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INTEGRATED STUDY MASTER'S THESIS

Gingival Recession and its Treatment Modalities

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Annotation

Gingival recession can be defined as the exposure of the tooth root due to the apical migration of the gingiva towards and behind the cementoenamel junction and is a widely common disease worldwide, increasing with aging (Stevens et al., 2021; Georgieva, 2019). The causes can be differentiated into predisposing and precipitating causes, while the most common factors influencing the development are gingival trauma, patient related habits, genetic predisposition, orthodontic treatment and insufficient restorations (Georgieva, 2019). Aim of this study was to analyse the etiologies and different treatment possibilities of gingival recession. Tasks:

1. To analyze research literature about the pathogenesis, etiology and risk factors of gingival recession.
2. To find research about the classification systems of gingival recession.
3. To analyze literature about the clinical examination and diagnosis of gingival recession patients.
4. To analyze literature about the non-surgical and surgical treatment possibilities of gingival recession as well as root coverage management.

The Research Literature search strategy was manual research in the PubMed database as well as Google Scholar database with the key words “gingival recession“, “gingival recession etiology“, “gingival recession classification“, “clinical examination and diagnosis of gingival recession“, “root coverage management“ and “periodontal flap surgeries“. The search was filtered by screening for “free available articles“ and “articles available via using VU VPN on PubMed and Google Scholar database“ in “languages: English and German“. Totally, 92 articles have been included into this research literature review and each article was screened according to its importance for the thesis especially regarding to etiology, classification, diagnosis and treatment modalities of gingival recession. To include the most recent literature, just 30 percent of the used articles are allowed to be older than five years. Conclusion of this thesis are that the research about the clinical examination, prognosis and treatment of gingival recession is highly established in the scientific field, several treatment options are available and treatment methods are often resulting is favourable outcomes. There are different factors influencing the outcome generally, but the co-operation between the dentist and the patient, as well as the guidance of the clinician to change the lifestyle and habits of the patient are main factors for the success. The preferred surgical approach depends mainly on the patient's

compliance and skills of the clinician. However, the gold standard surgical treatment is based on the use of autogenous connective tissue grafts with the coronally advanced flap technique.

Key words: Gingival Recession, Gingival Recession Etiology and Risk Factors, Root coverage management, Gingival Recession and Periodontitis relations, clinical examination and diagnosis, Periodontal flap surgery, classification of gingival recession.

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Used Abbreviations

GR	Gingival recession
CEJ	Cementoenamel Junction
MGJ	Mucogingival Junction
CBCT	ConeBeam Computed Tomography
RDA	Relative dentin abrasitivity
FGG	Free gingival graft
CTG	Connective tissue graft
SCTG	Subepithelial connective tissue grafts
LPF	Lateral positioned flap
DPF	Double papilla flap
CAF	Coronally advanced flap
PST	Pinhole surgical technique
GTR	Guided tissue regeneration
EMD	Enamel matrix derivative
ADM	Acellular dermal matrices
XCM	Xenogenic collagen matrices

1 Introduction

Gingival recession can be defined as an exposure of the tooth root due to the apical migration of the gingiva towards and behind the cementoenamel junction and is a widely common manifestation worldwide, affecting almost middle and older aged individuals (Stevens et al., 2021; Georgieva, 2019). Clinically, gingival recession results in unfavourable esthetics, root caries and dental hypersensitivity (Clark et al., 2019). The causes can be differentiated into predisposing and precipitating causes, while the most common factors influencing the development are gingival trauma, patient related habits, genetic predisposition, orthodontic treatment and insufficient restorations (Georgieva, 2019). For diagnostic purposes, the medical and dental history with an appropriate clinical examination together with an intraoral examination of the mucosa, gingiva, teeth and periodontal assessment as well as radiographic examination by using ConeBeam Computed Tomography or panoramic radiographs is crucial for the prognosis evaluation and the classification of the gingival recession status (Kasaj, 2018). The treatment can be divided into non-surgical and surgical treatment options, while the non-surgical ones are mainly based on deletion of causative factors, use of desensitizers, varnish, bonding agents and cervical restorations (Kasaj, 2018). The surgical options depend on the amount of defects (single or multiple) and are distinguished mainly on the technique itself and the used materials, including autogenous soft tissue grafts, pedicle autograft procedures and the use of soft tissue substitutes (Imber et al., 2021; Mostafa et al., 2022). Aim of this study was to analyse the etiologies and different treatment possibilities of gingival recession.
Tasks:

1. To analyze research literature about the pathogenesis, etiology and risk factors of gingival recession.
2. To find research about the classification systems of gingival recession.
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2 Gingival Recession

2.1 Definition

According to the American Academy of Periodontology, gingival recession (GR) is defined as the exposure of the tooth root caused by the migration of the gingiva to a point apical to the cementoenamel junction (CEJ). This frequently compromised dental and gingival aesthetics might cause dental hypersensitivity (Chambrone L., 2015; Stevens et al., 2021). By definition, GR is always associated with clinical attachment loss (Cortellini et al., 2018). It can be localized or generalized, affecting one tooth or multiple teeth in the same patient, and might be connected with one or more surfaces at the same tooth (Kasaj, 2018).

2.2 Anatomy

In a healthy patient, the free gingival margin, which can be also defined as the coronal border of gingiva, is located 1-2 mm coronally to the CEJ, while the epithelial attachment level is slightly coronal to the level of the CEJ (Perelli et al., 2019). If GR is present, an osseous dehiscence can be seen and the soft tissues around the tooth, including free and attached gingiva as well as alveolar mucosa, are displaced apically to the CEJ, with root surface exposure to the oral environment (Jati et al., 2016).

Histological studies showed in buccal-lingual cross-sections of the teeth affected by GR that the gingival unit, characterized by keratinized epithelium, tends to move apically with increasing depth of recession, while the mucogingival junction (MGJ), as well as the alveolar mucosa remains unchanged (Pini-Prato, 2011). Based on this study, the results confirm that with increase of recession depth, the keratinized tissue width is likely to decrease and might lead to partial or complete loss of attached gingiva. However, even when the MGJ is reached by the GR, a small amount of keratinized mucosa might still be present (Wang et al., 2022).

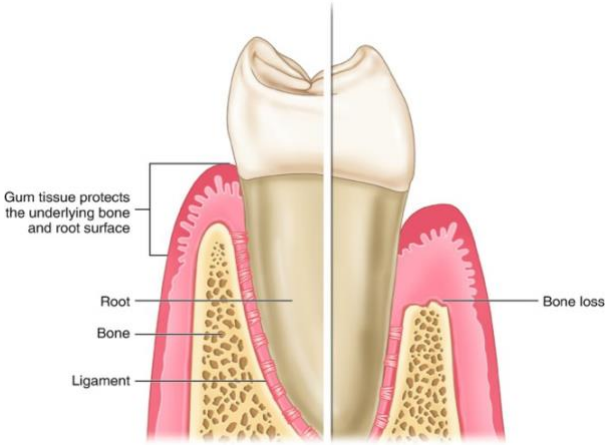

Figure 1 – Diagram of healthy gingiva covering the root of the tooth (left side) compared to root exposure due to apical migration of the gingival margin (right side) (Kasaj, 2018).

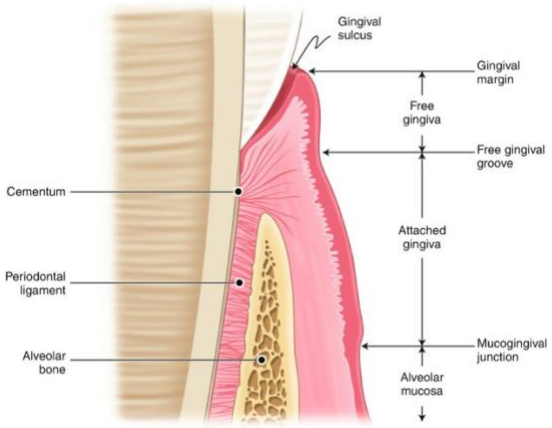

Figure 2 – Important anatomic landmarks of the healthy gingiva in cross section (Kasaj, 2018).

2.3 Epidemiology

2.3.1 Age

Population-based studies showed that the development of GR is associated with age. Both prevalence and severity of GR are decreased at younger ages and increase with time (Georgieva, 2019). Mythri et al. investigated the relationship between age and the appearance of gingival recession in their study. Of 710 Patients examined, 291 could be diagnosed with GR, while the frequency of GR seems to increase with age. In age group 15-25 years, the GR was 26.9%; age group 25-35 years had a recession frequency of 41.5%; age group 35-45 years were introducing with 66.1% of GR and in the age group of 45-60 years, 70.3% of the Patients had GR. Therefore, it can be interpreted that as age influences GR (Mythri et al., 2015). Mazur et al. determined in their study the influence of age on the prevalence of gingival recession in patients with periodontitis. In their study, 133 patients aged 29 to 59 were included and divided into four groups and showed that 65.86 % of the included patients presented with GR more than 1mm, while the average number of teeth presented with GR increased with age. While patients aged 20 to 29 presented with recession in 42.86 % of the teeth, the age group of 50 years and older presented with recession in 82.72% of the examined teeth (Mazur et al., 2020).

2.3.2 Gender

A study by Mythri et al. corroborates the finding that adult males consistently presented with a higher prevalence of GR than adult females. The study results showed that males were significantly more affected by GR (60.5%) compared to females (39.5%) (Mythri et al., 2015). However, another study by Fragkioudakis et al. checked the prevalence and clinical characteristics of gingival recession in greek young adults aged 18 to 30. They emphasized an equal distribution with 50 % of GR among females and males (Fragkioudakis et al., 2021).

2.3.3 Socioeconomic Status

A study by Anuraga et al. examined the distribution of the sample and prevalence of GR according to the socio-economic status. The results emphasized a total of 254 patients, with 108 patients, 30 patients and 8 patients presenting from upper, upper middle, middle and lower middle class. Out of 158 Patients with GR in total, 81 patients (75%) were associated to upper class, 27 patients (90%) were associated to upper middle class, while 7 patients (87.5%) were from middle or lower middle class. Based on this results, the authors came to the conclusion that patients with GR belong most often from middle or lower middle class (Anuraga et al., 2019). Rios et al. reported teeth affected by recession with increased percentage in lower socio-economical status individuals regardless of age in Brazilian population. The study emphasized that 43.7 % of the people with lower socio-economic status presented with GR, while 23.7% of the higher socio-economic status patients were affected by GR (Rios et al., 2020).

2.3.4 Location – Tooth

GR has a higher prevalence in mandibular teeth compared with maxillary ones. Mythri et al. were also comparing the location of GR at 710 patients with an age of 15 to 60 years in his study. They emphasize that GR was mostly seen in mandibular incisors (43%) followed by maxillary molars (13.2%), mandibular premolars (12.2%), maxillary incisors and premolars (8.9%), mandibular molars (4.9%), maxillary canines (4.6%), mandibular canines (4.3%) (Mythri et al., 2015). This result and frequency could also be confirmed in other studies. Rios et al. described in their four years follow up that mandibular central incisors and maxillary molars were the teeth with higher incidence of GR at buccal sites (Rios et al., 2021). These data were also confirmed for patients, who were undergoing orthodontic treatment. Renkema et al. were assessing in their study the prevalence of GR in patients before, immediately after, and 2

and 5 years after orthodontic treatment. Their Results showed a constant increase in GR after treatment from 7% at end of treatment to 20% at 2 years post-treatment and to 28% at 5 years post-treatment. Typical regions where recessions could be observed are the maxillary first premolars and first molars, as well as the mandibular central incisors (Renkema et al., 2013).

2.3.5 Location – Site

The most common site of all tooth surfaces for the development of GR is the buccal surface of the teeth. Studies emphasized that the buccal surface is associated with highest severity regarding to disease progression and complications (Alamri et al., 2019). Kim et al. investigated the influence of gingival thickness, keratinized tissue width and bone morphology on the development of GR. They concluded in their study that individuals with thin and small gingival areas seem to have more GR compared with those areas presenting with thick and wide gingiva. Thus, the soft tissue thickness at the different sites of the teeth and areas in the oral cavity plays an important role in GR development (Kim et al., 2019). Toker et al. were investigating the prevalence of GR and assessed different risk indications in a Turkish university hospital. They presented in their study that GR in male and female patients was significantly higher at buccal sites than those of all other sites. Moreover, GR at lingual sites was significantly higher than mesial and distal sites (Toker et al., 2009).

2.4 Etiology and Risk Factors

The successful prevention and management of GR is based on the knowledge and evaluation of underlying etiology. Therefore, at first it is important to identify and modify the etiological factors associated with GR development. Nowadays, the exact mechanism of the development is still unclear, but it is suggested that multifactorial factors play a role (Alamri et al., 2019). Generally, these factors can be categorized in predisposing ones, which include local anatomic conditions that favours the development of gingival changes, as well as the precipitating factors, which contribute to the onset of GR (Kasaj, 2018).

2.4.1 Predisposing Factors

Periodontal Biotype and attached Gingiva

For many years it was assumed that the existence of a definite amount of keratinized tissue as well as the height of this tissue was critical for maintaining the periodontal health and prevention of GR. However, evidence showed that the thickness instead of the height is an important factor (Patel et al., 2011). It has been corroborated that thin gingival tissue is more prone to GR in the presence of trauma or inflammation caused by plaque (Kim et al., 2019). Usually with thick biotype, the inflammation rarely extends deeper than 1-2 mm apically and just a small layer of connective tissue is affected. In case of thin gingival biotype or alveolar dehiscence the whole connective tissue might be affected, resulting in a breakdown of the marginal soft tissue and therefore in GR. Thus, the presence of thin gingival tissue can be seen as a predisposing factor (Georgieva, 2019).

Aberrant Frenal Attachment

The presence of a deviant frenal attachment is observed as another predisposing factor (Alamri et al., 2019). The influence of a high attachment position together with an apical pull on the gingival tissues may interfere with plaque control and makes oral hygiene procedures more difficult. Thus, the risk for localised periodontal problems is higher and is subsequently favouring GR (Bamel et al., 2021). Additionally, it has to be mentioned, that the risk is definitely increased if an aberrant frenal attachment is present together with a shallow vestibule and a minimal amount of keratinized tissue (Patel et al., 2011).

Dehiscence of Alveolar Bone – Fenestration Defects

Clinically, GR is always coexisting with alveolar bone decrease at the affected sites. Therefore, it can be concluded that dehiscence and fenestration defects of the alveolar bone are greatly connected to the development of GR (Kasaj, 2018). Those bone crest morphological defects are predisposing factors of GR and can be often seen in patients with tooth malpositioning in the dental arch (Mostafa et al., 2022). Sather et al. assessed in his study the correlation between GR and bone dehiscence and came to the conclusion that dehiscencding defects of the alveolar bone significantly influencing the probability of GR development (Sather, 2014).

2.4.2 Precipitating Factors

Toothbrushing Trauma

GR related to vigorous tooth brushing often presents in patients with a high level of oral hygiene and is more frequently seen at the buccal surface than approximately or lingually (Kasaj, 2018). Georgieva emphasized that "factors like horizontal strokes, brushing force, duration of toothbrushing, hardness of bristles and the frequency of changing the toothbrushes" are common risk factors (Georgieva, 2019, p.8). Generally, it presents as localized areas of recession and affects individual or a group of teeth and presents as wedge shaped defects with decreased interproximal recession. This type of GR presents often with low levels of plaque and might be associated with non-carious cervical lesions (Kasaj, 2018; Kanarakis et al., 2021). In the majority of people, the recession is related to their left side of the mouth due to the fact that most people are right-handed and brushing their left side first more effective as well as powerful. Clinically, the gingiva appears often healthy around the recession area with exposed root characterized by smooth, clean and polished surfaces (Kanarakis et al., 2021; Patel et al., 2011).

Oral Piercings

Another risk factor for GR is the wear of intraoral piercings, which gained more popularity in young people during the last years (Stevens et al., 2021). Studies reported a prevalence of almost 5% for oral and perioral piercings in young adults, while female individuals are predominating. The tongue was presenting most often with oral and perioral piercings, followed by the lip. Both piercing sites have been highly associated with development of GR (Kanarakis et al., 2021; Plessas et al., 2012). In a systematic review, the incidence of GR was 50% in patients with lip piercings and 44% in patients with tongue piercings. Therefore, individuals with lip piercings have a 4.14 times higher risk to develop GR, while people with tongue piercings have a 2.77 times higher risk, compared to people without any piercing (Hennequin-Hoenderdos et al., 2016).

Subgingival Restorations and Partial Dentures

The placement of subgingival restoration margins can be also seen as a risk factor for the development of GR due to direct periodontal tissues trauma or due to subgingival plaque

accumulation, which might result in an inflammatory response, ending in the development of marginal tissue recession. This effect is often caused by poor marginal fit, inadequate crown emergence angles, rough restoration surfaces and overhanging restorations (Georgieva, 2019; Stevens et al., 2021). Kim et al. demonstrated that teeth with minimal or no keratinized tissue, which were restored with insufficient subgingival cervical restorations, were more likely to develop gingival inflammation, resulting in GR. They argumented, that in the case of intracrevicular cervical restoration at teeth with minimal or no keratinized gingival tissues, clinicians should think about gingival augmentation as treatment option (Kim et al., 2015). Kanarakis et al. emphasized in their review the relation between fixed partial dentures and GR and described that patients using fixed partial dentures present with higher incidence of plaque accumulation, inflammation as well as recession (Kanarakis et al., 2021). A similar effect could be demonstrated by investigation regarding to the relation between periodontal health and wearing removable partial dentures. Silvano et al. presented that in patients wearing partial dentures, poor oral hygiene is considered as the most common risk associated with periodontal tissue damage, while GR have been recognized in most of the cases. Thus, the authors concluded that patients with removable partial dentures have a higher requirement for regular oral hygiene instructions, scaling and prophylaxis (Silvano et al., 2021).

Mechanical Trauma/Deep Traumatic Overbite

Georgieva concluded that “progressing apical proliferation of the gingival margin may also be a result of chronic recurrent minor trauma” to the gingival tissues (Georgieva, 2019, p.9). Examples for this kind of trauma might be frictional injuries by scratching, fingernail biting, impaction of foreign bodies or inadequate flossing (Georgieva, 2019). Another factor might be a deep traumatic overbite, which can cause sometimes a “direct soft tissue trauma from the opposing incisal edges” (Kasaj, 2018, p.24). Usually, it presents dominantly on the labial lower incisor surfaces and/or on the palatal upper incisor surfaces and is often associated with a Class II Division 2 malocclusion. This Problem can be often successfully treated with an orthodontic treatment (Kasaj, 2018).

Orthodontic Treatment

The beginning or progression of GR might also result from orthodontic movement during or after orthodontic treatment (Kanarakis et al., 2021). A study by Renkema et al. reported an

increase of the prevalence to develop gingival recession during orthodontic treatment of 47%. Especially the mandibular incisors seem to have the highest vulnerability regarding to the development of GR (Renkema et al., 2013). As long as the tooth is moving within the bony envelope, the risk for GR development during or after orthodontic treatment is very low. However, orthodontic forces pushing teeth labially outside of the alveolar bone envelope will lead to buccal bone loss (alveolar dehiscence) as well as result in decreasing the thickness of the gingival tissues due to gingival fibres stretching. The decreased gingival tissue thickness imitates a thin gingival biotype, resulting in a high susceptibility for GR due to plaque induced inflammation or mechanical tooth brushing trauma (Kasaj, 2018; Georgieva, 2019). Ji et al. investigated the prevalence of GR after orthodontic treatment of infraversion and open bite with totally 403 patients included in their study. The prevalence of GR were 80.6% and 75%, thus they concluded that patients with these two types of low occlusal function are more prone to exhibit GR after orthodontic treatment (Ji et al., 2019). Furthermore, we have to mention that orthodontic appliances may also induce GR by direct mechanical irritation or as retention area for plaque (Kanarakis et al., 2021). Kumar et al. assessed the effect of fixed orthodontics on gingival health of 120 patients, where most of them were females. The mean values regarding to visible plaque, inflammation and GR were after the treatment significantly higher and the authors concluded that GR is caused and influenced by orthodontic treatment (Kumar et al., 2021).

Plaque induced Periodontal Inflammation

Periodontal disease is another common cause of GR, resulting in connective tissue attachment loss as well as of the supporting bone encircling the tooth. Usually, a diminished bone support by an inflammatory reaction can be observed and results in an apical migration of the soft tissue margin. These patients have a higher incidence for generalised recession signs on all teeth surfaces (lingual, palatal, interproximal, buccal), although exceptions can be seen in some individuals as well (Jati et al., 2016; Kasaj, 2018). Kanarakis et al. emphasize in their review that especially supragingival calculus is a crucial factor in the formation of GR (Kanarakis et al., 2021). Especially in cases of thin gingival biotype, the connective tissue is affected fully by the inflammatory process caused by supra- and subgingival plaque. Thus, the gingiva margin loses support from underlying connective tissue and proliferates apically from the CEJ with clinical attachment loss, resulting in periodontal pocket formation (Yordanova, 2019). Furthermore, studies found out that also periodontal treatment can lead to GR. Several treatment

options imply tissue shrinkage as a result of a subsided inflammation leading to gingival recession during the healing period (Kasaj, 2018).

Smoking

Smoking is another factor that is connected to GR development and is one of the most common habits of adult population (Stevens et al., 2021). Indeed, several studies demonstrated a positive relationship between smoking and GR especially due to the loss of the tissue strength caused by harmful compounds in the tobacco (Jalayer et al., 2015). Furthermore, smokers are reported to have higher plaque and calculus levels compared to non-smokers, influencing the plaque induced periodontal inflammation as well. Is periodontitis present, clinical attachment loss and alveolar bone loss are more dominant in smokers than non-smokers (Ahad et al., 2021). Nandhana et al. were investigating the prevalence of GR in smokers and non-smokers in their cross-sectional study and concluded that smoking has significant effects on the gingiva leading to GR which might influence periodontal diseases. Smoking plays a major role in causing GR when compared to other factors that contribute to GR in non-smokers (Nandhana et al., 2019).

2.5 Pathogenesis

GR can be caused by inflammatory or non-inflammatory etiological factors such as trauma or bacterial infection, as well as due to the physiological result of bone resorption, tissue aging and due to an incorrect position of teeth in the dental arch. The anatomical gingival recession can be usually observed in absence of inflammation and without available loss of the interdental papilla height (Yordanova, 2020). The Pathogenesis of GR due to traumatic origin can be distinguished from that of bacterial etiology. The formation can be caused by the Patient himself due to improper toothbrushing, flossing, piercing, as well as due to iatrogenic factors, such as parafunction, orthodontic treatment or improper restorations (Amine et al., 2019). In cases of trauma-induced GR, an action of the etiologic factor on the healthy oral epithelium at the gingival surface can be observed, leading to abrasion of the gingival epithelium (Kanarakis et al., 2021). The inflammation starts, where the connective tissue lies between connective epithelium and the oral epithelium due to the irritational stimulation of the external traumatic force. If it continues, the irritation is increased by the secondary inflammatory process around the trauma and affects the connective tissue directly, ending in an ulcer formation. As soon as the entire thickness of the gingival connective tissue is affected, the onset of clinical attachment loss starts and ends in root surface exposure (Aslam Basha et al., 2022). Upon cessation of

trauma, the affected connective tissue re-epithelializes and the GR is clinically detectable. This pathogenetic mechanism is referred as centripetal, because the pathway of destruction is from outside to inside (Amine et al., 2019).

Bacterial-induced gingival recession is affected by an inflammatory response in the connective tissue between the oral epithelium and sulcular epithelium caused by a bacterial biofilm (Kanarakis et al., 2021). In presence of a thin phenotype, the inflammatory process in the connective tissue of the gingiva is caused by the subgingival bacterial plaque, resulting in loss of support of the gingival margin by underlying connective tissue. Thus, the gingival margin proliferates apically from the CEJ with clinical attachment loss, resulting in periodontal pocket formation. Therefore, individuals with a thin gingival biotype are more prone to the formation of GR. This pathogenic mechanism is defined as centrifugal due to the inside-out pathway (Yordanova, 2020; Aslam Basha, 2022).

2.6 Prevalence of Gingival Recession

Gingival recession plays generally a highly important role for the perception of oral health. Several epidemiological studies were investigating the global or local prevalence, emphasizing that GR is a common manifestation in several populations. Depending on the Population and analytical methods, the prevalence of GR can be observed in at least 50% of the Population. The Proportion of subject emerged lower in young individuals and increases with age (Kasaj, 2018). Yadav VS et al. investigated in their systematic review and meta-analysis the global prevalence of GR in the general population worldwide with 37,460 involved participants, concluding that more than two-thirds of the population worldwide was found to be affected by GR. The overall pooled prevalence was 78.16% with differences between the different continents worldwide. North America was observed with the highest prevalence of 91.63%, followed by South America with 88.01%, Africa with 86.07%, Europe with 78,36%, and Asia with 76.13%, while Australia had the least prevalence of 63.42% (Yadav et al., 2022). In a greek study supported by the Greek Ministry of Health and the Greek Dental Organization, 640 individuals between 18 and 45 years were investigated clinically and interviewed. The results showed an overall prevalence of GR with 62.7 %, while in 98.6% of the study Population were at least one tooth surface affected. Additionally, it could be seen that GR was highly influenced by risk factors like gingival inflammation, smoking, oral hygiene habits and the socioeconomic status (Chrysanthakopoulos et al., 2016). Hegab M. et al. were examining in their cross-sectional study 500 patients with an age range of 18 to 60 years for the presence of GR. The overall prevalence for GR on all teeth surfaces were 69.4%, while the association between

Periodontitis and gingival recession was 90.8% and the most important local factor was frenal pull with 54.8% (Hegab et al., 2020). In an US study of Romandini et al., the severity and extent of mid-buccal gingival recession in adults of the U.S. population was investigated. They emphasized that from 10.676 subjects, the patient-level prevalence of mid-buccal gingival recession was 91.6%, while risk factors like age, dental care exposure and oral hygiene habits are having a high impact on the development. It could be seen that GR affects almost the entire US population (Romandini et al., 2020).

2.7 Classification of Gingival Recession

Classification Systems

Different classification systems for GR were suggested in the literature, aiming to create specific categories covering all necessary information associated to diagnosis, prognosis and treatment plan. The main classifications were the following: Sullivan & Atkins (1968); Mlinek (1973); Liu & Solt (1980); Miller (1985); Smith (1997); Nordland & Tarnow (1998); Mahajan (2010); Cairo (2011); Kumar & Masamatti (2013); Bissada & Cortellini (2017).

Sullivan & Atkins (1968)

This is the first published classification for GR and divided it into four morphologic categories, including deep-wide, shallow-wide, deep-narrow and shallow narrow (Amine et al., 2019). Based on this system, the majority of deep-wide GR were more often difficult to treat, while the shallow-narrow was the most predictable one. A modification was proposed by Mlinek in 1973, who classified recession as: shallow-narrow defects, which are less than 3mm in both dimension and deep-wide defects, which are greater than 3mm in both dimensions (Kasaj, 2018).

Figure 3 - Classification by Sullivan & Atkins (1968): (a) Deep-narrow, (b) deep-wide, (c) shallow-narrow, (d) shallow-wide (Amine et al., 2019).

Miller (1985)

In 1985, Miller proposed a new classification system, concentrating on the extension of the recession to a MGJ, interdental soft tissue loss and proximal bone loss. Miller's classification is still the most widely used and was considered to be useful in predicting the final amount of root coverage for following coverage procedures. Four classes of marginal tissue recessions have been described (Mostafa et al., 2021):

- Class I: Marginal tissue recession, which does not extend to the MGJ. There is no periodontal loss (bone or soft tissue) in the interdental area, and complete root coverage can be achieved.
- Class II: GR extends beyond the mucogingival line, and there is no loss of interdental bone or soft tissue present. Complete root coverage can be achieved.
- Class III: Recession of the gingival marginal tissue, which extends to or beyond the MGJ. Bone or soft tissue loss in the interdental area is present or there is a malpositioning of the teeth, which prevents 100% root coverage. Partial root coverage can be expected. The amount of root coverage can be estimated using a periodontal probe pre-surgically.
- Class IV: Recession of gingival marginal tissue, which extends to or beyond the MGJ. The bone or soft tissue loss in the interdental area and/or malpositioning of teeth is so severe that root coverage cannot be predicted (Amine et al., 2019; Kasaj, 2018).

Figure 4 – Miller's classification (Chambrone et al., 2019).

Miller's classification is still the most popular compared to all classification systems, but it was found that this system has some limitations, counting the proximal bone, soft tissue and the MGJ as a landmark for measuring recession depth, which can be difficult to identify. It was suggested that it seems to be difficult to distinguish Class I and II, because it presents always with a certain amount of keratinized tissue apically to the exposure of the root. Thus, the GR can't extend to or beyond the MGJ (Kasaj, 2018; Mostafa et al., 2021).
Additionally, we have to point out, that facial or lingual involvement of marginal tissue is not specified in this classification system. The Classification of the palatal area is difficult on the maxillary arch as there is no MGJ. Another drawback emphasizes the missing reference point to difference in Class III or IV in cases of missing adjacent teeth due to the fact that both Classes are distinguished by the position of the gingival margin of the two adjacent teeth. Secondly, the amount and type of bone loss for categorizing the recession between Class III and Class IV is also not specified (Aslam Basha et al., 2022; Mahajan et al., 2019).

Smith (1997)

Smith published 1997 an index of recession for the vertical and horizontal assessment regarding to the extent of the defect. The horizontal component value was ranging from 0 to 5 depending on the exposed CEJ proportion, while the vertical component was measured in mm with a periodontal probe on a range from 0 to 9. The facial and lingual surfaces were considered as well and an asterisk was used to emphasize the involvement of the MGJ in vertical dimension defects (Kasaj, 2018; Mani et al., 2018).

Nordland & Tarnow (1998)

This classification system by Nordland & Tarnow was based on the loss of the papillary height and utilizes three important and identifiable anatomical landmarks: the interdental contact point, the facial apical extent of the CEJ, and the interproximal coronal extent of the CEJ (Mahajan et al., 2019). Three classes of papillary height loss were described:

- Normal: Interdental papilla fills embrasure space to the apical extent of the interdental contact point/area.
- Class I: The tip of the interdental papilla lies between the interdental contact point and the most coronal extent of the interproximal CEJ.

- Class II: The tip of the interdental papilla lies at or apical to the interproximal CEJ, but coronal to the apical extent of the facial CEJ.
- Class III: The tip of the papilla lies level with or apical to the facial CEJ (Aslam Basha et al., 2022; Yordanova, 2020).

Mahajan (2010)

In 2010, Mahajan was introducing a modification of the Miller classification system considering the diagnosis and treatment progress of GR defects. Based on the drawbacks mentioned before, the following modifications were suggested by Mahajan:

- The emphasis on the extent of gingival recession defects in relation to the mucogingival junction should be separated from the criteria of bone/soft tissue loss in interdental areas.
- Objective criteria should be included to distinguish between the severity grade of bone and soft tissue loss in Class III and Class IV.
- Prognosis assessment should include the profile of the gingiva due to the fact, that studies showed that gingival thickness influences the long-term prognosis of treated GR defects (Chambrone et al., 2019; Kasaj, 2018; Koppolu et al., 2023).

Four recession types based on the traditional Miller classification were identified and modified based on the parameters mentioned above:

- Class I: Gingival recession defect not extending to the muco-gingival junction.
- Class II: Gingival recession defect extending to the muco-gingival junction or beyond it.
- Class III: Gingival recession defect with bone or soft tissue loss in the interdental area up to cervical 1/3 of the root surface and/or malpositioning of the teeth.
- Class IV: Gingival recession defect with severe bone or soft tissue loss in the interdental area greater than cervical 1/3 of the root surface and/or severe malpositioning of the teeth (Aslam Basha et al., 2022; Mani et al., 2018).

According to the Prognosis, Class I and II defects with a thick gingival biotype are highly potentially for a favourable treatment outcome, while a thin profile in Class I and II has still a

good prognosis. A fair prognosis can be expected in patients with Class III and a thick gingival profile, while in Class III and IV with thin gingival profile a poor outcome can be expected (Kasaj, 2018). Thus, individuals classified by Miller System may have a different prognosis than individuals prognosed by Mahajan's classification system due to the fact that the gingival biotype and profile plays an important role as well. Additionally, the Mahajan modification helped to clarify about the confusion between GR defects without interdental hard/soft tissue loss (Mahajan's Class I and II) and GR defects with interdental hard/soft tissue loss (Mahajan's Class III and IV) (Mahajan et al., 2019).

Cairo (2011)

The classification system introduced by Cairo et al. used the interproximal and buccal clinical attachment level to classify GR and predict root coverage outcomes. Three main types of recession were described (Aslam Basha et al., 2022):

- Recession Type 1 (RT1): Gingival recession without loss of interproximal attachment. Interproximal cemento-enamel junction was clinically not detectable at both mesial and distal aspects of the tooth.
- Recession Type 2 (RT2): Gingival recession associated with loss of interproximal attachment. The amount of interproximal attachment loss (measured from the interproximal cemento-enamel junction to the depth of the interproximal pocket) was less than or equal to the buccal attachment loss (measured from the buccal cemento-enamel junction to the depth of the buccal pocket).
- Recession Type 3 (RT3): Gingival recession associated with loss of interproximal attachment. The amount of interproximal attachment loss (measured from the interproximal cemento-enamel junction to the depth of the pocket) was higher than the buccal attachment loss (measured from the buccal cemento-enamel junction to depth of buccal pocket) (Mahajan et al., 2019; Amine et al., 2019).

In case mesial and distal sites present with different extension of clinical attachment loss, the point with the highest clinical attachment loss should be contemplated for the identification of the recession type (Amine et al., 2019).

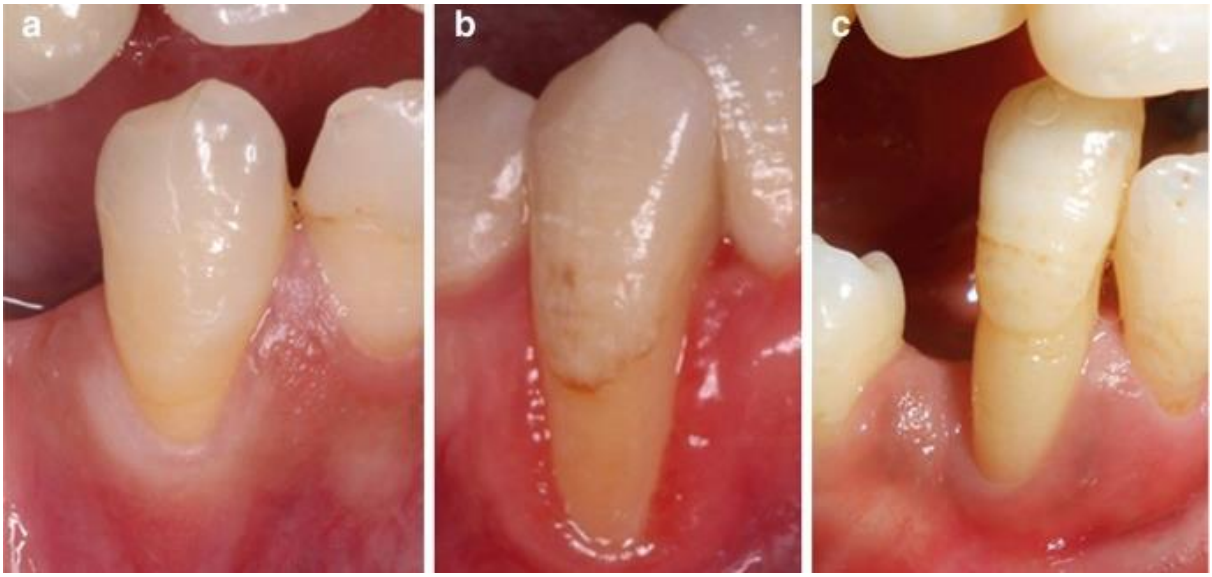

Figure 5 – Cairo classification of gingival recession. a) GRT1, b) GRT2, and c) GRT3 (Amine et al., 2019).

Kumar and Masamatti (2013)

This classification system is based on the position of the interdental papilla and the extent of buccal/lingual/palatal recessions. Basically, they combined criteria of Miller's system with some features of Nordland & Tarnow's classification system. The system is classified in three classes, which are additionally subclassified into categories (Mahajan et al., 2019). Recessions without loss of interdental bone or soft tissue were classified as Class I defects, while Class II and III defects are associated with interdental bone or soft tissue loss with or without tissue recession. Additionally, all classes were subdivided into A, B and sometimes even C sub-classifications. Class I was subdivided regarding to the gingival margin position in relation to the CEJ (Class I-A + Class I-B), while Class II was subdivided into three subclasses, defining clinical situations with or without marginal tissue recession (Class II-A, Class II-B, Class II-C). Class III was also subdivided into two subclasses, regarding to the extent of the marginal tissue recession (Class III-A + Class III-B) (Kasaj, 2018). Moreover, Kumar and Masamatto proposed an additional classification system for palatal recessions, which is generally based on the loss or no loss of the interdental bone/soft tissue, as well as the location of the tip of the interdental papilla referred to the CEJ (Mani et al., 2018).

Cortellini & Bissada (2017) – New classification of phenotype and gingival recession

During the 2017 World Workshop, a new classification system about phenotypes and GR have been introduced as well as approved by the American Academy of Periodontology and the European Federation of Periodontology for its official use. Before, most classifications were unsuccessful to provide an accepted clinical presentation of gingival recessions. Basically, just a limited focus on either soft tissue components or the root surface characteristics were emphasized. Thus, a new classification system was proposed, integrating recession-related factors, phenotype-related factors, as well as tooth-related factors (Pini Prato et al., 2021). This new classification is based on the Cairo classification system, but was modified with three different components:

- The recession characteristics, recorded as midfacial recession depth and interproximal recession type.
- Phenotype characteristics recorded as gingival thickness and keratinized tissue width.
- Root surface characteristics, recorded as detectability of the cemento-enamel junction or presence of root steps (Cortellini et al., 2018).

As a result, these prognostic factors were used to create a matrix table guiding the clinician regarding to treatment planning. The GR is still divided into: No recession, recession type 1, recession type 2 and recession type 3. Additionally, the table allows to emphasize the recession depth, interdental attachment height, gingival thickness, keratinized tissue width, CEJ detectability, as well as the occurrence of root surface concavities. These modification categories have to be examined in the following way (Imber et al., 2021):

- REC-Depth: Measuring the depth of the gingival recession from the cemento-enamel junction to the depth of the pocket.
- Gingival Thickness: Can be divided into Thick (> 1mm) and Thin (<1mm).
- Keratinized tissue width: Can be emphasized into more or less than 2mm.
- Cemento-enamel junction (A/B): Divided into A as detectable CEJ or B as undetectable CEJ.
- Step - root surface concavity (+/-): Divided into + with a cervical step of > 0.5 mm or – with an absence of a cervical step (Imber et al., 2021).

The maintenance of periodontal health under ideal oral conditions is most often possible, even if just a small amount of keratinized tissue is present. However, there is always a risk of development or progression of GR. This new classification system guides the clinician and allows an adequate clinical examination as well as treatment evaluation regarding to esthetic concerns, dentin hypersensitivity, cervical lesions, thin gingival biotypes and mucogingival deformations (Pini Prato et al., 2021).

2017 Classification of Phenotype and Gingival Recession					
	Gingival site			Tooth site	
	REC Depth	GT	KTW	CEJ (A/B)	Step (+/-)
No Recession					
RT1					
RT2					
RT3					

Figure 6 – The 2017 classification of phenotype and gingival recession (Pini Prato et al., 2021).

2.8 Clinical Examination and Diagnosis

Gingival recessions are highly prevalent and as already mentioned present and extent in the population while even increasing with age. If the clinician is noticing regression of the gingival margin at the Patient, a structured diagnosis and information collection has to be performed (Kasaj, 2018). Due to the fact that GR has different etiologic factors, it is important that the clinician is able to collect anamnestic, clinical and radiologic signs and symptoms, as well as checking the laboratory information to evaluate the differential diagnosis for possible underlying reasons and treatment options. The clinical examination and tissue assessment is fundamental “to qualify and monitor changes during periodontal, restorative, prosthetic, orthodontic, or implant therapy, as well as longlife maintenance” (Kasaj, 2018, p.33).

2.8.1 Chief Complaints

The anamnesis of clinical examination and diagnosis always starts with questions about the main complaints of the Patient. This step in mainly based on the reasons of the dental visit, as well as patient's expectations, demands and fears. The clinician should mainly ask first about the chief complains of the Patient, as well as pain or if the tooth is or was sensitive (Bruckmann et al., 2018). Many patients with receding gums often fears future tooth loss. Additionally, we can ask if the recession was noticed by the Patients itself or if he was made aware of it. During this step, the onset of recession can be mentioned as well as to evaluate the history of the complain and the time frame of progression. Lastly, the clinician should ask about the relevance and importance of aesthetics to obtain complaints like toothy smile, tooth discolouration or black triangles (Kasaj, 2018). Especially for Patients with disabilities or older Patients with mental restrictions, a visual analogue scale might be useful (Khanna, 2020).

2.8.2 Medical and Dental History

The background of the Patients is an important and crucial factor for the diagnosis of GR. Several systemic diseases and conditions are related to oral signs and symptoms, and many drugs are capable to influence gingival diseases and Periodontitis. One of the main risk factors for periodontal inflammation, especially in bad controlled patient cases, is Diabetes mellitus (Mehriz et al., 2022). Other factors associated with gingival diseases are the influence of age, hormonal changes (e.g. puberty, pregnancy, menopause) and stress (Kanarakis et al., 2021). Particular importance for the evaluation of GR are tobacco use, dietary habits and drugs. The clinician should obtain the duration and daily consumption of tobacco, because it is very important for the diagnostic process, the healing response of the patient, as well as the risk of recession itself. Regarding to the dietary habits, the increased risk for root caries has to be evaluated, as well as the erosive potential to check for hypersensitivity and abrasion. In case of daily use of drugs (e.g. cocaine, meth, smokeless tobacco etc.) we have to keep in mind that they might have a direct influence on oral tissues itself, present as risk factors for caries by reducing the saliva flow or induce careless behaviour or habits. Regular intake of alcohol might have a negative influence on the periodontal tissues itself and/or the adherence to treatment (Kasaj, 2018). For the evaluation of the dental history, an extensive examination is necessary as past dental treatments might be the reason for acute problems. Old radiographs and/or intraoral pictures, as well as casts can be used. Basically, there are several dental history factors influencing the outcome of GR. The clinician should ask for past orthodontic treatment or other

oral appliances (e.g. removable partial dentures, occlusal splints, removable orthodontics), which can have an impact on periodontal tissues or might be identified as the reason for present recessions (Bruckmann et al., 2018). However, the history of periodontal health plays an important role as well. Diseases like periodontitis, necrotizing ulcerative gingivitis/periodontits, or mechanical/chemical traumata are often identified as explanations for soft and/or hard tissue attachment. Linked to this point, the clinician should check and ask for oral habits, like nail biting or pen chewing, as well as mental diseases associated with frequent daily use of oral hygiene aids. Lastly, the dentist has to ask and check for previous treatments. Periodontal treatment or surgical procedures might be the cause for soft tissue recession or aesthetic fillings/splinting of anterior teeth to mask tooth drifting or pathological migration have been performed in the past (Kisely, 2023; Bruckmann et al., 2018).

2.8.3 Clinical Examination

The clinical examination is an important step for the evaluation of causes, risk factors, the treatment options as well as to rule out other pathologies. It is basically divided into the examination of the esthetic component, the mucosa, gingiva, periodontal component, the teeth and present restorations or appliances (Kanarakis et al., 2021). For an adequate examination and evaluation, the areas should be dried sufficiently with suction and compressed air to allow correct inspection and palpation. Especially if we have progressive recessions together with pain, inflammatory processes have to be excluded (Bruckmann et al., 2018). Thus, it's recommended to screen all patients for periodontal disease. Factors for soft tissue and/or bone loss, as well as predisposing and precipitating factors has to be assessed by the clinician. Furthermore, the determination of the periodontal biotype, based on gingival thickness, tooth dimension, amount of keratinized tissue and the bone morphology plays an important role for the patient management (Kasaj, 2018). Additionally, the soft tissues of muscles, cheeks, tongue, the floor of the mouth, throat, salivary glands and the tonsils have to be examined by the clinician as well. In case of acute painless lesions, further investigations have to be performed to check the possibility for malignancy (Parakh et al., 2020).

2.8.3.1 Aesthetic Assessment

During the examination of the aesthetic component, harmony and symmetry of the facial appearance should be observed. The clinician should evaluate the red/white esthetics and focus on the facial symmetry, angle class relation (molar, canine, incisor), occlusion, dysgnathia, as

well as the lip position at rest, in function and during smile (Bruckmann et al., 2018). Furthermore, the extent of soft tissue during smiling as well as the arrangement of soft tissues in relation to teeth and lips are important factors for the aesthetic evaluation. In case the patient has for example a high lip line, more attention might be given to uneven gingival contours (Khanna, 2020).

2.8.3.2 Mucosa

The examination of mucosa includes the inspection of the lubrification, pigmentation, lesions and/or growths. Sometimes aphteous lesions can be observed, which are often associated with medications (e.g. NSAIDs), stress or the Behcet syndrome. Additionally, the mucosa has to be examined for colour changes. Pigmentation is correlated to ethnicity, tobacco, medications, diseases (e.g. Haematomas, varices, petechiae), dietary intake or with syndromes, while pallor colour is often present in anaemia (Bruckmann et al., 2018; McNamara et al., 2019). If the mucosa presents with cobblestone or diffuse swelling, the Patient should be asked about intestinal problems. Generally, it is recommended to focus on the depth of the vestibulum to record if there is adequate space for oral hygiene procedures, the frenula attachments to check possible pull parafunctions, as well as Piercings, which positions often lead to traumata of the tissues (Kasaj, 2018).

2.8.3.3 Gingiva

During the examination of the gingiva, it is important to check for gingivitis and periodontitis while assessing for colour, contour, texture and swellings. Abnormal intraoral pigmentation consistency is often seen in mucogingival disorders, amalgam tattoos or in cases of malignancy (Kasaj, 2018). Gingival enlargement can be drug-associated and presence of desquamative gingivitis might be caused by diseases like lichen planus, lichenoid reactions, pemphigus or systemic lupus erythematosus. Basically, the dentist should assess the periodontal biotype, which is not just based on a visual inspection alone. It is important to evaluate the gingival thickness by describing the observations of the periodontal probe shining through the tissue. Differences between the upper and lower jaw might be seen (Bruckmann et al., 2018). Summarized, the examination is focusing on the assessment of the gingival biotype, width of keratinized mucosa, width of attached tissue, width of keratinized tissue at neighbouring teeth, soft tissue margin level, interdental papilla, gingival thickness and checking for self-induced oral hygiene lesions (Kasaj, 2018). During the examination of the gingival biotype, the dentist

has to categorise it according to the visibility of the periodontal probe after insertion into the facial suclus. The gingival biotype can be differentiated into three main components:

- Thin scalloped: Associated with triangular shaped crown, cervical convexity, interproximal contacts close to incisal edge, narrow zone of keratinized tissue, thin delicate gingiva, and thin alveolar bone.
- Thick scalloped: Associated with thick fibrotic gingiva, thin slender teeth, narrow zone of keratinized tissue and a high gingival scallop.
- Thick flat: Associated with more square-shaped tooth crown, pronounced cervical convexity, large apical interproximal contact, broad zone of keratinized tissue, thick fibrotic gingiva and thick alveolar bone (Shah et al., 2021).

The width of the keratinized attached and free tissue can be examined by doing the rolling test, where a periodontal probe is used to push the adjacent mucosa softly coronally for identifying the blanching attached gingiva width, or the staining test with Lugol's iodine solution based on the difference in the glycogen content. Histochemical differences of the glycogen content in the alveolar mucosa compared to keratinized gingiva result in a brownish colouring iodo-positive reaction (Jennes et al., 2021).

Figure 7 – (a) Rolling test and (b) Staining test with Lugol's iodine (Kasaj, 2018).

During the examination of the soft tissue margin level, it should be focused on alterations in their morphology or any irregularities. A line, which connects most apical points of the buccal area at the midfacial level of the soft tissue margins of neighbouring teeth, can be used to compare the margin levels with each other (Kasaj, 2018).

Figure 8 – (a) Irregular gingival scallop due to developmental enamel indentation at 11, loss of central papilla height; (b) incosistent height of gingival margin (Kasaj, 2018).

In case of interdental papilla examination, we have check for its presence or absence, which is often caused by loss due to periodontal disease, a tooth position near an edentulous area or by missing contact points. The height of the papilla can be measured by the distance between papilla tip to a line connecting the midfacial level of the soft tissue margin of two neighbouring teeth (Bruckmann et al., 2018). The height itself can be classified with the Nordland & Tarnow classification system (Aslam Basha et al., 2022). For the measurement of the gingival thickness, transgingival probing can be performed by pushing a needle or periodontal probe vertically to the mucosal surface until bone resistance after local anesthesia. Alternatively, an ultrasonic pulse-echo can be used (Bruckmann et al., 2018).

2.8.3.4 Periodontal Assessment

The Periodontal assessment is done by running with the periodontal probe around the gingival margin area at the dentoalveolar junction by using a periodontal probe with millimeter markings. Note that in case of healthy conditions, bleeding should be absent and in patients which are smoking, bleeding might be diminished. In cases of inflammation, bleeding on probing or exudation should be assessed within 30 seconds after probing (Ko et al., 2021). Important for the assessment of the periodontal condition, as well as for GR, is the identification of the CEJ. In healthy situations this margin shouldn't be visible and covered by the free gingival margin. The clinician should tactile around the tooth with a 45-degree angulation while the side of the probe tip should always be kept in contact with the tooth surface. In molars the location, extent and presence of furcation needs to be assessed as well. Beware of diagnostic pitfalls in cases of cervical abrasions, restorations, incompletely erupted teeth or rotated teeth. Especially if the CEJ is not visible, comparison with adjacent tooth margin helps for a correct

assessment of the CEJ (Ko et al., 2021). If an exposure of the tooth root surface is detectable, then it results from apical migration of non-inflamed gingival tissues with normal bone height, due to periodontal bone loss or a mix of both. In this situation, it's important to assess the location of the recession and check for interproximal recessions as well to evaluate if circumferential attachment loss might be present (Bruckmann et al., 2018). The recession depth is measured by using a periodontal probe to measure the distance between the free gingival margin and the CEJ. Additionally, it is necessary to focus on the MGJ as well to check if the apical gingival border is reaching it already. The measurement of the recession depth should be done at the most coronal part (Kuralt et al., 2021). Afterwards, the measurement of the periodontal pocket depth should be performed. It is done through a measurement of the distance between the free gingival margin and the bottom of the sulcus using a periodontal probe with an angulation of zero to ten degrees. It is important to guide the probe along the root surface until first resistance of the connective tissue is detectable. The deepest measurement of six sites around the tooth should be taken for the periodontal assessment, while it is counted as positive if it's apical to the CEJ and negative if the gingiva extends above the CEJ. The addition of the periodontal probing depth and the recession measurements results in the clinical attachment level (Bruckmann et al., 2018).

Figure 9 – (a) shows at 11 + 12 reduced periodontium with circumferential recession and loss of interdental papilla. Incomplete eruption of 13. Papilla height class III between 12 and 11. (b) Assessment of width, and (c) height of recession by periodontal probe or (d) caliper (Bruckmann et al., 2018).

2.8.3.5 Teeth

During this examination step, the patient's oral hygiene has to be checked for plaque and calculus, while the anatomy is examined regarding to features like furcations, concavities, resorptions and grooves. It is necessary to determine the tooth position in the dental arch, the CEJ and the form of the teeth, which correlates with the extent of the keratinized tissue, its buccal/lingual gingival thickness and the interdental papilla height (Kasaj, 2018). The tooth form can be distinguished into three different types:

- Square: Associated with thick flat tissue, large interproximal contact located more apically, a broad zone of keratinized tissue, thick, fibrotic gingiva, and a comparatively thick alveolar bone.
- Square-tapered: Higher interproximal papilla, less keratinized tissue, and thinner bucco-lingual gingival tissue than patients with square teeth.
- Triangular: Association with higher interproximal papilla, less keratinized tissue and thinner bucco-lingual gingival tissue, and a relatively thin alveolar bone (Shah et al., 2021).

Additionally, the clinician has to check the teeth for malposition in the dental arch, especially for rotation, tilting, displacement and incomplete eruption. This assessment step has to be done in all three planes. In the sagittal plane, the variability of the gingival thickness and underlying bone has to be checked, while in the vertical plane the clinician should check if the cervical portion is apical or coronal of the free gingival margin. Horizontally, the teeth need to be checked for crowding and rotation (Kumar et al., 2019).

2.8.4 Radiographic Examination

Single oral recessions might not need radiographic assessment. However, in case of a surgical treatment, additional information is required. If recessions are just locally, periapical radiographs can be used to evaluate the root morphology, crown-root ratio, as well as the periodontal ligament space. The clinician should check for widening of the periodontal ligament space and signs of occlusal trauma or ankylosis. Additionally, the furcation involvement and root proximity can be assessed as well to use the gained information for the treatment plan. If a periodontal assessment has to be performed as well, a panoramic radiograph can be done to gain a general overview of the bone loss, furcation involvements and other additional necessary

information (Kanarakis et al., 2021; Ko et al., 2021). In case of generalized recession and the necessity to analyze the buccal and lingual surfaces, a ConeBeam Computed Tomography (CBCT) can be performed to visualize the morphology of the defect, as well as evaluate dehiscencies, fenestrations, interradicular bone and furcation defects (Bruckmann et al., 2018).

2.9 Prognosis of Gingival Recession

"A prognosis is defined as foreseeing the possible time, course, and result of an ailment according to a common understanding of the ailment's pathogenesis and the occurrence of dangers associated with the ailment" (Stevens et al., 2021, p. 157). The prognosis of GR depends mainly on the ability to achieve complete root coverage of the exposed root surface. The most important factors, influencing the prognosis, is the height of the interproximal supporting periodontal tissues, based on the attachment of the connective tissue and the alveolar bone height and is established by papillary probing and periapical radiography or ConeBeam Computed Tomography (Kanarakis et al., 2021). CBCT is one of the methods which can be used to analyze the lingual/buccal and palatal surfaces, as well as provides successful visualisation of the periodontal defect morphology, which is important to analyze dehiscences and fenestration (Touyz, 2009). Complete root coverage and reestablishment of the gingival margin coronally to the CEJ is just possible if the interproximal periodontal tissue is presenting healthy. The physiologic probing depth is between three and four millimetres, depending on different papilla design and the physiologic periapical radiography shouldn't show bone loss in the interproximal area with a distance of approximately one millimeter between the alveolar crest and the CEJ. Due to the fact that the interproximal papilla is the reception area of the surgical papilla, decresement of the interproximal papilla height can reduce the progression and vascularization of the flap and therefore the treatment outcome (Kanarakis et al., 2021). To assess the Prognosis of Recession regarding to the Treatment modalities and options, one system has established and is described below:

- Good prognosis: Sufficient periodontal aid and management of etiological elements confirm that the tooth will be simple to preserve by the clinician and the patient.
- Fair prognosis: An estimated loss of 25% of the attachment or grade I furcation invasion (depth and placement enable the correct preservation with a sound acceptance of the patient).
- Poor prognosis: An attachment loss of 50%, grade II furcation invasion (depth and placement make preservation tough but feasible).

- Questionable prognosis: bad root formation, attachment loss of 50%, bad crown-to-root ratio, grade II furcation invasion (depth and placement make it hard to approach), or grade III furcation invasion; closeness to the root; mobility grade two or three.
- Hopeless prognosis: Insufficient attachment to look after one's daily functions, well-being, and contentment (Stevens et al., 2021).

Generally, the information about the interdental supporting tissue and therefore the prognosis is based on the classification of each gingival recession case. But next to the defect classification other factors influencing the prognosis as well. There are additional prognostic factors associated with the defect itself, the patient and the operator (Stein, 2019). Factors related to the defect are the interdental papilla dimension and the recession classification, as well as the recession size with depth and mesio-distal width. The wider the GR, the more challenging is the treatment. The Prognosis of root coverage is better when the baseline recession depth is less than 4 mm. Additionally, the presence of adequate keratinized gingival tissue is influencing the prognosis towards positivity significantly. To achieve complete root coverage, it is necessary to have more than 1.2 mm thickness of gingival tissue and the baseline. The height of the keratinized tissue plays also an important role, since science found out that 2mm height located apically to the GR provides better treatment outcome than 1mm height. It may be explained by the fact that the presence of keratinized tissue in the flap improves the marginal stability and stabilizes during suturing (Kanarakis et al., 2021). Non-carious lesions, root caries as well as the frenulum attachment near the defect site have also a negative influence on root coverage prognosis (Kasaj, 2018). Especially the presence of non-carious cervical lesions may make it difficult to detect the CEJ adequately, which acts as a reference point in root coverage decision-making process. Lastly, the negative influence of tooth malposition has to be mentioned due to the case that it changes the interdental papilla size in absence of attachment loss. In case of tooth rotation, unilateral papilla height loss is present and the CEJ become closer to the papilla tip, while in tooth extrusion bilateral papilla height loss is present and the CEJ approaches both papilla tips. In both situations, complete root coverage is not reachable (Amine et al., 2019). If extrusion of the tooth can be observed, the status of a CEJ which is closer to the tip of the papillae is present, which leads consequently to the situation that there is a bilateral reduction in interdental papillae height. Therefore, complete root coverage cannot be achieved (Kanarakis et al., 2021). Patient related factors involve plaque control, toothbrushing and tobacco smoking. Traumatic toothbrushing techniques and/or the absence of patient's oral hygiene are related to relapse of GR. The improvement of the toothbrushing technique stimulates the formation of

keratinized gingival tissue, while plaque control improves the healing outcome. Thus, in terms of stability following surgical treatment, both of them are advantageous for maintaining the gingival margin (Stein, 2019). Moreover, unfavourable for the stability of the gingival margin is smoking, which negatively influences the outcomes of root coverage and might result in relapse. Kanmaz et al. reported in their review that significantly better root coverage reported in non-smokers compared to smokers. Smokers tend to respond less favourably to surgical interventions performed for root coverage (Kanmaz et al., 2022). Operator-related factors include acquired expertise and skills, which might have an impact on the root coverage treatment, since the physician is accountable for adhering to specific guidelines to ensure the best predictability of root coverage (Kanarakis et al., 2021).

3 Treatment of Gingival Recession

3.1 Conservative and non-surgical Treatment

Gingival recession is associated with several unfavourable conditions, where the most obvious is of aesthetic nature, but dental hypersensitivity, a weakened resistance against pathogenic stimuli and impacted plaque control are additional factors resulting in patient's discomfort. Although gingival augmentation is a well-studied and efficient method to prevent further progression and reduce pain, patients are not always comfortable with an invasive surgical treatment and other steps can be performed and evaluated to guide the Patient (Imber et al., 2021). The main aim in this case should be to address the patient's concerns of sensitivity and/or esthetics. Non-surgical treatment options focus mainly on monitoring and prevention of further progression, the use of desensitizing agents, varnished and dentine bonding agents and composite restorations, but include more invasive treatment options like root canal treatment and Laser therapy as well (Aslam Basha et al., 2022).

3.1.1 Eliminating the Etiology

The main reason for tooth hypersensitivity involves the exposure of dentinal tubules, which are in a healthy state covered and protected by cementum and enamel. However, if the gingival margin level decreases below the CEJ, the thin cementum is exposed. This thin protective layer can easily be abraded leading to the exposure of dentinal tubules. Thus, for the further prevention of progression, the clinician should be aware about the precipitating and

predisposing risk factors, as well as try to guide the Patient to decrease precipitating risk factors (Kasaj, 2018).

3.1.2 Monitoring and prevention of further recession

In case of a minimal recession defect, there is no or just minimal association with dentin hypersensitivity or root caries and if the defect is not located in an esthetic zone, it might be acceptable for the patient to do nothing and just observe the situation, as well as check it regularly. In this case, the identification and management of the recession causes like tooth brushing trauma or chronic periodontal disease, as well as deleting negative oral hygiene habits is necessary. Maintaining good oral hygiene and the prevention of plaque induced inflammation, which might result in continuous recession especially in thin gingival biotypes, is crucial for a keeping the present recession levels (Imber et al., 2021). The prevention of unnecessary gingival abrasion can be achieved by recommending soft-bristled toothbrushes together with an explanation why they should be used over hard-bristled brushes. Providing a short explanation may enhance patient compliance. Together with toothbrush recommendations, the clinician should mention the influence of high relative dentin abrasitivity (RDA) toothpastes to gingival recession as well (Kasaj, 2018). Toothpaste abrasiveness is measured using RDA and there are differences in their abrasiveness levels according to their recommended use. Whitening toothpaste mostly have a higher RDA intended to remove stain, while toothpastes with high RDA are suspected to be associated with dentin exposure. Therefore, studies recommend for patients with dentin exposure, hypersensitivity and gingival recession itself the use of toothpastes with low RDA.

The American Dental Association imposes the highest RDA of less than 250 (Clark et al., 2019). Additionally, special sensitivity toothpastes that affect nerve polarization or fluid movement within the dentinal tubules can be recommended or prescribed. Various types of toothpastes can be used to obtain relief from hypersensitivity prior starting with more invasive treatments. The various active ingredients in sensitivity toothpastes are given in the following table. In cases where sensitivity toothpastes are acting insufficient, dentin desensitizers can be used (Clark et al., 2019).

Active ingredients	Mechanism of action	Commercially available sensitivity toothpaste
Potassium nitrate	Depolarization of the nerves at the dentin–pulp border that may be associated with tooth hypersensitivity	Proenamel marketed by GlaxoSmithKline Maximum strength sensitive toothpaste marketed by Toms of Maine Colgate enamel health marketed by Colgate Palmolive Colgate Prevident Sensitive marketed by Colgate Palmolive
Strontium	Occlusion of dentinal tubules	Sensodyne original marketed by GlaxoSmithKline
Arginine and calcium carbonate	Occlusion of the dentinal tubules and remineralization of enamel	Colgate sensitive pro-relief by Colgate Palmolive
Calcium sodium phosphosilicate	Occlusion of the dentinal tubules and remineralization of enamel	Sensodyne complete protection marketed by GlaxoSmithKline
High-fluoride concentration (commonly stannous fluoride or sodium fluoride)	Occlusion of the dentinal tubules	Crest sensi-repair and prevent Colgate prevident booster plus marketed by Colgate Palmolive
Hydrated silica (silicon dioxide hydrate)	Occlusion of dentinal tubules	Colgate total marketed by Colgate Palmolive

Figure 10 – Active ingredients in sensitivity toothpastes (Clark et al., 2019).

Plaque accumulation is strongly associated with GR, a consequence of periodontal disease. Thus, it is important to teach patients proper home care techniques to manage their plaque accumulation and improve their oral hygiene. These techniques should include proper brushing with soft-bristled toothbrush and interdental cleaning using interdental brushes. Cleaning techniques should be demonstrated in the patients's mouth, and the patient's competence should be regularly reassessed at recall appointments (Kasaj, 2018). Periodontal disease can cause the exposure of dentinal tubules as well, rendering them vulnerable to fluid movement that results in dentinal hypersensitivity. The periodontal treatment procedures can also lead to initial tooth hypersensitivity, which should be explained to the patient before undergoing this treatment. In order to prevent this sensitivity from occurring, sensitivity toothpastes can be used before starting with the periodontal treatment (Kasaj, 2018). If the patient needs to undergo orthodontic treatment, the clinician should consider various risk factors for the development of gingival recession such as gingival biotype, oral hygiene, and the presence of periodontal disease due to the fact that orthodontic treatment increases the potential for GR and is associated with tooth hypersensitivity. Basically, the clinician should inform the Patient about this and discuss alternative options as well with the Patient. Lastly, the Patient should be asked about past or current use of facial piercings, which are connected to exposure of dental tubules due to soft tissue destruction and gingival abrasion. If the Patient presents with facial or oral piercings, the patient should be informed about the potential consequences (Clark et al., 2019).

3.1.3 Desensitising agents, varnishes and dentine bonding agents

If patient's main complaint is sensitivity, the esthetic factor is not important and toothpastes and other preventive factors were not helping, the clinician can focus mainly on the treatment of this hypersensitivity. Patients suffering from hypersensitivity might avoid brushing in these

areas, which can lead to plaque accumulation and later on plaque induced recession, which should be avoided. The treatment in based on either blocking the dentinal tubules or preventing nerve stimulation, which can be mainly performed by using desensitising agents, varnished or dentine bonding agents (Liu et al., 2020). Dentin desensitizers have to be applied locally to the affected tooth to relieve the hypersensitivity and can be seen as a non-invasive treatment option. A common desensitizer in the dental office is fluoride varnish, which contains higher fluoride concentrations than normal toothpastes. The fluoride varnish is applied by painting it onto the affected tooth surfaces and allowing it to be set by saliva, resulting in a prolonged flouride uptake and remineralization of the affected tooth surfaces. Therefore, a significant reduction of the symptoms can be provided (Clark et al., 2019). Another desensitising agent is Gluma by Heraeus Kulzer, which contains a combination of hydroxyethyl methacrylate and glutaraldehyde and treats effectively dentinal hypersensitivity by occluding the dentinal tubules between 50 and 200 μm into the tubules. This material can be also combined with wetting agents or self-etching adhesives to maximize the occluding process. In cases, where the treatment was not completely effective after one time, it can be repeated (Kasaj, 2018). Another in-office desensitizer is oxalate, which occludes the dentinal tubules by the formation of a complex with calcium ions of the saliva, resulting in the inhibition of fluid movement within the tubules. Moreover, oxalate owns the ability to be more durable than other desensitising agents due to the fact that it is more resistant to an acidic environment. Bahal et al. investigated in their study the efficacy of oxalate for the management of dentine hypersensitivity by comparing it with arginine desensitising calcium carbonate toothpaste in a time period up to 4 weeks. They emphasized in their results, that both groups showed significant reductions of dentine hypersensitivity after two and four weeks, but the application of 3.14% potassium oxalate was more effective in pain management than just brushing with arginine toothpaste (Bahal et al., 2019). In cases where sensitivity toothpastes and desensitizers fail to provide pain relief, bonding agents should be used to treat the hypersensitivity. Generally bonding agents are used for the adhesion of composite to the tooth surface, but in the treatment of dentinal hypersensitivity the mechanism of action can be used to create a protective coating over the dentinal tubules, resulting in pain relief up to six months. Self-etch bonding agents contain acidic components for conditioning the dentin, as well as monomers to create a hybrid layer, serving as protective layer (Kasaj, 2018). This hybrid layer effectually reduces hypersensitivity up to four weeks. The two-step bonding system is acting differently by applying the acidic component separately from the monomer, resulting in a higher durability and effectivity. However, even if the bonding agents are providing a useful treatment for dentinal

hypersensitivity, the increased costs for this treatment method might serve as motivation turning to sensitivity toothpastes instead of continuing with more expensive treatment options (Clark et al., 2019).

3.1.4 Cervical Restorations and Root Canal Treatment

Cervical restorations occlude dentinal tubules with a restorative material to provide pain relief from dentinal hypersensitivity. Small, localised recession defects which are appearing with sensitivity, wear or caries on the root surface can be treated and redesigned with colour-matching restorative materials over the exposed surface (Kasaj, 2018). This will result in a prolonged height of the clinical tooth crown. Because restorative materials occlude and cover the dentinal tubules immediately, direct and fast pain relief can be achieved compared to toothpastes, which has to be used for some weeks until pain relief can be obtained. The restorations are mainly performed with glass-ionomer cement or composite. Composite has higher esthetic outcomes, but is a technically sensitive material, which can be difficult in Class V restorations due to the liquidation of the sulcus. In posterior regions, glass ionomer might be an alternative and better option due to its ability to bond to enamel and dentin and release fluoride simultaneously. Moreover, careful placement of the restorative material should be performed to avoid plaque accumulation by plaque retentive margins (Kasaj, 2018). In cases, where all treatment options couldn't relief the dentinal hypersensitivity and there are no more treatment options, the clinician can discuss the root canal treatment with the patient. Root canal treatment involve removing the vital element of the tooth and consequently eliminating all sensation. Endodontic treatment is mainly performed in cases of pulpitis or pulp necrosis, but would also work for pain management in intense dentinal hypersensitivity. However, dentinal hypersensitivity is not a main indication for this invasive procedure and the root canal treatment should be contemplated as last treatment option (Clark et al., 2019).

3.1.5 Laser Therapy

A different approach to treat dental hypersensitivity is based on laser therapy, which becomes increasingly popular nowadays. The Er:YAG, CO2, Diode, ER, CR:YSGG, Nd:YAG and Nd:YAP lasers have the ability to occlude dentinal tubules and reduce tooth hypersensitivity, while the He-Ne and GA1As lasers act by affecting the nerve depolarization to avoid exceeding the neurobiological threshold of the membrane's potential and thus decrease the hypersensitivity (Pion et al., 2023). Pion et al. investigated in their systemic review and meta-

analysis 34 studies regarding to laser treatment in dentinal hypersensitivity and emphasized the positive treatment outcomes in cases of laser therapy for patients with dentinal hypersensitivity. They concluded that regardless of the type of laser used in the treatment, the laser therapy is an effective option for the long-term control of pain symptoms (Pion et al., 2023). Forouzande et al. compared in their study the effect of sodium flouride varnish, Gluma and Er,Cr:YSGG laser for the treatment of dentinal hypersensitivity. They compared the outcome of laser therapy alone or combined with gluma, while groups treated with sodium fluoride varnish and gluma alone were selected as control groups. They came to the conclusion that the laser, alone or in combination with gluma, in one week, one month and six months follow-ups, had significantly diminished the hypersensitivity up to six months. The Er,Cr:YSGG laser alone or in combination with gluma was more effective than sodium fluoride varnish (Forouzande et al., 2022).

3.2 Surgical Treatment of Gingival Recession

If the non-surgical recession treatment is not bringing the expected results and the patient is comfortable with performing surgical treatments to treat the GR, different modalities are available. The main objective of periodontal plastic surgery is the establishment of homogenous pink aesthetics by the regeneration of gingival margins. Prior to any root coverage surgery, root planning and conditioning should be performed (Mostafa et al., 2022). The aims of mechanical root instrumentation is to remove root caries, reducing root convexity, reducing cementum toxins and smoothening the root surface. It was suggested that mechanical instrumentation might result to a closer adaptation of the graft to the root surface, therefore reducing root shrinkage and graft exposure (Amine et al., 2019). Root conditioning is usually performed by using chemical agents like citric or phosphoric acids, ethylenediaminetetraacetic acid and tetracycline hydrochloride. The root surfaces have to be in contact with the solution for two to five minutes, leading to detoxification, decontamination and demineralization of the root surface. Thus, the smear layer is removed and the collagenous matrix covering dentin and cementum is exposed (Mostafa et al., 2022). The most common surgical root coverage modalities are free gingival graft (FGG), subepithelial connective tissue graft (SCTG), lateral positioned flap (LPF), double papilla flap (DPF), semilunar flap, coronally advanced flap (CAF), guided tissue regeneration (GTR), vestibular incision subperiosteal tunnel access (VISTA) technique and the pinhole surgical technique (PST). In case, the GR results from pulling by a frenum, a frenectomy might have to be performed as well (Stevens et al., 2021; Bamel et al., 2021). The choice of the treatment depends on the size and number of the defects,

as well as the quantity and quality of keratinized tissue, the depth of the vestibule, the width and height of the interdental papillae and the patient's functional and aesthetic demands (Amine et al., 2019).

3.2.1 Frenectomy

The frenum is a mucous membrane fold attaching the lip and the cheek to the alveolar mucosa, the gingiva and the underlying Periosteum. Abnormal frenum attachment may lead to difficulties while speaking, mastication and esthetic issues. Additionally, the abnormal attachment location and pull due to muscular activity can lead to an increased tension on the gingival margin and thus GR over time. The diagnosis is generally detected by visual clinical examination due to the application of tension to see the movement of the papillary tip. Clinically papillary and papilla penetrating frenum are considered as pathological (Carnino et al., 2023). The management of such abnormal frenum can be treated by Frenotomy or Frenectomy procedures. During frenotomy, an incision and relocation of the frenal attachment is performed, while frenectomy includes the complete removal of the frenum with its attachment to the underlying bone (Bamel et al., 2021). The most commonly used methods for frenectomy are based on using the scalpel, laser and electrocautery device. The conventional technique involves excision by using a scalpel. However, each of the methods has its advantages and disadvantages regarding to aesthetic requirements, cutting characteristics, hemostasis, healing time, undesirable effects and the costs of the treatment. While scalpel and electrocautery were more prominent in the past, lasers rapidly replacing them, due to their benefits regarding to increased accuracy and visibility, little or no bleeding, less discomfort for the patient, quicker healing period and no unfavourable post-operative consequences (Khan et al., 2020). Regarding to the technique modalities, there can be differentiated between the classical technique, the Miller Technique, the Z-plasty and the V-Y plasty, while for the treatment of GR the V-Y plasty the treatment of choice is. During the V-Y plasty, the clinician relocates the frenum at an apical position and the V shaped incision is converted into a Y while it is sutured (Bamel et al., 2021).

3.2.2 Autogenous Soft Tissue Grafts

3.2.2.1 Free Gingival Graft

Gingival graft transplantation has been performed since the 1960s for the root coverage in cases of GR. The first case was published by Björn (1963), reporting harvesting and transplantation

of a gingival graft with connective tissue and its overlaying epithelium (Amine et al., 2019). Nowadays, the FGG is a still widely used surgical technique to increase the width of the attached gingiva and is indicated in patient cases with a thin gingival biotype and insufficient apicocoronal gingiva that cannot be placed coronally (Mostafa et al., 2022). The palate is most widely used as donor site, while the maxillary tuber can be used as an alternative. A study by Horning et al. assessed the effectiveness and predictability of gingival grafting using different surgical procedures and reported that the treatment with a FGG was the most effective technique in augmentation of the amount of keratinized gingiva. The authors gained more than 3 mm of keratinized gingiva in 100% of the cases (Amine et al., 2019). The application of FGG show high predictability regarding to graft survival and post-surgical tissue stability. It is necessary and clinically important that the palatal soft tissue graft with epithelial coverage maintain their original characteristics after transplantation to the recipient site to create favourable results regarding to induced keratinization (Windisch et al., 2019). However, the FGG contains the genetic information of its donor site which might result in colour mismatch and graft hyperplasia. Due to this fact, the FGG is not recommended in esthetic areas and the application of alternative allogenic, xenogenic graft might be an alternative (Kasaj, 2018). To assure the presence of adequate blood supply in connective tissues, the graft should have at least 1.25 mm thickness and sutured coronally to the CEJ to compensate soft tissue shrinkage and adapt the convexity of the crown to minimize coagulum exposure and destabilization. After suturing the FGG, the flap is apically positioned underneath the free gingival flap in one stage surgical procedure, while in two stage procedures the FGG is adapted to the periosteal bed apically. Therefore, widening of the keratinized tissue can be achieved and after at least two months of graft integration, a CAF is used to reposition the sufficient keratinized tissue coronally covering the GR (Mostafa et al., 2022).

Figure 11 – Root coverage and gingival augmentation of Miller Class I gingival recessions with free gingival graft: 2 years of follow-up (Amine et al., 2022).

3.2.2.2 Subepithelial connective tissue graft

Subepithelial connective tissue grafts are the first grafting approach of choice for root coverage procedures and allowing highly esthetically predictable and versatile grafting procedures in transplantation (Windisch et al., 2019). “The application of SCTG in combination of split-thickness pedicle-, envelope-, or tunnel-type flaps aims at the bilaminar reconstruction of lost gingival tissues using both free and recipient connective tissue layers to preserve graft viability and to cover denuded root surfaces” (Kasaj, 2018, p.99). It is indicated for patients with high esthetic demands, insufficient keratinized tissue, deep root abrasion, root pigmentation or root prominence and GR connected to prosthetic crowns or implants (Mostafa et al., 2022). The decreased epithelial keratinization is associated with more favourable tissue blending and allows therefore a raised colour matching and highly esthetic outcomes due to surface characteristics of the overlying flap with similarities to neighbouring gingival tissues (Kasaj, 2018). “In addition, if SCTG is harvested via partial-thickness flap preparation, wound healing in both the donor and recipient sites occurs mostly by primary intention” (Kasaj, 2018, p. 99). This might promote tissue development and increases the post-operative comfort (Kasaj, 2018). Even if these grafts allow highly favourable esthetics and predictability, they are not the first choice when a substantial increase of keratinized gingival width and thickness should be achieved. Moreover, in patients with thin palatal masticatory mucosa and thus limited amount of donor tissue, alternative donor sites or the application of allogenic and xenogenic grafts should be considered (Windisch et al., 2019). During this operation, a partial-thickness flap is used to ensure an adequate blood source for the graft. It was reported that the bilaminar techniques are the most predictable ones for root coverage due to the fact that a high blood supply can be provided by the covering flap and enhancing the survival of the graft above the avascular surface (Mostafa et al., 2022).

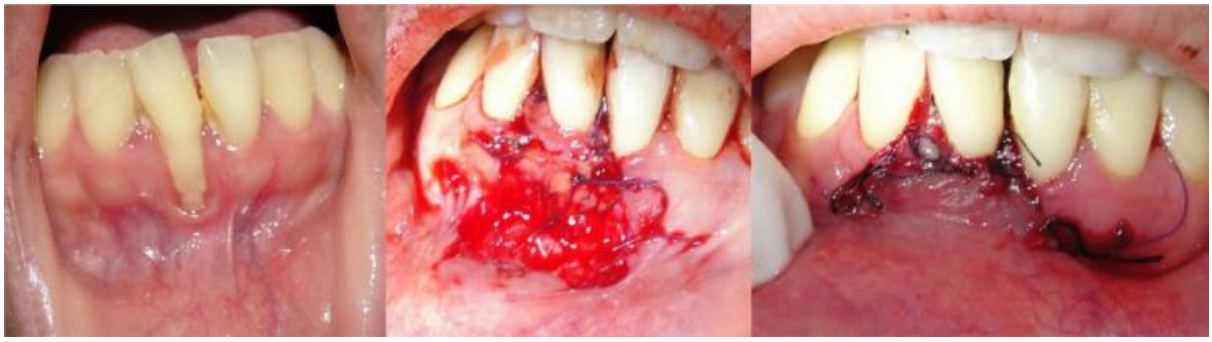

Figure 12 – Subepithelial connective tissue graft used for gingival recession treatment (Mostafa et al., 2022).

3.2.2.3 Partly epithelialized soft tissue grafts

In patients with high frenal attachment or muscle pull, transplantation of SCTG in combination with pedicle or tunnelled flaps might result in impaired graft stability and therefore treatment failure. Thus, a modification of the SCTG has been developed. The epithelialized-subepithelial connective tissue graft, a modification combining advantages with the FGG, can be used to cover exposed root surfaces while the SCTG is adapted to the recipient bed and covered by the flap. This modification increases the resistance against mucosal tension and amount of keratinized tissue (Mostafa et al., 2022). A similar procedure, the partly epithelialized soft tissue graft is used to treat GR of the anterior mandible combined with an apical repositioning flap. Both treatment possibilities deliver increased resistance against the tension of the muscular-mucosal environment, as well as reduce the risk for MGJ displacement (Windisch et al., 2019).

3.2.3 Pedicle autograft Procedures

These procedures are known as soft tissue autografts covering the exposed root surface while they are not completely detached from the donor site and transferred to the adjacent recipient site. Since the flap remains attached at the base, it retains the blood supply, facilitate the revascularization with the recipient site and allow a harmonious colour matching. Pedicle flaps involve rotational flap procedures, including LPF and DPF, as well as flap advancement procedures like CAF (Mostafa et al., 2022).

3.2.3.1 Coronally advanced flap

This procedure involves the repositioning of the gingival tissue which is lying apical to the defect site to a more coronal level and is indicated in patients presenting with shallow recession defects below 4 mm and thick periodontal biotype. In other cases, when the thickness and/or amount of keratinized tissue is insufficient, increasement of the thickness and amount using a free gingival graft, a connective tissue graft (CTG) or a resorbable/non-resorbable membrane has to be performed. Because the soft tissue which is used to cover the exposed root surface is almost coinciding in colour, texture and thickness, the CAF procedures allow highly adequate esthetic results (Kasaj, 2018). “For single recession defects, a flap with trapezoid design is the treatment of choice” (Imber et al., 2021, p. 181) . This surgical procedure is based on two vertical releasing incisions mesial and distally of the exposed root surface, as well as a split-full-split approach to get control of the blood supply problem and the scar tissue development

(Imber et al., 2021). At the papillary zone, a split-thickness flap is prepared, elevated and dissected from the MGJ into the vestibule. A harvested SCTG is placed at the level of the CEJ and fixed with mattress sutures to the adjacent mucosa. Afterwards, complete de-epithelialization of the anatomical papillae has to be performed and the flap hast to be 1 mm coronally from the CEJ secured (Windisch et al., 2019). In cases when the recession is less than 3 mm, thick biotype of periodontium is present, as well as sufficient keratinized tissue at the apex of the defect, the semilunar coronally advanced flap is an alternative. It is performed by horizontal semilunar incision at the MGJ with split-thickness flap elevation starting from the sulcus where the tissues moved coronally and sutured (Mostafa et al., 2022). Several clinical studies, systemic reviews, and meta-analyses reported that CAF alone or together with CTG allows a notable and successful reduction of GR, while the combination increases the outcome for complete root coverage (Amine et al., 2019).

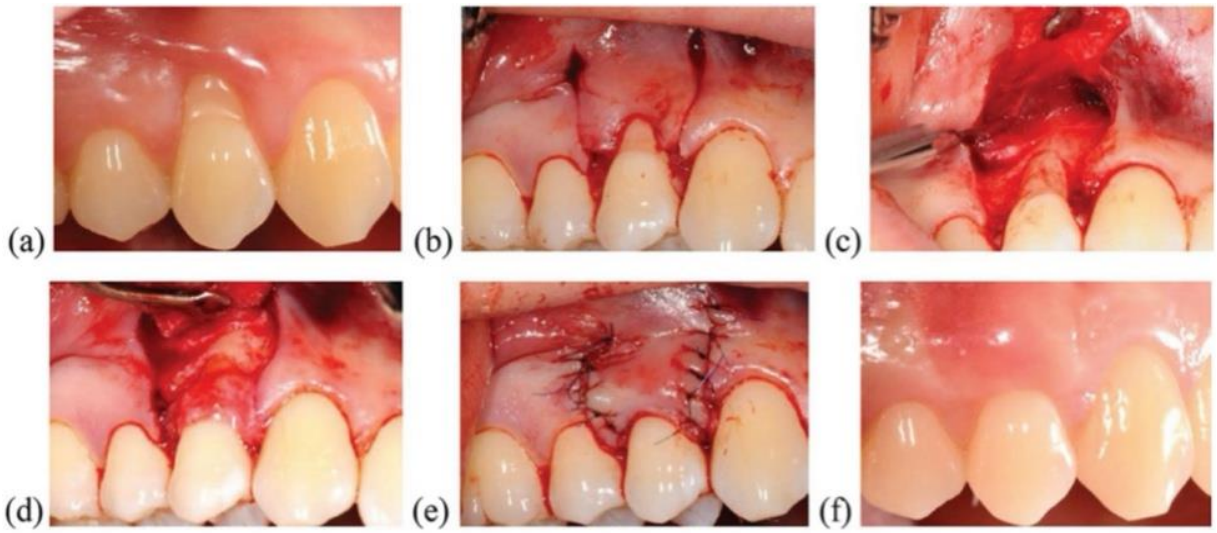

Figure 13 – Coronally advanced flap with a subepithelial connective tissue graft for treatment of single Miller class I defect. a) Baseline, b) incisions, c) split-full-split preparation, d) SCTG application, e) Sutures, f) 5 years outcome (Windisch et al., 2019).

For the coverage of multiple recessions, the modified CAF technique can be used, which is basically a re-designed version of the classic CAF approach (Windisch et al., 2019). This treatment method also contains the “split-thickness preparation of the interdental papilla, the full-thickness preparation of the keratinized gingiva between the gingival zenith and the MGJ, as well as the split-thickness preparation of the mucosal flap beyond the MGJ” (Kasaj, 2018, p. 112). The differentiation from the original technique is based on the incision direction outlining the surgical papillae, which is always running towards the center of the flap. The flap center is mostly a canine or a tunnelled midline papillae. After graft placement, the flap and operation site is fixated and sutured (Windisch et al., 2019).

3.2.3.2 Laterally positioned flap

The LPF technique is an effective, simple and predictable procedure in cases of isolated GR defects with highly satisfying esthetic outcomes and lower morbidity. It is an alternative option in patient cases, when local anatomic conditions are not allowing the CAF technique. The anatomical conditions might include lacking keratinized gingiva apically of the GR, the appearance of shallow vestibulum and/or abnormal frenal attachment (Amine et al., 2019). In this condition, the clinician can use the adjacent keratinized tissue laterally of the GR defect, which allows a perfect colour match as well. However, this technique is just suitable for single recessions, to avoid the development of new recession sites at the donor area (Stevens et al., 2021). Its advantages include the well-tolerance of the patients due to the absence of a second surgical donor site, the less operation time and its good postoperative healing results. However, the LPF technique might lead to scar formation at the donor site. Thus, the esthetic results can be diminished (Mostafa et al., 2022). To decrease the risk for GR at the donor site, Zucchelini et al. described a new design of the original surgical procedure, including a CAF combined to a lateral movement of this flap (lateral moved coronally advanced flap). The combination of both techniques results in good root coverage and esthetics, as well as increased keratinized gingiva. The authors emphasized in their study that the modification of the flap design led to excellent clinical results regarding to root coverage, as well as no GR was noted at the donor sites (Amine et al., 2019).

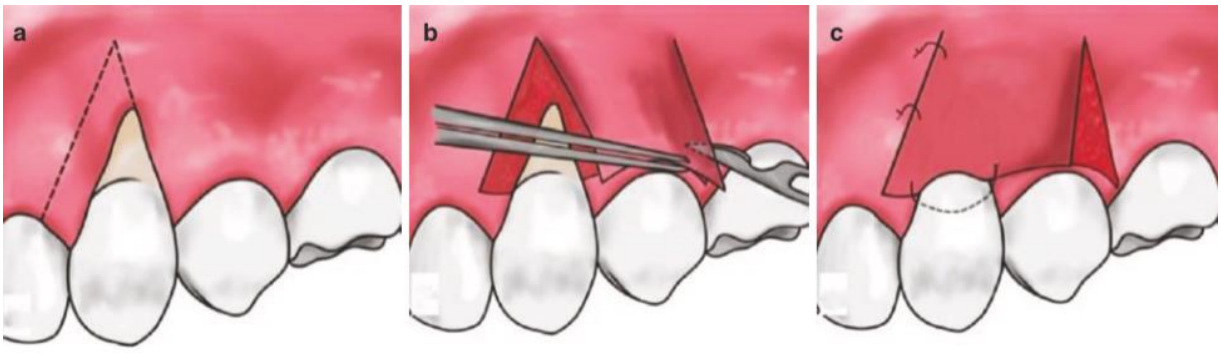

Figure 14 – Three stages of lateral sliding flap technique. (a) Initial incision passes mucogingival junction. (b) Releasing the flap at the buccal surface. (c) Sliding the partial thickness flap and positioning it on the recession area (Stevens et al., 2021).

3.2.3.3 Double papillae flap

DPF was first described 1968 by Cohen and Ross to get rid of limitations appearing with the LPF associated with adequate width and height of the keratinized gingiva (Amine et al., 2019). Thus, it is indicated for single recessions in patients with a thick gingival biotype. In this technique, bilateral interdental soft tissues are used as a donor site to cover the exposed root surfaces. It is a type of rotational flap technique which doesn't require a second surgical site, leading to less risk for flap necrosis, as well as better suturing outcomes due to the increased thickness of the interdental papillae. This surgical technique results in excellent aesthetic outcomes due to the perfect colour matching of the donor site with the recipient (Patil et al., 2021). During the surgical procedure, two partial-thickness flaps are raised and rotated obliquely to allow suturing of the adjacent papillae together, resulting in coverage of the exposed root surface (Mostafa et al., 2022). In case that not enough adequate keratinized gingiva is present to perform a pedicle flap, Nelson and Harris described the full- or partial-thickness flap combining the DPF with a CTG. The combination of both might improve significantly the outcomes of the root coverage procedure due to more keratinized gingival augmentation. More recently, another modification by Acunzo et al. proposed a DPF together with a split-full-split design to cover localized GR. "The authors showed the predictability of this modified DPF procedure in achieving root coverage in cases of Miller Class I and II localized GR defects" (Amine et al., 2019, p. 62).

3.2.4 Tunnel Technique

The envelope approach is the first flapless, incision-free method created for the treatment of isolated GR and adapted for multiple defects. After giving local anesthesia, planing of the exposed root surfaces has to be performed (Kasaj, 2018). Intrasulcular incisions around involved teeth are perfomed and the mucoperiosteal envelope flap elevation has to be carried out by blunt preparation with tunnelling knifes up to the MGJ level, resulting in untouched interdental papillae tips. After the preparation of the confluent tunnel over the exposed root surfaces by interconnecting the mucoperiosteal envelopes, the MGJ needs to be prepared in a split-thickness of up to three to five millimeter depth. A harvested SCTG or epithelialized-subepithelial connective tissue graft can be adapted to the created supraperiosteal envelope by using horizontal mattress sutures or using sling sutures (Windisch et al., 2019). An advantage of this technique is that there is no compromised blood circulation of the papillae leading to post-surgical healing complications. This technique results also in an extension of the

keratinized gingiva with superb colour matching of the graft and recipient site (Kasaj, 2018). Nevertheless, the partial coverage of CTGs by the flap increased the risk for flap necrosis, based on the limited mobility of the envelope coronally (Amine et al., 2019). Therefore, the modified coronally advanced tunnel technique was developed, allowing sufficient root coverage even in Miller class III recessions. “The main difference is that more excessive split-thickness flap mobilization is performed, attaching muscles and inserting collagen fibers are separated and released from the inner aspect of alveolar mucosa…” (Kasaj, 2018, p. 115). This procedure allows an increased mobility of the tunneled flap coronally. Microsurgical elevators can be used to carefully undermine the interdental papillae in order to achieve complete flap mobilization. The tunnel technique is mainly used in multiple GR defects, leads to successful colour matching with lacking any scar line, while substantial root coverage can be achieved (Windisch et al., 2019). Several studies emphasized the high success rate of the tunnel technique in terms of GR treatment, especially for Miller class I and II. However, clinical studies are also emphasizing that the CAF technique is more effective in terms of recessions reduction and keratinized gingiva increase than the modified coronally advanced tunnel technique (Amine at al., 2019). Tavelli et al. compared in their randomized and controlled clinical trial the CAF with the tunnel technique and concluded that over a period of 12 months, the treatment with CAF and CTG provided significantly greater clinical and volumetric outcomes than tunnel technique together with CTG (Tavelli et al., 2023).

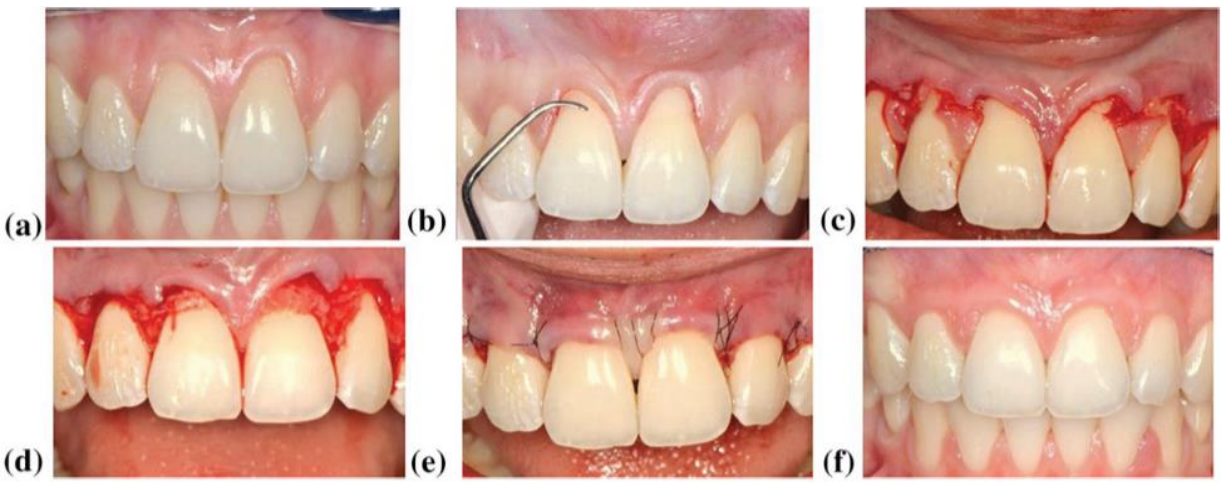

Figure 15 – Modified coronally advanced flap with a subepithelial connective tissue graft for treatment of multiple Miller class I defects. (a) Baseline, (b) Incisions, (c) split-full-split preperation, (d) subepithelial connective tissue graft application, (e) Sutures, (f) One year outcome (Windisch et al., 2019).

3.2.5 Pinhole surgical Technique

The Chao PST, introduced by John Chao in 2012, is a minimally invasive option for the treatment of GR, which is basically incision and suture free. In this technique, a needle is used for puncturing the mucosa and create a tiny hole in the gingival tissue four to five millimeter beyond the MGJ in the alveolar mucosa apically to the defect site (Mostafa et al., 2021). Special designed instruments are used for loosening the gingival tissues and expand them in an apico-coronal direction to release all muscular and fibrous adhesions, as well as elevate the periosteum from the bone to be able to create the full-thickness flap (Mostafa et al., 2022). If mandibular premolars are involved, the hole is made midfacially of the adjacent cuspid, while for the involvement of multiple teeth the holes should have a distance of approximately two to four teeth, depending on factors such as recession severity, frenum, vestibulum depth, tissue type, as well as the vascularization of the area (Mostafa et al., 2020). If the flap is mobile with absent tension, the clinician will be able to adapt the flap coronally over the receded part of the tooth covering the gingival defect and exposed roots towards the CEJ (Mostafa et al., 2020). The stabilization of the flap is achieved by inserting resorbable collagen strips through the pinhole and push them into the interdental papillae, resulting in a better holding of the new gingival position as well as better healing outcomes (Mostafa et al., 2022). Afterwards, gentle pressure should be applied to the flap for five minutes. The healing of the pinhole is achieved by first intension wound healing without any sutures, tissue adhesives or periodontal dressing (Mostafa et al., 2020). The advantage of PST is that just coronal adjustment of the existing gingival tissues without any incisions or grafts is involved. Thus, a treatment of an unlimited number of GRs within one appointment is possible and patients can expect minimal postoperative complications (Mostafa et al., 2022). However, this technique has also limitations and disadvantages affecting the success, such as its technique sensitivity and the need of special instruments for the flap elevation (Agarwal et al., 2020). Additionally, occlusal discrepancies, bone defects, parafunctional habits, the gingival phenotype, as well as the amount of keratinized gingiva influencing the outcome and act as risk factors for the achievement (Mostafa et al., 2021).

3.2.6 Recession Coverage using Soft Tissue Substitutes

There are several surgical treatment modalities for the management of GR defects, while the most often used surgical method is based on the use of autogenous connective tissue grafts with

the CAF technique (Kasaj, 2019). To avoid complications associated with CTGs, numerous soft tissue substitutes for covering GR defects are available (Imber et al., 2021).

3.2.6.1 Guided tissue regeneration

GTR with use of resorbable or non-resorbable barrier membranes was presented as an alternative treatment possibility for GR defects (Kasaj, 2018). The idea is to avoid a secondary surgical site and promote the reconstruction of the connective tissue attachment and bone, resulting in the regeneration of the periodontal tissues itself (Mostafa et al., 2022). The principle is based on the creation and maintenance of space between the root surface and overlying barrier membrane allowing periodontal ligament cells to repopulate on the root surfaces (Aslam Basha et al., 2022). GTR is indicated for wide deep recession defects, where a high esthetic demand is desirable and achievable due to its advantage of blending with adjacent tissues giving successful colour results and gaining new attachment. Additionally, the postoperative comfort is increased by the absence of a secondary surgical site (Mostafa et al., 2022). However, the GTR technique is associated with numerous disadvantages limiting the clinical benefits compared to other treatment modalities such as CAF (Kasaj, 2019). Membrane exposure was announced as a frequent complication resulting in site contamination, failure and infection of the operative treatment (Mostafa et al., 2022). Moreover, the use of non-resorbable membraned requires a second surgical procedure for the membrane retrieval, resulting in an additional trauma of the regenerating tissue (Imber et al., 2021). Another drawback is that this technique is not suitable for the treatment of multiple recession defects at the same time (Kasaj, 2018).

3.2.6.2 Enamel matrix derivative

Using enamel matrix derivatives (EMD) has been presented as another possibility to substitute the CTG during root covering procedures and promotes the periodontal regeneration (Kasaj, 2018). The use of EMDs together with CAF is contemplated as safe with better results than the use of CAF alone regarding to the reduction of the GR defect, complete root coverage and gaining keratinized tissue (Imber et al., 2021). The main advantages for the clinician and the patient include the simplicity of the procedure itself, the avoidance of a second surgical site, better postoperative comfort for the patient and improved early healing (Kasaj, 2019). The biological effect of EMD is based on imitating the normal development of the periodontium. This process is supported by proteins such as amelogenin, enamelin, amelotin and ameloblastin, which can be found in EMDs and influencing the periodontal wound healing and regeneration

(Dubey et al., 2021). Histologically, newly formed woven bone and cementum, new connective tissue attachment, as well as the migration of junctional epithelium apical to the sulcus could be observed (Stähli et al., 2020). Compared to CAF alone, several studies have demonstrated that CAF combined with CTG or EMD increased the likelihood of achieving full root coverage in Miller Class I and II recession defects (Meza Mauricio et al., 2021). Another study by Dubey et al. compared the outcome of GR defects treated with CTGs with or without EMD and emphasized that the addition of EMDs improved the outcome of recession depth reduction as well as gaining of clinical attachment levels (Dubey et al., 2021).

3.2.6.3 Acellular dermal matrices and Xenogenic collagen matrices

Originally, acellular dermal matrices (ADM) have been developed and used for the plastic surgery management of full thickness burn wounds, but were also becoming popular for root coverage management during the last two decades (Shaikh et al., 2021). The ADM allograft is collected from the donated human skin and is treated by removing all viable cells that might influence or provoke inflammatory or immunogenic processes (Petrie et al., 2022). ADMs are consisting of an allogenic freeze-dried connective tissue matrix with removed epidermal layer and cellular components, keeping its three-dimensional structure including collagen and extracellular matrix components such as fibronectin, vascular channels and proteoglycans resulting in the support of cell migration and capillary proliferation (Halim et al., 2023). The ADM showed to enhance keratinized tissue and gingival thickness, but not in the same manner as autogenous grafts (Halim et al., 2023). The main advantages of the acellular dermal allograft is its unlimited supply, the availability in different sizes and that no second surgery is needed, and therefore decreasing patient morbidity and discomfort (Kasaj, 2018). Although the use of ADMs are beneficial, the use for root coverage management is more complicated than with autogenous grafts due to the fact that its an avascular and acellular material whose function is depending mainly on essential revascularization and nutrition received from the recipient site. Thus, the matrix has to be covered completely by the overlying flap (Kasaj, 2019). Due to the fact that the allogenic origin of ADMs are restricted in some european countries, xenogenic materials are more popular such as xenogenic collagen matrices (XCM) (Halim et al., 2023). The collagen matrices are newly developed porcine-derived bioresorbable products and are based on a bilayered composite of pure type I and III collagen without any crosslinking. It is composed of an outer compact layer intending to hold sutures and protect the defect in open healing situations, while the inner layer presents with a porous structure to promote the stabilization of blood clots, as well as the vascularization and ingrowth of the tissue (Huang et

al., 2019). XCM promoting successfully the migration, adhesion and proliferation of periodontal ligament and oral fibroblast cells (Halim et al., 2023). After the procurement of the porcine dermal tissue, the antigenic cellular components need to be eliminated, while the structure of the donor tissue keeps retained. The dermal tissue of porcine origin is favourable, because it has structural and immunological similarities compared to the human skin and can diminish drawbacks related to ADM (Kasaj, 2019). A study by de Carvalho Formiga et al. compared the clinical efficacy of xenogenic and allogenic matrices with CTGs and emphasized in their results that both, ADMs and XCM, provided similar results for root coverage than CTGs (de Carvalho Formiga et al., 2020). However, Halim et al. concluded that CTGs still provide better long-term results compared to ADM and XCM. Admittedly, when CTG harvesting is not necessary, both matrices might be a good alternative in treating GR (Halim et al., 2023).

4 Post-operative Complications

Complications are arising as consequences of another disease and should be absent in an ideal situation. However, sometimes they are inevitable under certain circumstances. Complications can be defined as secondary diseases developing in the course of primary diseases and regarding to periodontal surgery include mostly postoperative pain, bleeding, swelling, delayed healing, tissue changes and bruising (Suchetha et al., 2018). Decreasing the risk for complications is crucial before and during root coverage procedures. Therefore, the assessment of patient's health status, medical and dental history and additional risk characteristics has to be performed wisely. Especially, the anamnesis regarding to medications, habits like smoking or nutrition, genetical diseases and other systemic diseases should be performed adequately (Mazzotti et al., 2023). Especially smoking can influence the wound healing process due to alteration of tissue vascularization, immune and inflammatory responses as well as the healing potential of the periodontal tissue (Sanari et al., 2020). Post-operative complications can be generally divided into general complications arising after periodontal surgery or complications arising due to the surgical procedure. The most common general complications include bleeding, swelling, postoperative pain, root hypersensitivity, delayed wound healing, trismus, postoperative bacteremia, taste changes and bruising (Suchetha et al., 2018). Postoperative infection is always a risk factor after surgical procedures because of the well-defined oral cavity character and its open space toward the outside. Pathological microorganisms might produce free radicals, destructive enzymes and toxins influencing the healing process, as well as the immune system negatively and inhibit collagen formation. Basically, the bacteremia level is depending on the

tissue trauma and can be averted by antibiotic prophylaxis such as Amoxicillin (Cho et al., 2021). Postoperative bleeding up to twelve hours can be seen as normal, while persistent hemorrhage or oozing could be problematic to wound healing (Mazzotti et al., 2023). Is the hemorrhage uncontrolled, it is important to find the source to plan its management. Mild bleeding can be treated by pressure applied for 15 to 20 minutes or hemostatic agents such as silver nitrate or ferric sulphate can be used. Is the bleeding arterial, ligation of the vessels should be performed (Suchetha et al., 2018). Postoperative Pain during the first three days after surgery are considered as normal and should progressively diminish during the healing phase. Pain management can be supported by prescribing medications like non-steroidal anti-inflammatory drugs, such as ibuprofen or paracetamol (Mazzotti et al., 2023). Wound healing can be divided into four phases including hemostasis, inflammation, proliferation and remodelling and is mainly affected by Infection, Vascularization, flap design and incision, systemic diseases like Diabetes Mellitus and smoking. To prevent complications associated with impaired vascularization, flap design and incision, an accurate cognition on the branching of periosteal vessels is required (Cho et al., 2021). Thorough debridement and irrigation followed by antibiotic prescription and analgesics usually decreases symptoms and accentuates wound healing (Suchetha et al., 2018). Complications arising due to the surgical procedure can be divided into local anaesthesia related, flap related, graft related, suture related, periodontal pack related or guided tissue regeneration related (Suchetha et al., 2018). Flap related complications are often associated with flap dehiscence, caused by infections or suture failure, which affects the flap approximation and leads to flap shrinkage with severe influences on the treatment results. Avoidance of flap dehiscence can be achieved by an adequate management of the flap tension, appropriate de-epithelialization of the anatomical papillae as well as surgical stability (Mazzotti et al., 2023). Associated to suture failure are also graft related post-operative complications, including the displacement or contamination of the graft due to suture loosening. Other graft related complications include the failure due to improper root preparation resulting in decreased blood supply, inadequate size or an allergic reaction (Suchetha et al., 2018). To minimize the risk for premature graft exposure, some operative steps have to be respected. Regarding to the graft position, it should be secured at the CEJ level or slightly apical, while smaller grafts achieved better esthetical outcomes and minimized the impingement on the blood supply flow from the connective tissue to the covering flap. Less early flap shrinkage can be achieved by reducing the graft dimensions (Mazzotti et al., 2023).

5 Conclusion

Gingival recession is a common clinical finding in the population, affecting especially older generations, increasing with age and are always associated with clinical attachment loss. Next to the genetic predisposition there are several factors influencing the development, the progression as well as the treatment of it. While on one hand epidemiologic factors such as gender, ethnicity, age and the location influencing the development of gingival recession, playing predisposing and precipitating factors an important role as well. Thus, the anatomic considerations, oral hygiene, existing restorations and patient related habits has to be examined by the clinician to adjust a good treatment plan. Therefore, the medical and dental history together with an appropriate clinical examination based on the intraoral examination of the mucosa, gingiva, teeth and periodontal assessment is crucial for the prognosis evaluation as well as the classification of the gingival recession status. Additionally, radiographic examination methods such as periapical and panoramic radiographs or ConeBeam Computed Tomography can be used for the examination support to visualize the defect morphologies. The following treatment can be differentiated into non-surgical and surgical, while non-surgical treatment options such as the elimination of etiologies also playing an important role for the regeneration and outcome after surgical treatment, as well as the re-establishment of the periodontium. Several surgical treatment methods are available for the clinician, while autogenous soft tissue grafts are still the gold standard treatment of choice. Furthermore, the treatment option is mainly depending on the location of the gingival recession, if single or multiple recession sites are present as well as the skills of the clinician itself. However, even if autogenous soft tissue grafts are still most often used, soft tissue substitutes are nowadays well developed and scientifically investigated, and the combination of them with autogenous flaps resulting in successful and favourable outcomes as well. Generally, we can conclude that the research about the clinical examination, prognosis and treatment of gingival recession is well established, and several treatment options are available and resulting in favourable outcomes, if the co-operation between the dentist and patient is successful. However, more research is necessary for the development and improvement of treatment options and materials, especially scientific research about soft tissue substitutes such as enamel matrix derivative, acellular dermal matrices or xenogenic collagen matrix due to their advantage that a second surgery site is avoidable. Furthermore, an improved and expanded education about the prevention, epidemiology and etiologic factors of gingival recession with patients in the dental practice is crucial to influence patient’s compliance as well as decrease the development of gingival

recession in the population. Thus, the dentist plays an important role in the inducement and support of lifestyle changes for the patient.

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