**R**egenerative medicine typically aims to promote and improve the healing properties of tissues and organs by repairing or replacing damaged cells, tissues or organs. The rapid development of regenerative medicine and tissue engineering in recent years has brought regenerative applications to the agenda in dentistry (1).

In the last 10 years, studies on stem cell biology and tissue engineering have positively affected the field of dentistry (2). As Endodontics involves pulp-dentin complex which is rich source for regenerative applications such as vital pulp therapies, pulp revitalization. The aim of regenerative endodontic treatment is to reconstruct a healthy and functional dentin-pulp complex. Recent developments in tissue engineering concepts and biomaterials, make soft tissue hard tissue acquisition possible in immature necrotic teeth (3). Promising results have been obtained in studies with stem cells, and positive developments are still being recorded in the regeneration of dental-environmental tissues (2). In this chapter, regenerative endodontic treatment method, materials used and current developments in this field will be discussed in detail.

In recent years, there has been a great increase of interest in the field of regenerative endodontics especially for immature necrotic teeth (3). Previously,

the main treatment method used in immature teeth was long-term apexification treatment with calcium hydroxide, but nowadays, new treatment protocol called revitalization became the first treatment choice for these cases (4). Revitalization is a new treatment method focused on restoring pulp vitality and maintaining root formation. This clinical method is based on the idea of forming blood clot inside the root canal space, it would act as natural scaffold and moreover brings stem cells from neighbor tissues.

## **2. Regenerative Endodontic Applications**

The management of an immature necrotic tooth presents several clinical challenges. Previous studies and case reports have shown that the treatment of an immature permanent tooth with apexification with biomaterial or calcium hydroxide is acceptable (4,5). On the other hand, these treatments have some drawbacks like prolonged treatment duration, unpredictable apical barrier formation and thin root canal walls(4). Besides these disadvantages, revitalization treatments promote hard tissue and soft tissue acquisition. Moreover, it generates vital cellular tissue that acts as a natural defense against infections. In many case reports, it has been reported that the prognosis in regenerative endodontic treatment methods is better compared to apexification (4-7).

### ***2.1. Revitalization of Root Canals***

Removal of necrotic pulp tissue and disinfection of root canals are important steps for revitalization therapy. Some researchers recommended using 0.5-5.25% NaOCl solution as an irrigation solution (8-11). NaOCl is a powerful antimicrobial agent and a good necrotic and organic tissue solvent (12). On other hand it should be toxic to stem cells (13). These properties depend on its concentration (14).

Chelating agents, such as ethylene diamine tetra acetic acid (EDTA) are another very important irrigation solution in revitalization therapy. It is reported that EDTA, can significantly increase the release of growth factors and cytokines from the dentine which is natural rich source for growth factors (13). EDTA has a crucial role in cell homing step of revitalization.

### ***2.2 Elements of Revitalization***

The presence of stem cells, signaling molecules and scaffold are three important factors for the success of revitalization (15). Scaffolds are three-dimensional, temporary structures used to regulate cell functions and give mechanical

support to cells (16,17). In teeth with necrotic pulp, the empty canal area cannot produce new tissue from its own periapical tissues (18). Tissues are 3-dimensional structures, and an appropriate scaffold is essential for cell growth and differentiation (19). It is a known fact that extracellular matrix molecules control the differentiation of stem cell. For this reason, scaffolding is used as a framework in regenerative treatments for cell formation and vascularity (20). An ideal scaffold should have tissue-like mechanical and biological properties (21).

In the literature, there are many studies in which revitalization therapy is applied using autogenous materials such as blood clot, platelet-rich plasma (PRP), platelet-rich fibrin (PRF) and concentrated growth factor (CGF) (22-24). During revitalization therapy, blood clot, platelet-rich plasma (PRP), platelet-rich fibrin (PRF) and concentrated growth factors (CGF) can be used as a natural scaffold (22-24). It is reported that usage of thrombocyte concentrates enhance the revitalization treatment outcomes (23).

Growth factors are microprotein structures that bind to receptors on the cell surface and generate signals for the growth and differentiation of cells (25). The pulp tissue includes main growth factors like bone morphogenetic growth factor (BMP), transforming growth factor- $\beta$  (TGF- $\beta$ ) and fibroblastic growth factor (FGF) (26,27,28). TGF- $\beta$  provides signal generation for odontoblast differentiation and proliferation from the dentin matrix (29). BMP-2, 4 and 7 directly provide differentiation of stem cells to odontoblasts that form dentin (30). Studies have shown that dentin contains many natural bioactive molecules that play an important role in regenerative treatments (13,24). Growth factors controls the wound healing process (31). Growth factors have a critical role in cell migration, cell proliferation and tissue regeneration, angiogenesis. These growth factors are found in blood, platelets, and plasma. Platelet concentrates such as PRP, PRF, and CGF have been used for remodeling and revascularization (30).

Platelet concentrates has been reported to facilitate angiogenesis, hemostasis, osteogenesis, and bone growth, and has been found to have an anti-infective effect (32). Recently, researchers introduced PRF and CGF and their production methods that differ from PRP and include growth factors (24). The production method of PRF presented by Choukroun is simpler than PRP and does not require the addition of thrombin and calcium chloride. Similarly, CGF introduced by Sacco is produced by centrifugation and platelets are concentrated in a gel layer containing fibrin matrix (30).

Many researchers recommend the use of stable blood clots acting as tissue scaffolds in the revascularization treatment of infected immature teeth. Bleeding

is achieved by bleeding the periapical area with a canal instrument. This blood, which fills the disinfected canal, coagulates. This clot not only acts as a support, but also provides some factors that enable the growth and differentiation of odontoblast-like cells. In addition, bleeding aids angiogenesis, which is necessary for stem cell healing. In addition, the limited concentration of growth factor in the blood clot may reduce the success rate of revascularization therapy (33).

PRP is a first-generation autologous platelet concentration rich in growth factors and has been used to increase the success of regenerative endodontic treatments (34,35). PRP; It contains various growth factors such as platelet-derived growth factor, transforming growth factor- $\beta$ , insulin-like growth factor, epithelial cell growth factor. For growth factor release, thrombin or calcium-bound products (Ca sulfate, Ca phosphate) must be added to the medium (36). The higher growth factors amount means better the stem cell proliferation, tissue healing and regeneration (37,38). Growth factors released from PRP have an important role in the ability of cells to stimulate mitosis, chemotaxis, differentiation and healing (38). On the other hand, PRP has disadvantages such as requiring special equipment and PRP markers (36). Bovine thrombin or calcium sulfate can be selected for PRP activation: but bovine thrombin has been reported to cause important immune reactions such as hemorrhage, thrombosis, and systemic lupus erythematosus (SLE) (37,39). Therefore, calcium sulfate is generally selected to activate PRP due to the negative effects of bovine thrombin (37).

Torabinejad et al. (40) reported rapid periapical healing and apical closure by using PRP during revitalization treatment. Jadhav et al. (36) reported that apical healing, apical closure, and thickening of the dentin wall were observed more prominently in teeth treated with PRP. It has also been reported that the use of PRP causes the continuous release of growth factors that cause proliferation and differentiation of stem cells (36). Martin et al. (41) applied revascularization treatment with using blood clot and PRP to the distal canal of the mandibular first molar and reported that the tooth was clinically asymptomatic and healing of periapical lesion was observed. In a clinical study of Bezgin et al, they applied PRP or blood cloth as tissue scaffold and observed the patients for 18 months (42). As a result of their study, they reported that PRP can be used as a tissue scaffold in the treatment of revascularization successfully.

Dohan et al. developed PRF as a second generation of platelet concentration (43,44). The most important advantage of this technique is that it is simple and inexpensive compared to PRP. In addition, when compared to PRP, it is applied in a shorter time and easier, since it does not involve activating processes with bovine thrombin or calcium sulfate (45). PRF contains platelets, growth factors

and cytokines that promote healing (46). In some studies, it has been reported that PRF provides a slow and continuous release of some important growth factors such as PDGF and TGF- $\beta$  from one week to 28 days. Moreover, PRF releases growth factors slowly and restrained way (44, 46, 47). Shivashankar et al. (48) reported periapical healing, apical closure, increase in root dentin wall thickness after revitalization treatment with using PFR. According to the results of the study; revitalization of infected immature teeth is possible in which root canal disinfection is applied effectively, and PRF is an ideal material for the regeneration of the pulp-dentin complex. In the literature it is reported that combined use of photodynamic disinfection and PRF allowed satisfactory root development in necrotic immature teeth (49).

CGF was originally developed by Sacco (50). CGF is produced by centrifugation of venous blood as in PRF. However, the technique varies with centrifugation speed and time. Unlike PRF, CGF uses variable speeds between 2400 and 2700 rpm to separate cells from venous blood. This results in larger, dense fibrin-rich blocks which is rich in growth factors than PRF, resulting in a better regenerative capacity and greater versatility.

### 3. Results

Conventional root-canal treatment is an effective endodontic treatment option that involves removing the entire pulp and filling the canals with gutta-percha. However, vitality of pulp should be maintained as long as possible. For this purpose, in addition to vital treatments, revitalization of pulp tissue has come to the fore (51,52).

Regeneration of dental pulp is complicated in terms of regenerative dentistry because of the limited potential of pulp self-renewal and healing. Advances in tissue engineering and biomaterial science allow to improve the regeneration process, which involves generating dental pulp tissue from stem cells. The treatment of permanent immature teeth is a challenge for most dentists. When the tooth loses its vitality, root formation stops. This may result in a high rate of root fracture. Revitalization treatment may provide cellular repair/regeneration of pulp-dentin complex which may supports the tooth strength in many aspects. There are many case reports published in the literature since 2004, nonetheless there are few controlled clinical studies.

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# CHAPTER 5

## NON-SURGICAL RAPID MAXILLARY EXPANSION IN ADULTS

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### 1. Introduction

Maxillary transverse deficiency (MTD) is the main reason of many malocclusions. Orthopedic and orthodontic forces are routinely used to treat MTDs in young patients. Rapid maxillary expansion (RME) is the treatment method preferred in the developing individuals. Surgically assisted rapid maxillary expansion (SARME) has become widely used as a different treatment option in the skeletally mature patients. However, surgical procedure is high-cost and carry risks. Therefore, the implementation of non-surgical RME against SARME should be discussed again.

In the present chapter, the efficacy of RME and the stability of the expansion will be discussed in the light of complications such as pain and edema, tilted molars, mandibular rotation, and gingival recession.

Haas has introduced the maxillary rapid expansion appliance in his article published in 1961, and transverse deficiency has started to be treated with RME in the children and young adults after this date.(1, 2) On the other side, the expansive appliances used in the adult patients to expand maxillary arch significantly have been usually unsuccessful. Bishara(3), Proffit(4), McNamara(5) have reported in their studies that the efficacy of palatal expansion applied in the young adults and early twenties is controversial.

The essential criterion in making decision for the application of RME and SARME in the treatment of MTD is patient age. Wertz has detected relapse rates

of 16%, 10% and 63% in the distance between molars after maxillary expansion in the patient group aged below 12 years, patients in the age group of 12-18 years and patients aged over 18 years, respectively, and reported that the best age interval for maxillary expansion is 13-18 years.(6)

Mossaz et al.(7) have accepted the age over 20 years as the optimal patient age for maxillary expansion. Mommaerts(8) has considered that RME is appropriate for the patients aged below 12 years and advocated that performing corticotomies is needed to relieve the resistant fields against expansion in the patients aged over 14 years. Alpern(9) have considered that sex also should be evaluated as a selection criterion. They have reported that surgical intervention should be performed for expansion for the male patients aged over 25 years and female patients aged over 20 years.

Some cases which indicated that RME was successful in very much older patients have contributed to this conflicting condition.(9, 10) According to these authors, clinically favorable result can be obtained with an amount of sutural stretching even no orthopedic impact is observed, however, its negative effects on gingival should be taken into consideration.(11)

The assessment of the skeletal age is an important parameter in case selection.(12) It can be concluded that chronologically elderly patients in whom RME was successful may not have skeletally matured. The opposite of this case is also valid; RME may be unsuccessful in the chronologically young patients with skeletal maturity.

The pessimistic approach to maxillary expansion in adults has been attributed to the anatomic studies conducted in the maturing faces; midpalatal suture and surrounding neighboring maxillary articulations begin to harden by reaching the age of mid 20s.(12, 13) SARME has been recommended to overcome the sutural resistance against expansion. The surgical approaches varying between Subtotal LeFort (14, 15) to more limited osteotomies of the lateral maxilla and palatal bone(7, 14) can be successful by allowing opening of the midpalatal suture and enlargement of the maxilla when combined with fixed palatal expansion appliances.

The authors of the surgical research have advocated that surgery is necessary since maxillary expansion cannot exceed limited dental changes or they relapse. Maxillary expansion involves the complications such as pain, edema, ulceration, inflamed posterior teeth, opening of the closure, gingival recession, and perforation of the buccal alveolar bone.(7) Astekar(16) has reported that even the individuals with mixed dentition in whom maxillary transverse deficiency was diagnosed may be exposed to gingival recession after RME. In

addition, Vardimon et al. have declared their concerns that root resorption may be observed with bone-supported distracters in the elderly patients.(17)

Only a very small number of the adults treated with RME have been published as case reports.(2, 6) Capelozza et al.(10) have tested sutural expansion in non-growing 38 individuals and obtained complicated results. Also, according to this study, expansion failure, pain, edema, or ulceration are the frequently seen complications.

It has been found to report a case series conducted on older adult patients taking the negative conclusions on non-surgical palatal expansion, other complications and the concerns about gingival recession into consideration. (18) Handelman has defined the maxillary transverse expansion performed in the adults as rapid maxillary alveolar expansion instead of rapid maxillary expansion. Expansion occurs in the alveolar process rather than maxilla after growth and development ceased in the adults and beginning with the ages of 20s.(18)

## **2. The Comparison of RME Between Young and Adult Patients**

The application of RME has been first recommended for children.(1, 2, 6) The opening of midpalatal suture as shown in the occlusal films and formation of the diastema between the incisors indicate the skeletal expansion of the maxilla.(1, 3) However, opening between the palatal layers is not as much as the increase in the width between the molars. Krebs has shown by using metallic implants that approximately 50% of the expansion obtained in the children by RME is skeletal while remaining is dentoalveolar.(19)

Capelozza et al.(10) have implemented RME in a group of non-growing patients and they tried to create a remarkable sutural opening with midline diastema. They have used Haas appliance and activated the screw with four quarter turns in the first 24 hours. In the following days, they applied totally four turns per day set as two turns in the mornings and evenings for each until the detection of the midline diastema. No opening was encountered in 18% patients and surgical procedure was performed in these patients. The unexpected side effects (pain, edema and/or ulceration) were frequently seen. No complication was recorded in only 32% patients. It is recommended to apply only two turns initially and one turn in the following days during the process of RME in the adults to avoid the complications. The sutural opening is very rarely seen.(18)

Chester and Handelman(18) have shown that an amount of dental inclination and dentoalveolar expansion occurred in their examination of palatal contours. Expansion begins between 1/3 apical level and middle level of the

palatal depth. In some cases, expansion may be observed along the palatine vault, this condition may indicate that an expansion will occur in the midpalatal suture.

RME shows semi-skeletal and semi-dentoalveolar impact in the children whereas it exhibits predominantly alveolar impact in the individuals during post-pubertal period. On other side, it has completely dentoalveolar impact in the adults.

Iseri and Ozsoy have applied semi-rapid maxillary expansion in the adults with a mean skeletal age of 14 years (chronological ages between 12-17 years), and the patients turned the RME appliance two times set as once in the morning and once in the evening for the first week and the used it as a removable appliance after determination of the sutural opening, they turned the appliance once every two days along averagely 4 months and they used the appliance as retainer for 3.5 weeks.(20)

Haas(2) has stated that the opening of midpalatal suture is generally impossible after the age of 18 years. Haas has emphasized the importance of the use of a tissue-borne expander against tooth-borne expander and the necessity of moderating the expansion program.

### **3. The Comparison Between SARMA and RME**

Maxillary osteotomy allows the expansion of maxillary skeletal base. SARME is a real orthopedic expansion that starts at the apex of the palatine and occurs with bone apposition in the suture. In the adult patients, also Haas palatal expansion appliance creates an orthopedic expansion, and this generally starts at apical lateral walls of the palatal bone or half of the lateral walls. An increase is achieved in the volume of the palatal vault by this treatment. The transverse width of the maxillary skeletal base does not increase; however, it is an acceptable alternative.

Betts et al. have presented the radiographic analysis of the posteroanterior cephalogram to identify the maxillomandibular width difference.(15) They have noted that any difference more than 5 mm compared with normal value will indicate surgically-assisted expansion. Biederman(21) has compared maxillary transverse arch widths measured in the study models with control samples and measured the amount of the achieved expansion. Unfortunately, PA cephalograms were not performed during the treatment.

Northway and Meade(11) have compared SARME group with RME group including non-operated adult individuals. Each group included 15 individuals. They have obtained an orthopedic effect as suggested by Haas, however, they

have reported that surgically assisted maxillary expansion is predictable and consistent. They obtained a higher increase in the volume of palatal bone by surgical assistance.

Cureton and Cuenin(22) have obtained diastema between the maxillary central incisors resulting from osseous defects, tooth mobility, gingival recession and external root resorption. Also, Subtotal LeFort I procedures lead to life-threatening complications for the patient, although rare. Lanigan(23) has pointed out the probability of excessive bleeding due to the separation of pterygoid layers, thrombosis, and formation of arteriovenous fistulas between carotid sinus and carotid artery.(18)

Every case should be evaluated individually with respect to complications, risks and patient cooperation, and it should be decided whether maxillary transverse arch discrepancy can be treated at an acceptable success level with nonsurgical intervention.(18)

The cases that need expansion larger than 8-10 mm and the patients with severe unilateral posterior crossbites and significant gingival recession can be accepted as the candidates for SARME. Glassman et al has recommended a limited procedure with lateral maxillary corticotomy.(24) Compared with detailed surgical alternatives, this procedure carries lower risk and requires lower cost. However, non-surgical RME applied using Haas appliance is a reliable and consistent treatment method for many patients with maxillary transverse deficiency.(18)

The limitations and complications of non-surgical RME applied in adults can be summarized as follows(6, 7, 15):

1. Expansion is limited and appropriate for only dental expansion
2. The results are instable, and relapses are frequently seen.
3. Anatomic resistance developing against expansion, ischemia, pain due to ulceration and swellings resulting from the compression of the appliance on the tissue may be seen.
4. Posterior teeth incline and they lead to malocclusion and instability.
5. Inclination of the teeth and subsequent relapses causes clockwise mandibular rotation, opening of the closure and increased facial height.

The first maxillary molars tilt from the alveolar bone towards buccal, consequently gingival recessions, bone loss and root resorptions occur.

There is a limited number of reports for the adult cases applied with palatal expansion. Haas(1), Werts and Dreskin(25) have reported a male patient aged of 20s who were applied expansion. More currently, Capelozza et al.(10) have tested sutural expansion in 38 individuals with completed maturity and

obtained complicated results. Expansion failure, pain, edema, or ulceration are the frequently seen complications. Handelman(18) has reported 27 adult cases in whom a successful expansion was performed. Northway and Meade(11) have reported successful implementation of expansion in 15 adults, however, they declared their concerns about the observed gingival recession.

### ***3.1 The Amount of the Expansion***

Howe et al. have determined the mean width between the molars to be 36.2 mm and 37.4 mm in the female and male adults without crowding, respectively. (26) The mean width between molars was found to be 34.4 mm using the same measurement method in the adult orthodontic patients (predominantly female patients) without significant maxillary transverse discrepancy in a previous study of Howe.(26)

Even though, impossibilities related with nonsurgical maxillary arch expansion applied in the adults have been noted in the literature.(3, 7, 27, 28) An increase in the transverse dimension was detected in the study of Handelman. This result was confirmed by the elevated widths between the lower and upper arches that normalize maxillary widths during retention from 3.4 mm to 7.5 mm. An enlargement was identified in the alveoli of the first molars. It should be noted that the youngest patient was 23 years old while the ages of the others ranged between 30-44 years.(18)

The measurements of the changes that occurred around the arches were not carried out. Adkins et al. have determined that an increase of 0.7 mm around the arch corresponds to each millimetric increase due to palatal expansion in the width of arch. This is an important factor regarding the approach followed without imaging studies taking the coefficient of Adkins into consideration.(18)

Chester and Handelman(18) have demonstrated an expansion of 6-7.5 mm in 4 of the 5 cases. The highest achieved amount of expansion was determined according to the lower arch width instead of RME limit planned for adults. The arches were extremely expanded in the cases except the third case. The inclinations of the buccal segments were partially adjusted, and the balances of the expanded teeth were increased. There is a limit for RME applied in adults and some patients need surgical assistance. However, surgical assistance may not be required in the cases in whom transverse arch width was elevated to 7.5 mm. Betts et al. have stated that expected expansion up to 5 mm can be obtained by the orthodontic forces and that SARME will be needed for higher expansion.(15)

Since the separation of midpalatal suture is not very likely, appliance screw should be turned once daily. The patients that turn more frequently may suffer

pain, edema and tissue ulcerations under the palatal acrylic pads as shown in the study of Capellozza et al.(10) It has been considered to be reasonable to turn the appliance screw once every two days as applied in the semi-rapid maxillary expansion by Iseri and Ozsoy.(20)

#### **4. The Evaluation of The Complications**

##### ***4.1. The Axial Angulation of Maxillary First Molars***

In the study of Chester and Handelman, at the end of the treatment, considering that the maxillary first molars are in symmetrical movement, it was observed that they were tilted towards the buccal between 5°-9°. Buccal overangulation of molars will exert undesirable opposite force to the entire posterior as the molars attempt to erect when all teeth are clamped with archwire during fixed treatment. This point should be beared in mind.(18)

##### ***4.2. Root Resorption***

In the study of Chester Handelman(18); the post-treatment evaluation of the periapical radiographs of the maxillary molars and premolars revealed that root resorption was minimal. When root resorption was encountered in the first molars, maxillary incisors also revealed a similar resorption.

In the root resorption studies related with RME; the roots of the extracted anchorage teeth were evaluated in animals(17) and children or adolescents(29). In these studies, large but shallow resorption fields appear on the buccal surfaces of the roots, particularly towards cervical 1/3 of the tooth more remarkably. Barker and Sims(18) have pointed out that these resorption fields cannot be seen in the patient radiographs. The resorption fields on the buccal surfaces may be more remarkable in the adult patients applied expansion. However, no clinical evidence is available.

##### ***4.3. Buccal Gingival Recession***

It has been noted in the literature that gingival recession is strongly correlated with labial incisors and canines.(30, 31) It has been demonstrated that mandibular incisor proclination prior to orthognathic surgery is associated with gingival recession in the Class III patients.(32) The labial expansion of the incisors causes gingival recession in the experimental animals.(33) According to Vanarsdall(15) thin buccal bone layer of the teeth will be perforated due to RME and consequently gingival will recess in adults.

In the study of Serino G et al.(34) compared with control subjects, buccal attachment loss observed in the adults applied RME showed no significant difference between male patients, however, little but significant differences were identified between the first premolars and first molars in the female patients. Attachment loss is not clinically important, the values of attachment loss were 0.6 mm and 0.3 mm in the adult female RME and adult male RME individuals, respectively, the value of attachment loss was 0.1 mm in the adult control individuals.

Gingival recession is defined as gingival attachment loss encountered to cause the exposure of the root cements by the periodontal researchers.(30, 34) This condition is generally seen due to the hypersensitivity of the cement. (35) Serino et al.(34) have noted in their longitudinal adult studies that gingival recession is not frequently seen in the buccal fields unless a remarkable buccal attachment loss of at least 3 mm occurs.

Some iatrogenic response is inevitable in the orthodontic treatment, the essential issue is the determination of the excessive amount that will create risk for the health of the dentition. Lupi et al.(36) have reported that most adults receiving orthodontic treatment experience an amount of bone loss and root resorption. These researchers have noted that treatment of the adults is generally reliable and that these changes are seen moderately.

It has been observed in the studies on adults that buccal gingival attachment loss is experienced by advancing age.(34, 37) The increase in the crown height identified in the maxillary teeth within the 10 years after completion of the RME therapy is similar to mandibular teeth, and evidence of recession is similar to the normal healthy adults at the ages of 30s-40s.(34)

It has been supposed that gingival recession after RME is seen most in the most elderly individuals with the highest maxillary arch discrepancy and highest baseline crown height. Surprisingly, none of these variables is related with the grade of observed gingival recession.(18) Can the patients with preexisting and advanced gingival recession be a candidate for non-surgical RME? In the light of the available studies, there is no adequate evidence on the fact whether weakened buccal periodontium significantly increases the recession however meticulous attention should be paid. The patients with preexisting recession have the gingival fields that reveal the highest recession by time.(34, 38) Expansion screw is turned less frequently in the moderate-degree cases (once every three days). However, SARME is indicated in the advanced levels of recession. Northway and Meade(11) have compared an adult patient group who used Haas appliance with SARME groups and demonstrated that a lower increase occurred in the crown height in SARME groups.

Gingival recession may be due to any level of individual predisposition independently from the expansion treatment. Serino et al. have carried out a longitudinal study on gingival recession in the patients with excellent oral hygiene and identified an attachment loss of approximately 2 mm in 52% of the buccal regions of the patients aged between 30-41 years.(34)

Chester and Handelman(18) have found no significant increase in the crown height of the teeth in the adult patients after RME treatment and this result indicates the absence of gingival recession of according to the author. Handelman has detected a mean increase of 0.5 mm in crown height in the previously treated 27 adults as well as the increase of 0.2 mm in the orthodontic control patients, and the 0.5 mm increase in the RME patients was interpreted to be minimal.(26)

Some authors have reported that RME applied in the adults causes gingival recession and thin buccal bone perforation.(15, 27)

Greenbaum and Zachrisson have evaluated the patients aged below 21 years who were applied RME.(39) They have directly analyzed the buccal alveolar bone levels and gingival attachment and concluded that the conditions of the periodontal tissues were clinically acceptable after expansion although some individuals revealed excessive changes in the bone levels.

In the study of Artun and Steiner(32, 33) it was identified that posterior dentition expanded together with alveolus instead of expanding in the alveolus. This is a favorable condition considering the thin structure of buccal alveolus. Contrarily, labial expansion with orthodontic fixed treatment was considered to be associated with gingival recession and labial bone separation.(33, 40) There is no adequate evidence on the fact whether RME accelerates gingival recession in the actually weakened buccal periodontium, however, meticulous attention should be paid. SARME may be indicated in the cases with maxillary deficiency and tendency to significant gingival recession.(18)

#### ***4.4. Mandibular Rotation and Opening of the Closure***

In the study of Chester and Handelman no increase was found in the distance between the occlusal planes of the lower and upper first molars, mandibular plane angle and face height in the patients applied RME. No evidence of the fact that RME caused the extrusion of the posterior teeth in these cases.(18)

On the other side, the patients with excessive divergent mandible carry risk for increased mandibular rotation. In such cases, potential necessity for LeFort I operation should be noted in the treatment plan and recorded in the patient file. The patients with anterior open-bite and hyperdivergent

mandible can be treated most appropriately by LeFort I maxillary surgery. Any increase in mandibular plane angle due to RME is corrected during the operation.(18)

Surgically assisted RME is not a handicap for the increase in mandibular plane angle. Alpern and Yurosko have used bonded appliance that covers the maxillary occlusion to prevent the increased mandibular divergence in the surgically assisted RME patients.(9)

It has been commonly reported in the literature that mandibular rotation and opening of the sutural closure are observed as the side effects in the children applied RME.(41, 42) The extrusion of the maxillary posterior teeth or downward rotation of the maxilla are considered as the mechanisms that lead to mandibular rotation.(41) It has been noted that bonded expansion appliances with occlusal surfaces coated with acrylic prevent the opening of the sutural closure which is considered to accompany with palatal expansion.(5, 42)

Chang et al.(43) have denoted that most of the previous studies have evaluated the short-term changes and they lack of untreated control subjects for comparison. In their study, they have evaluated the children who completed a comprehensive orthodontic treatment (for 3 years after RME) during a long-term period (for 10 years after RME). No increased mandibular plane was encountered in both time intervals and increased lower face height was detected compared with the control subjects. No change was encountered in SN-MP angles tested within the 1-year and 2.5-year periods following RME in the RME group.

Does the application of RME in adults lead to opening of the mandibular plane and extrusion of the molars? These negative side effects have been suggested since unopened midpalatal suture, inclination and anchorage create extrusive forces on the maxillary teeth.(41) If molars are extruded; palatal depth may increase in molar tubercle and gingival height, however, these measurements are not consistent. Compatibly with this finding, no change was found also in the heights of mandibular plane and lower face. The absence of opening in the sutural closure is also crucial, because deviation more than  $4^{\circ}$ - $5^{\circ}$  from normal caused the emergence of the individuals with very divergent mandibles in both pediatric expansion and adult expansion groups. Mandible is exposed to rotation due to tubercular interactions at the beginning of the expansion process. However, after the removal of the expander appliance; closure is observed also in the occlusion as occlusal forces and orthodontic treatment regulate the relationships of the posterior teeth.(18)

#### **4.5. Retention and Relapse**

The acrylic palatal retention appliance inserted at the same day or after the removal of Haas appliance holds a support for steepening posterior teeth and limits the relapse of unexpected palatal width. Since posterior teeth are excessively expanded, an amount of reduction is estimated in the width of arch length. The placement of occlusion should not be interpreted as relapse, real relapse has been defined as the return to the original malocclusion.(18)

The patients are recommended to use retention appliance in the night-time for 5 years. The relapse of crossbite was detected in none of these patients, only two patients showed incomppliance to retention in the night-time. The use of appliance in the night-time poses no difficulty for most of the patients.(18)

#### **4.6. Pain and Tissue Swelling**

Haas (1, 2) has stated that acrylic masses of RME should not overflow to the gingival margins of the teeth and second molar region by rounding. Capelozza et al.(44) have applied RME in a large patient group who completed growth process. They have used Haas appliance and activated the screw by 4 quarter turns per day to separate the midpalatal suture. The separation of the midline was not detected in 18% patients and these patients were accepted to be appropriate for SARME. The unexpected side effects such as pain, edema and ulceration were frequently seen. For instance, only 32% had no complication.

In the study of Haas(1, 2) pain or tissue swelling was determined in 9 of 47 adult individuals applied RME. All the individuals completed the expansion period of the treatment, they had a resting period and received a slower program. The program was applied as one turn every two days as well as one turn for the patients aged over 50 years or those detected with gingival recession. The complications observed in this study is 100% lower than the complications of surgical-assisted expansion such as facial swelling, discomfort, and loss of working day.

RME applied in the adults was easily tolerated by the patients in the study of Chester and Handelman.(18) Palatal gingival swelling was found as a rare complication in another study of Handelman carried out with a larger number of patients.(18) This is caused by the large size acrylic pads that affect palatal gingival. Acrylic was cut from the related area and expansive screw was turned back for 3-4 times. After a resting period, expansion was continued without a complication. The poorly adapted appliances also may lead to formation of the compression points on the lateral walls and a new appliance may be needed unless the necessary adjustments are performed.

#### **4.7. *The Expansion of Alveolus***

The contour records of 5 adults applied RME were evaluated and it has been concluded that expansion begins between the apical triple and middle level of the palatal vault and is achieved by the displacement of alveolar process.(18) This expansion has been defined as the rapid maxillary alveolar expansion.

Handelman have used metal implants and showed that 50% of the expansion obtained in the children by RME is skeletal while remaining is dental-alveolar. A 4.4 mm expansion was achieved at midpalatal level and this rate constitutes 80% of total arch expansion.(18) The 56% expansion at the level of palatal height was found 18% in the adults. However, it is not concluded that the mechanism involves separation in the maxilla because separation between central incisors is rarely seen. The expansion at midpalatal level is 4.1 mm or 80% of the total arch expansion. In another saying, total arch expansion at midpalatal level shows similar rates in the children and adults.(18)

Non-surgical RME results are most likely; It represents a whole, ranging from young children who experience half of the expansion at the base of the maxilla and the other half at the dentoalveolar component, to adolescents who experience a higher proportion of them in the alveolus, and to adults who experience expansions predominantly in the alveolus. (18)

We can explain this orthopedic cycle that occurs with non-surgical RME in the alveolus as follows; With its hard acrylic body pressing on the lateral walls of the palate, the forces created by the Haas appliance are quite high and sufficient to bend the bone. (45) Epker and Frost, they examined bone formation under various forces and stated that when the bone surface is bent, it becomes more concave and there is bone deposition on that surface. On the other hand, when the bone surface is curved, its concavity decreases, and bone resorption occurs at that surface. A concavity of the buccal wall of the maxilla is formed by the bending of the palate walls in the buccal direction away from their upper articulations, thereby stimulating bone formation. The palatal surface becomes convex and bone resorption is stimulated. The occlusal forces active during prolonged retention also contribute to this trend.(46)

### **5. Conclusion**

Rapid maxillary expansion is considered as an unreliable procedure with several side effects when applied in the adults, whereas surgically-assisted RME is a preferred procedure. However, it is reported in the literature that non-surgical RME applied in the adults is a successful and reliable technique in the treatment

of transverse maxillary arch discrepancies. Every case should be evaluated individually with respect to complications, risks, and patient cooperation, and it should be decided whether maxillary transverse arch discrepancy can be treated at an acceptable success level with nonsurgical intervention.

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## CHAPTER 6

# ORAL HEALTH RELATED QUALITY OF LIFE: DEFINITION AND TOOLS

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### 1. Introduction

While the concept of quality of life has been initially applied in the field of sociology, today it is applied to the disciplines of politics, economics, health, and even popular films and music. Although it is a frequently used concept due to its application to many disciplines, it is sometimes thought that it cannot be fully defined and understood (1). In 1948, health was defined by the World Health Organization as a “state of complete physical, mental and social well-being, not merely the absence of disease or infirmity”. Health includes a range of states from wellness to illness to disability (2). It is now widely accepted that personal disease burden cannot be defined by measures of disease status (such as infarction size, tumor load) in the light of data obtained using a medical device. This definition should also include psychosocial factors such as pain, anxiety, mobility limitation, and other functional disorders, difficulty in fulfilling personal and family responsibilities, financial burden, and decreased cognition. The new field emerging as a result of this definition is called health-related quality of life (3).

Oral diseases are among the most common chronic diseases. In addition, oral diseases can be considered an important public health problem due to their prevalence, their effects on the individual and society, and the high cost of their treatment (4). Diseases in the mouth area, including dental caries or

periodontal diseases, are quite common in the community. The consequences of these diseases cannot be judged by physical losses alone. Because they also have psychological, economic, and social effects. The aforementioned disorders may cause a decrease in the quality of life of some people, as well as affect the fulfillment of oral functions such as eating and drinking, appearance, and social relations (5).

Health-related quality of life evaluation with health status indicators was successfully performed in medicine. However, these procedures are not fully settled in dentistry (6). The lack of patient-oriented measurement in assessing oral health was introduced in 1976 by Cohen and Jago. They stated that data on the psycho-social effect of oral health troubles are lacking in the field of dentistry (7). Since Cohen and Jago advocated the development of socio-dental indicators, researchers have sought to develop scales, indicators, and tools to assess and measure oral health-related quality of life (8).

## 2. Quality of life

It is thought that quality of life was tried to be defined even by the Greek philosopher Aristotle in the past, so it is not a new concept (1). The concept of quality of life was first used as a term in Priestley's play "Daylight on Saturday" in 1943 (9). In the field of health, the term quality of life was first used in an article titled "On the Quantity and Quality of Life" published by Long in 1960 (10).

After the II. World War, as a result of economic growth and developments in living standards, the expectations of individuals regarding their satisfaction, well-being, and psychological state increased. This perception about the quality of life continued in the following periods, and studies were performed by researchers to define and measure this concept (1).

Although there is no clear description of the notion of quality of life, a common consensus regarding this concept has multidimensional nature. (11). Due to the multidimensional nature of quality of life, it has been shown that it is correct to use subjective and objective indicators together. (12,13). In addition, quality of life should include dimensions defined as minimum: physical (individuals' perceptions of their physical states), psychological (individuals' perceptions of their cognitive and emotional states), and social (individuals' perceptions of interpersonal relationships and social roles) (11). 'Physical Well-Being' refers to the individual's doing the activities and personal care of the day without needing anyone else. Although the objective dimension is important in defining a person's quality of life, subjective perceptions and expectations of the person transform this objective assessment into a real quality of life assessment (14). Subjective

indicators of quality of life include economic, social, and psychological well-being. The 'State of Economic Well-being' includes meeting the basic needs of the individual such as health and shelter, as well as having job security and feeling financially secure for the future. 'Social Well-being' means that people can fulfill what is expected of them in social relations and social activities. It is seen that the general happiness and satisfaction of the person are included in the 'Psychological Well-being'. Satisfaction with life means that an individual can adapt to different life conditions and be emotionally well (13). In addition to these explanations made with the quality of life, it is thought that quality of life is a dynamic concept (15). The notion of quality of life is affected by many factors and these factors are divided into the different fields within themselves. In addition, there are some indicators related to certain fields of these factors. In summary, the notion of quality of life can be briefly explained with four basic principles. i) The notion of quality of life is multidimensional. It is affected by both individual and environmental factors, as well as the interaction of the individual and the environment, ii) It has similar components for all individuals, iii) It is evaluated both subjectively and objectively, iv) Quality of life increases with self-care, a sense of having a goal and belonging somewhere. (16).

### **3. Health-related quality of life**

When describing the concept of quality of life in the healthcare field, the term quality of life is often used to focus on the effects of disease and treatment. In addition, the term health-related quality of life is used to distinguish education, the standard of living, environmental quality, transportation, public safety, and cultural opportunities, political freedom from health care, and to draw a line between the fundamentally health-related and non-health-related aspects of life (17).

Spilker and Revicki developed a classification for health-related quality of life in four areas: (a) personal-internal (aspects influencing perceptions and interactions with the environment within the individual); (b) personal-social (the individual's social network and immediate social circle); (c) outer-natural environment (geographic and natural environment); and (d) the outer-social environment (organizations and institutions created by society) (18). It is stated that health-related and non-health-related quality of life is intertwined and each component can become health-related at any time. For example, at the level of the external natural environment, longer, darker winters than summer may increase seasonal mood disturbances, and air pollution may be considered one of the causes of chronic respiratory diseases. In addition, when an individual gets sick, almost every area of life can become health-related (19).

Health-related quality of life has a multidimensional structure such as emotional, physical, social, functional, and mental well-being with a current approach (20). Researchers argue that health-related quality of life includes both disease-related and cognitive components. These two components are complementary to each other. Illness-related components reflect “happiness,” that is, the feeling of satisfaction or dissatisfaction with the situation. Cognitive components, on the other hand, reflect “appreciation, thoughts and perceived satisfaction with the situation”. It is thought that the components related to the disease vary according to the emotional states of the individuals. Cognitive values are considered to be more stable (21). The influence of culture is also one of the elements to be considered in the definition and measurement of health-related quality of life. Quality of life is considered a subjective issue, and this subjectivity brings with it the influence of culture. The data obtained through studies have revealed that culture has an impact on individuals’ personal identification of health and disease, the importance they attach to health, and their struggles to cope with the disease (19). As stated before, that health-related quality of life has an active and dynamic content, and current studies have shown that perception on this subject may change over time. Past experiences in health cause change in the expectations of individuals and their functional well-being standards. With such experiences, individuals adapt to their diseases and their standards regarding quality of life vary (22). This raises the question of measuring the changes in individuals’ perception of quality of life more sensitively. In order to accurately determine the changing standards associated with health-related quality of life, it is necessary to evaluate past life status and current well-being from low to high, from bad to good, from poor to excellent (etc.). In addition, the continuity of the comparison on all subjects should be ensured (23,24).

Due to the fact that the concept of health-related quality of life is multidimensional and includes different factors affecting each other, it is envisaged to make a detailed definition. The concept can be classified into three groups, from the narrowest to the broadest. The first category provides the narrowest reflection. This category deals with physical dysfunction, symptoms, mental health problems at the health-related quality of life. These issues, which fall under the jurisdiction of the health system and doctors, have a negative approach because they have a structure that focuses on solving problems.

The second category focuses on the impact of the disease and the treatment applied on quality of life. This category includes the concerns of healthcare

providers, but also allows assessment of the impact of the illness on other aspects of an individual's life. To illustrate this statement with some examples, people are more concerned about the financial impact it will have on them than the ability to work that they will lose. It is important not to focus solely on sexual function, as this can affect married life in a larger and more alarming way. In short, as can be seen from the examples, well-being is a broader concept than functionality. In addition, although the term "well-being" indicates a positive situation; in fact, its focus is on the impact of illness on well-being, which is primarily negative.

In the definition of health-related quality of life, the last category focused on the evaluation of the quality of life of individuals with a certain disease. Such a broad perspective better expresses that the disease affects all areas of individuals' lives. While in the previous two categories, the quality of life was approached from a negative perspective, in this category there is a positive perspective. This category includes dimensions, during the illness such as the development of one's relationships with other people, and the changes in the values, and priorities of the individual. Especially if the disease has progressed and the end of life has been approached, issues related to existence such as finding the meaning of life and conscientious relief should also be considered (17).

#### **4. The concept of oral health and its relationship with general health**

On September 6, 2016, the FDI World Dental Federation General Assembly decided that it was appropriate to describe a definition of oral health with a descriptive framework to illustrate the scope of the term oral health and what it means in clinical practice and policies (25). While creating the FDI 2020 vision, it was set out with the idea that oral health, which is known to be a component of general health, needs to be recognized by many stakeholders which states that oral health is a universally accepted, basic human right, and to facilitate its inclusion in all policies. Oral health is traditionally known as the absence of disease, but this definition does not include the values, perceptions, and expectations of the person. However, the new description acknowledges the versatile nature of oral health and its different components. Oral health had described as "Oral health is versatile and includes the ability to speak, smile, taste, chew, touch, smell, swallow and get into touch a range of emotions with facial expressions safely and lack of craniofacial complex disease, pain, and discomfort". In addition, other features of oral health are defined as follows.

- It is an important component of mental, physical and healthy well-being. It is influenced by the values and attitudes of people and communities. This situation causes it to exist constantly.
- It discloses the social, psychological, and physiological characteristics necessary for quality of life.
- It is affected by one's changing expectations, experiences, perceptions, and ability to adapt to conditions (26).

The World Health Organization (WHO) describes oral health as the state of being free from discomforts such as oral and facial pain, mouth infections and wound, oral and throat cancer, periodontal disease, caries, missing teeth, and other diseases, biting, chewing, smiling, speaking and limiting personal capacity in psychosocial well-being.

Oral health is one of the important and complementary components of general health. In addition, symptoms of systemic diseases can be observed in the mouth. For example, severe periodontal disease can increase the risk of cardiovascular disease. On the other hand, periodontal diseases can occur as a complication of diabetes. Due to this feature, the oral cavity is the gateway to the body of the individual for health care providers and thus has great importance in the early diagnosis of many diseases. While the first symptoms of HIV can be observed as lesions in the mouth, different appearances in tooth shapes may be the cause of serious nutritional disorders (27).

As a result;

- Various systemic diseases have symptoms in the mouth.
- Microbial infections negatively affect general health. The oral cavity is an entrance gate for these infections as well as a disease area.
- Pharmaceutical and other treatments of systemic diseases can adversely impair the oral cavity and its functions. The negative intraoral effects of these treatments may impair the patient's compliance while continuing the treatment.
- General morbidity due to oral infections poses a great risk for hospitalized patients receiving immunosuppressive therapy.
- Diabetes poses a great risk for periodontal diseases.
- Many animals and population-based studies have reported an association between periodontal diseases and risky pregnancy, stroke, cardiovascular disease, and diabetes.
- More research is needed on similar subjects in order to clearly determine to what extent the aforementioned relationships are coincidental or causal (28).

In addition, the increase in life expectancy around the world shows that the importance given to oral health will continue throughout life. Awareness and knowledge of these identified close relationships between oral and general health can increase collaboration among oral and general health professionals. The fact that both oral health and general health affect each other bilaterally and this relationship affects the health and quality of life of the individual reveals the necessity of including oral health in general health approaches (27).

## **5. Oral health-related quality of life**

Oral health problems rarely threaten patients' lives. However, its prevalence in a large proportion of the population is in fact an indication that it is a major public health issue (29). The problems that people experience with oral diseases can cause a series of problems in their daily lives. Chief among these is the chewing problem, which results in less food consumption and weight loss. In addition, low self-esteem, insomnia, and irritability are some of these reflections (30). While diagnosing the physical complaints and limitations of the patient during the history taking and examination, dental health providers should also make a psychosomatic assessment. This information not only helps to identify conditions that may prevent the patient from healing and/or adhering to treatment, but also helps to develop a patient-specific treatment plan (31). Diseases related to oral and dental health negatively affect the purpose of living longer and better for people. Although it is seen as a local problem in the mouth area, it is thought that it affects the external appearance of people and worsens the well-being of the individual by damaging the self-confidence of the patients. Pain in the face and mouth region and loss in sensory-motor function prevent individuals' diet, satisfaction, social environment, and social communication. In addition, systemic disorders also show some symptoms that negatively affect patients in the mouth and face region. For example, neurodegenerative conditions in speech, taste, and smell observed in Parkinson's patients, mouth and facial pain, dry mouth and mucosal infections in AIDS patients, painful ulcers, widespread dental caries in the mouth of cancer patients after treatment, are some of these (28). Knowing the oral health-related quality of life of each patient, depending on all the problems that individuals may experience due to insufficient oral health or other illnesses associated with stomatognathic system health, is as important as knowing the factors that contribute to both oral and general health (30). An article published in 1995 emphasized the importance of three topics that they thought were related to each other. These topics were oral

health, oral health-related quality of life, and general health. This study also made clear that oral health should not be excluded from general health and its support for overall health-related quality of life (2). Today, oral health-related quality of life aims to evaluate ‘the person’s satisfaction with oral health, self-confidence, comfort during meals, sleep and social communication’, and also shows that the continuity of oral health is one of the reasons for being healthy in general (8,32). Oral health-related quality of life is thought to consist of three assumptions. These assumptions are interrelated.

1. This assumption includes the data obtained as a result of the evaluation of the oral cavity and suggests that the oral health of the individual should be at an optimum level. In other words, the absence of pain or discomfort in the mouth is a desired condition.
2. Conditions that affect the inside of the mouth also affect general health. According to the assumption that oral health is a component of general health, it is thought that oral health also contributes to the general health quality of life.
3. Systemic diseases and general health quality of life affect oral health-related quality of life. It is thought that general health is also effective on oral health and many systemic diseases cause intraoral symptoms. This situation negatively affects both the general health quality of life of the person and the quality of life related to oral health (2).

Locker has developed a multidimensional conceptual model for oral health-related quality of life using the WHO’s International Classification of Disability, Disability and Handicap. The definition of the concepts in this model is as follows.

1. Functional Restriction: Often defined as a result of the body’s components or organs not working as expected.
2. Discomfort: It is the response to illness. Examples include pain, discomfort, physical or psychological symptoms expressed by patients.
3. Disability: It is defined as the absence or abnormality of the physical, psychological or anatomical structure that occurs during or after birth. Examples include edentulism, periodontal disease or malocclusion.
4. Incapability: It is the lack of abilities that are considered normal.
5. Deficiency: It is the inability of individuals to fulfill social expectations within the group (21).

According to this model, diseases cause disability, defined as any loss of anatomical function or abnormalities. These disabilities cause functional

limitations, such as the inability to make certain sounds as a result of tooth loss. As a result of the disability experienced, discomfort and pain occur in addition to functional limitations. Physical, social and psychological disabilities occur due to the resulting functional limitations and the discomfort experienced by individuals. In this model, disability refers to the limitations in performing daily activities. Disabilities experienced by the person lead to the emergence of physical, mental, and social inadequacies. Disabilities tend to occur when there are both functional limitations and a sense of discomfort, but disabilities are more likely to occur when there are disabilities and functional limitations and a feeling of discomfort (33).

In the traditional studies of dentists, subjects such as the definition of caries and periodontal problems-like diseases and the determination of their frequency in the community are discussed. Indicators such as decay/missing/filling teeth (DMF/T) and the community periodontal index of treatment needs (CPITN) are used for their measurements (34,35). Although these and similar indexes provide clinically important information by evaluating the presence, progression, and severity of diseases, they do not provide information about the evaluation of individuals in relation to social issues, the functional status of the individual, or the psychological and social effects of the disease (6,20). This situation revealed the multidimensional nature of health and the need to develop some scales that include not only physicians but also patient-oriented outcomes (6). Today, there are various tools available to assess patients' satisfaction in practice. These tools are used to evaluate oral health as an indicator of patient satisfaction. Each of these instruments selected by physicians allows us to obtain unique data. Through clinical trials, some tools have been tested, used, and approved by researchers (36).

## **6. Tools commonly used to assess the oral health-related quality of life**

### **6.1. *General/Geriatric Oral Health Assessment Index (GOHAI)***

This index, which was used by Atchison and Dolan in 1990 to evaluate the effects of dental treatments, is a 12-item measure of patient-reported oral function problems and psychosocial effects caused by oral disease. It was first introduced in the USA as the Geriatric Oral Health Assessment Index but was later changed to Geriatric as General. Its validity and reliability study in Turkey was conducted by Şafak Dağhan et al. The 12-item question in this index evaluates the extent of the person's physical function, psychosocial functions, and discomfort or pain. Participants responded to their experiences in the last three months with five-point Likert-type measures for each of the 12 items. When the questions in the

index are answered by the patients, a score between 0-60 is obtained. If GOHAI scores are less than 50, they are graded as low, between '51-56' as moderate, and between '57-60' as high. The scores of people who have good oral status and have no problems are recorded as high (37,38).

### **6.2. Oral Impact on Daily Performance (OIDP)**

The basic of OIDP is based on WHO's disability classification. It is easy to use. The reliability and validity of different arrangements used in adult and elderly populations have been successfully tested. OIDP assesses the impact of oral health on the capacity to perform tasks that need to be done during the day (39).

The effect of oral health on daily activities is evaluated in areas such as eating, enjoying the food one eats, relaxing, laughing, sleeping, smiling, and shamelessly showing someone their teeth, speaking, pronouncing words properly, cleaning their teeth, and establishing normal social relations. Individuals are evaluated by asking how often they experience problems while doing these activities due to oral health-related trouble in the last 6 months (6,20). OIDP is scored on eight categories determined by frequency: eating, speaking and speaking clearly, teeth cleaning, relaxing and sleeping, shamelessly smiling, maintaining emotional state, communicating with other people, and executing success in a social environment. Ranges on the scale used: (0) "not at all affected", (1) "less than once in a month", (2) "once or twice in a month", (3) "once or twice in a week" (4) "3-4 times in a week" 4", (5) "every day or almost every day" (40,41).

### **6.3. Dental Impact on Daily Living (DIDL)**

This scale, which was used by Leao and Sheiham in 1996 to determine the effects of oral health on the quality of daily life, consists of a total of 36 questions in five main categories. These five categories are classified as comfort (tooth loss, bad breath, bleeding gums, tenderness), appearance (position, color, appearance of the teeth), pain (spontaneous pain, pain with chewing, pain in hot/cold, joint pain), general performance (stress due to pain, insomnia, decreased work capacity, shaky self-esteem) and restriction in eating (limited chewing, limited biting) (6,42).

### **6.4. Dental Impact Profile (DIP)**

It was published in 1993 by Strauss and Hunt. It is a scale that evaluates patients' perceptions of events. It consists of four sub-titles: eating, health/well-being, social relations, and romance (41). DIP assesses how quality of life is affected,

reduced or improved by the condition of intraoral structures and oral health. A self-reported questionnaire, the DIP was developed after a series of consultations with dental practitioners, researchers, and consumers. The questionnaire, which included 37 items when it was first developed, became a 25-item survey after it was applied to university students and elderly individuals (36). The questions evaluate the effect of teeth or dentures on comfort, self-confidence, taste, chewing and biting, laughing, social life, speech, breathing, general health, continuity in daily activities, and job success (41). The questions are ‘Do you think that your teeth or dentures have a positive (good), negative (bad) effect on your eating, or have no effect at all?’. The total score from patient records is calculated by adding the percentage of positive or negative responses from all answers. (43,44).

In addition, the “Dental Impact Profile” is the first tool to show the existence of positive or negative effects on the lives of patients’ teeth and dentures they use. DIP is an indicator that proves the necessity and importance of the health and existence of teeth for a better life. (12). Short and simple, this test helps patients appreciate and evaluate the value of their teeth, as well as assess the ethical impact on life. (36).

### ***6.5. Oral Health Related Quality of Life- United Kingdom (OHRQoL-UK)***

It was first developed by McGrath and Bedi in 2000. It provides the opportunity to measure the effects of oral health on quality of life in four categories. The 16 questions prepared for the tool measure both positive and negative effects. These categories are respectively; 2 questions for symptom, 5 questions for physical condition, 5 questions psychological condition, 4 questions for social situation (45,46,47). It was thought that the negative effects of oral-dental related diseases on the quality of life prevent individuals from noticing the positive effects of a healthy state in daily life. A low score on the OHRQoL-UK scale, which evaluates both positively and negatively, indicates a low oral health-related quality of life. In the OHRQoL-UK questionnaire, the questions scored according to the Likert scale are given a value between 1 and 5. When the scores of 16 questions are added together, there is a value between 16-80 (45).

### ***6.6. Visual Analog Scale (VAS)***

It has been argued that words may fail to describe the precision of subjective experience and that digital grading imposes wrong categories on the phenomenon of emotion. For this reason, it has been argued that it is impossible to provide the scoring precision offered by the VAS with digital and verbal rating scales. The VAS is a suitable scale for measuring change and its significance (48).

This scale is a 10 cm long line. The vertical or horizontal direction of this line does not affect the results (49). The patient marks on the line the state he feels in response to the question asked, and the distance between the marked part and the starting point of the line is measured in centimeters. The advantage of this method is that it can be easily applied in the clinic, is understandable and can be applied in all patient groups (48).

### **6.7. Oral Health Impact Profile (OHIP)**

It was first applied by Slade and Spencer in 1994, based on the WHO's International Classification of Deficiency, Inadequacy, and Disability (50,51). It is a quality of life scale belonging to the family of oral health that can be used in all medical conditions related to the oral region. The scale is based on Locker's conceptual framework (52).

The 49 questions in OHIP address the oral health model developed by Locker in previous years by formulating it in seven conceptual dimensions. These conceptual dimensions formulated are pain, functional limitation, social disability, psychological inadequate, physical disability, psychological discomfort, crippled. (7,54). While separate subscales for each of the seven dimensions can be evaluated and calculated within themselves, general social impact levels were calculated using 49 questions (53). The answers are scored according to the Likert scale. The questions in the questionnaire are answered by choosing one of five answer options (0 = never, 1 = seldom, 2 = sometimes, 3 = frequently, 4 = always), scored between 0-4. The efficacy of each substance is determined using Thurstone's paired comparison method. After the results are calculated separately for each of the seven subgroups, they are all added together to calculate the actual result. Obtaining high-score data from the patient as a result of the questionnaire shows that the quality of life is negatively affected (6,51,53).

The biggest advantage of OHIP is that issues are generated through conversations with representative patient groups. In other words, the functional, psychological and social effects of intraoral problems were determined by the patients (6,53). According to Nuttall et al., it increases the possibility of being measured by revealing these social effects that are perceived as important by the patients, thus emphasizing the idea that this scale is a sophisticated scale (52).

The hierarchy at scale deals with outcomes that have an increasingly devastating impact on people's lives. Oral diseases may have occurred due to tooth loss. This may cause inability to chew (functional limitation) or pain (discomfort) due to the use of prosthesis. In addition, this situation may cause restrictions in eating desired or needed foods. These disorders can prevent the

person from eating in a crowded environment, and thus cause people to stay away from their family and social environment. Epidemiological studies using OHIP; found that lost teeth, untreated disorders, periodontal tissue loss, and limited dental care have increased effects on health/well-being (52,53,54).

Consisting of 49 questions, the OHIP is suitable for researchers or physicians who want an objective line related to oral health. However, some researchers did not consider it necessary to use all 49 questions. Because although it is known that the reliability of the index reduces as the number of questions decreases statistically, it is also desired that the questionnaire be easy and simple. The reasons for shortening the Locker and Allen scales are i) Answering and scoring the scales can take a long time and it is not possible to allocate such a long time in the clinic ii) Long questionnaires increase the cost iii) It may be difficult to answer the long form of the questionnaire for some segments of the society such as the sensitive and elderly patient population iv) They explained that the length of the questionnaire may lead to an increase in the number of unanswered questions, thus causing more data loss and a decrease in the number of individuals in the study group (55). Various statistical techniques, including internal reliability analysis, regression analysis, and factor analysis, have been used to identify brief forms of information. The short version of the OHIP consists of 14 questions, with two questions for each dimension. The validity and reliability of OHIP-14 have been confirmed by Slade (52,53).

## **7. Final considerations**

We should consider oral health as an integral part of general health and not ignore that it can negatively affect people's quality of life. In order for people to keep their quality of life high, it is necessary to eliminate the negative factors that affect the quality of life. It is very important for individuals to acquire good health habits in the early years of their lives. The habits necessary for oral health are at the forefront of these.

During the examination, a dentist's measurement of oral health-related quality of life gives valuable information about the diagnosis of the disease, the treatment to be applied to the patient, and the course of the disease. In addition, it allows to predict the patient's level of adherence to the treatment plan and to adjust the treatment plan according to perceptions. Every dentist should try to administer a questionnaire to assess his patient's quality of life. The data obtained from these tools, which are easy and fast to apply in the form of a questionnaire, are necessary for dental practitioners who care about the professional-patient relationship and aim to move this relationship in the right direction.

Although oral health problems are not life-threatening in general, they are responsible for the decrease in the quality of life due to reasons such as prolonging the painful events experienced by individuals, creating limitations in functions, creating a feeling of aesthetic dissatisfaction, developing nutritional problems, and psychological problems.

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