CHAPTER 1

GENERAL INTRODUCTION
Maxillofacial prostheses are used to replace parts or complete stomatognathic or craniofacial structures. According to the Glossary of Prosthodontic terms, a facial, also named extraoral, prosthesis is a maxillofacial prosthesis that replaces a portion of the face that is lost or deformed due to, e.g., trauma, congenital abnormalities or ablative surgery [1]. Already the ancient Egyptians were involved in maxillofacial prosthetics as part of their attempt to preserve normal body appearance of the deceased. There is some evidence that around 3000 B.C. the face of deceased subjects was reconstructed with filling the mouth and filling the empty eye socket with artificial eyes made of limestone, calcite, bone or linen with pupils delineated using black paint [2]. In the 16th century A.D. a more lifelike facial prosthesis was made, a nose, fabricated from metal, colored with oil to match the skin and attached with an adhesive to the face (Figure 1a). Later, different materials are used for fabricating facial prostheses (Figure 1b) [2]. Nowadays, these facial prostheses are usually fabricated from silicone rubber and retained either by using adhesive, undercuts, eyeglasses or implants (Figure 1c) [3].

FIGURE 1 (a) Early nasal prosthesis made of metal (16th century) [4]; (b) collodion nasal prosthesis with vulcanite pads for retention (1870) [2]; (c) an implant retained silicone auricular prosthesis.
The inner surface of facial prostheses is in contact with soft tissues and body fluids. Therewith microorganisms can colonize and form biofilms on the facial prostheses. From silicone soft lining materials used for dentures it is known that microorganisms can degrade these softliners [5]. The composition of biofilms on surfaces of prostheses, in particular on surfaces of facial prostheses, and how microorganisms can affect the silicone rubber and other components facial prostheses made from in particular are not yet thoroughly investigated. So far, most studies have focused on biofilms around percutaneous implants used to retain facial prostheses [6-9], i.e. the peri-implant flora, instead of focusing on flora that has colonized the silicone rubber of the prostheses. The latter is of interest as infections of, e.g., the skin underlying the prostheses is a common clinical phenomenon that causes distress to the patient.

Biofilms are of particular interest regarding the maintenance of facial prostheses due to a long held notion that microorganisms within the biofilm have properties to degrade the material facial prostheses made from and to change the color of the prosthesis. In 31% of the cases discoloration was the main reason to fabricate a new prosthesis [10]. Pollution, exposure to UV, natural aging and nicotine all have been presumed to underlie the observed discoloration [11-13]. In addition, the use of intrinsic colors, either alone or as a result of interaction with microorganisms, is thought to be a contributing factor to degradation and discoloration of facial prostheses, but this presumption is in need of further study [10].

Since facial prostheses are in contact with skin for extended time, the surface of facial prostheses that covers the skin creates pressure, heat, higher humidity, occlusion and friction [14]. Biofilms formation are suggested to occur on skin as well [15]. The prevalence and incidence of silicone rubber related adverse skin reactions in facial prostheses patients is unknown, but occlusion and humidity are amongst the factors that promote adverse skin reactions [16, 17]. The occurrence of biofilms on both silicone facial prostheses and skin, in conjunction with aforementioned factors, is thought to contribute to the problem. This is especially true for adhesively retained prostheses, but implant retained prostheses also face this problem. Implant retained prostheses are still accompanied by skin occlusion and humidity because the
margins of the prosthesis need to be properly adapted to the skin as well and there still might be constituents of the prosthesis material that are harmful for the patient. Regarding orbital prostheses, 5% of these prostheses fail due to in-growth of microorganisms [10]. For other type of facial prostheses, i.e. auricular and nasal prostheses, it is unknown what percentage of failure is related to microorganisms, but adhesion of microorganisms to and formation of biofilms on surfaces of prostheses are well known causes for infections of medical devices.

The incidence of medical devices failures due to bacterial contamination ranges from 1-4% for hip prostheses to 100% for urinary catheters [18]. Chronic infections by biofilms are of interest because of resistance of microorganisms present in the biofilm to antibiotics. Furthermore, the architecture of a biofilm, i.e., the layer on the surface of a prosthesis in which the cells are embedded in extracellular polysaccharide matrix, renders poor penetration of antibiotics through that layer [19]. Therefore it is possible that a biofilm on a medical device is 500-1000 times more resistant to antibiotics than planktonic bacteria [20, 21].

New strategies to prevent biomaterial related infections are underway. Among these strategies are modifications of the surface of biomaterials, e.g., through incorporation of antimicrobial agents into the biomaterials itself and use of surface coatings. With these modifications, infections related to medical devices can be inhibited or prevented [22]. While new strategies are being developed, the routine method used currently to prevent biofilm formation on silicone facial prostheses is to instruct patients to clean their prostheses meticulously. As a result, most studies on facial prostheses focus on biofilms and cleansing of the percutaneous implants that are increasingly used to retain facial prostheses currently [23-26] instead of assessing the efficacy of cleansing the prosthesis itself. This approach might be driven to the presumption that rigorous cleaning or use of inappropriate cleaning agents can lead to damage of the silicone rubber [26]. It is also still questionable whether the most inner surface of the prosthesis is sufficiently accessible to optimal hygiene.

Therefore, it is required to focus on efficacy of routine cleaning methods and materials to help establish suitable cleaning methods and or agents, not only for
peri-implant tissues but also for the material the prosthesis made from. When adverse skin reactions persist despite correct hygiene procedures, antibiotics and anti-inflammatory drugs are prescribed with recurring events of adverse skin reactions once the medication is discontinued. Therefore, life-long follow up and studies to improve facial prostheses longevity with low burden to the patients’ own tissues are indispensable as well as studies to develop easily applicable, nontoxic and non-prosthesis material damaging procedures to effectively clean a facial prosthesis.

**Aim of this thesis**

The general aim of this thesis was to make an inventory of biofilms on facial prostheses and to analyze the composition of these mixed species biofilms. In addition, routine methods to clean a facial prosthesis were studied to assess how efficient they are in killing biofilms.

In chapter 2 the current state of facial prosthetic rehabilitation was reviewed. The main conclusion of this chapter was that facial prostheses are a reliable treatment option to restore maxillofacial defects and to improve quality of life. Significant progress has been made in the utilization of implants and digital technology. Improvements to enhance prostheses longevity include a better understanding of the biofilm on the surface of the prosthesis and to judge which methods are most effective in removing this biofilm from the prosthesis.

In chapter 3 we studied the composition of biofilms on facial prostheses and the influence of the prosthesis on the microbial composition of the skin underneath prostheses. The main result of this chapter was that occlusion of the skin by the prostheses created a favorable niche for opportunistic pathogens such as *Candida* spp. and *Staphylococcus aureus*. Biofilms on healthy skin, skin underneath prosthesis and the prosthesis had a comparable composition.

In the study described in chapter 4 the efficacy of cleansing agents to affect the biofilm on facial prostheses was studied. Chlorhexidine mouthrinse showed the
highest efficacy in eradicating bacteria and yeasts in the biofilms, especially after repeated treatment compared to the other cleansing agents.

The case study in chapter 5 assessed efficacy of cleansing agents in killing biofilms of ex vivo silicone facial prostheses. Essential oils and chlorhexidine were effective in reducing microorganisms of ex vivo silicone facial prostheses biofilms.

The general discussion described in chapter 6 places the results of the studies performed in a broader perspective. It is discussed which other factors might affect the longevity of facial prostheses including the in vitro effect of pigments on silicone rubber and the effect of adding pigments to silicone rubber on the growth of microorganisms on silicone rubber.
References