Er:YAG laser in dentistry

Patients' experiences and clinical applicability

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To my beloved husband
Mehran Mohsenpour
and to our darlings
Daniel & Desirée
Love you

Abstract

Er:YAG laser in dentistry. Patients' experiences and clinical applicability

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Objective: This thesis focuses on the patients' experiences and the clinical applicability of the Er:YAG laser method in the excavation of caries and oral soft tissue surgery. **Design:** Both qualitative (Study I) and quantitative (Studies II and III) research methods were used. Study I was performed as individual interviews of 12 patients who had undergone at least one caries excavation with the Er:YAG laser method. Study II was a single blind, RCT investigation of 25 patients with at least two equal primary caries lesions (a total of 56 cavities). The patients compared their experiences of caries excavation using the laser method with the conventional rotary bur method and the time required for the treatments was measured. The restorations were evaluated over 24 months. In Study III, a single blind, RCT study was performed, based on 40 patients requiring frenectomy and treated with either conventional scalpel surgery or laser surgery. Patients' experiences, treatment time, bleeding and wound healing were evaluated. **Results:** In Studies I and II, patients described the Er:YAG laser method as less painful and less unpleasant, safe and more relaxing. In Study II the mean time for caries excavation using the laser method was three times longer than with the rotary bur. The quality and durability of restorations were assessed as equivalent after two years. In Study III conventional scalpel surgery took 50% longer time and bleeding was three times higher than after Er:YAG laser surgery. The patients assessed both methods as equal and were satisfied with both treatments. No differences concerning wound healing were found. **Conclusion:** Patients preferred the Er:YAG laser method in caries excavation to the rotary bur despite significantly longer treatment time, but valued it as equivalent to conventional scalpel surgery in frenectomies. The Er:YAG laser was less time-consuming and led to less bleeding when used in frenectomies, while no differences in wound healing were recorded.

Keywords: Dental caries, Er:YAG laser, Labial frenectomy, Patients' experiences, Qualitative research, Randomized controlled trial, Rotary bur.

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Sammanfattning

Er:YAG laser i tandvård. Patienters erfarenheter och klinisk användbarhet

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Mål: Denna avhandling har studerat patienternas erfarenheter och den kliniska användbarheten av Er:YAG lasermetoden vid exkavering av karies och vid mjukvävnadskirurgi. **Design**: Både kvalitativa (delarbete I) och kvantitativa (delarbeten II och III) forskningsmetoder användes. Delarbete I var en intervjustudie som omfattade 12 individuella djupintervjuer av patienter som hade genomgått kariesexkavering av minst ett kariesangrepp med Er:YAG lasermetoden. Delarbete II var en enkelblind RCT-studie av 25 patienter med minst två likvärdiga primära kronkariesangrepp (totalt 56 kaviteter). Patienterna jämförde lasermetoden med konventionell borrmetod och behandlingstiden mättes. De efterföljande restaurationerna utvärderades under 24 månader. I delstudie III, en enkelblind RCT-studie baserad på 40 patienter som genomgick frenulaplastik av överläppens frenula med antingen konventionell skalpell eller Er:YAG laser, utvärderades patienternas erfarenheter, behandlingstid, blödning och sårläkning**. Resultat**: I delstudie I och II beskrev patienterna lasermetoden som mindre smärtsam, mindre obehaglig, säkrare och mer avslappnande. Den genomsnittliga tiden för exkavering av karies med lasermetod i delarbete II var tre gånger längre jämfört med konventionell borrmetod. Fyllningars kvalitet och hållbarhet bedömdes vara likvärdiga efter 24 månader. I delarbete III tog konventionell skalpellkirurgi 50% längre tid och blödde tre gånger mer jämfört med Er:YAG laserkirurgi. Patienterna värderade båda metoderna som likvärdiga och de var nöjda med båda behandlingarna. **Slutsatser**: Patienter föredrog Er:YAG lasermetoden vid kariesexkavering jämfört med borrmetoden trots betydligt längre behandlingstid men de utvärderade lasermetoden som likvärdig med konventionell skalpellmetod vid frenulaplastik. Er:YAG laser var mindre tidskrävande och ledde till mindre blödning vid frenulaplastik medan ingen skillnad gällande sårläkning kunde noteras.

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Contents

Original papers

This thesis is based on the following studies, referred to in the text by their Roman numerals (I- III):

I. Sarmadi R, Hedman E, Gabre P: Laser in caries treatment - patients' experiences and opinions. Int J Dent Hyg. 2014; 12:67-73.

II. Sarmadi R, Andersson EV, Lingström P, Gabre P: A Randomized Controlled Trial Comparing Er:YAG Laser and Rotary Bur in the Excavation of Caries - Patients' Experiences and the Quality of Composite Restoration. Open Dent J. 2018; 12: 443-54.

III. Sarmadi R, Gabre P, Thor A: Evaluation of upper labial frenectomy - a randomized controlled comparative study of conventional scalpel technique and Er:YAG laser technique. Submitted for publication.

Abbreviations and definitions

The following terminology is used in this thesis

Ar = Argon

AFR= Annual failure rate

CDA= California Dental Association

Er,Cr:YSGG= Erbium, chromium: yttrium- scandium- gallium- garnet

Er:YAG= Erbium: yttrium- aluminium- garnet

KTP= Potassium titanyl phosphate

Nd:YAG= Neodymium-doped yttrium aluminium garnet

PRO= Patient reported outcomes

RCT= Randomized controlled trial

USPHS= United States Public Health Service

VAS= Visual analog scale

VOS= Visualization of similarities (VOS viewer program)

WOS= Web of science database

Introduction

Although the prevalence of oral diseases has decreased in Sweden [Norderyd et al., 2015], oral diseases are still a major public health problem in many countries [Frencken et al., 2017]. A preventive approach is the primary focus on the management of oral diseases, but even if large resources are put on health promotion and preventive measures, oral diseases will always have to be treated operatively. In most countries dental caries is a major health problem affecting the majority of the population [Bagramian et al., 2009]. In larger caries lesions, caries tissue need to be removed. Rotary bur is the most commonly used method when excavating caries tissue, a well-known and efficient method [van Dijken and Pallesen, 2010]. At the same time rotary bur is connected with some disadvantages such as risk of over preparation, negative pulp effects due to vibrations and heat and, the most important for patients, discomfort and pain [Kani et al., 2015]. The negative experiences have led to a search for other methods to excavate caries tissue [de Almeida Neves et al., 2011]. One alternative method is laser, a technique that can be used in dentistry not only for excavation of caries tissue but also for soft tissue surgery, periodontal and endodontic treatments.

History of science: light and lasers

Scientists have used light in diagnostics and medical treatment since ancient times. Light was described for the first time in 1021 by Ibn al-Haytham, a mathematician, researcher and philosopher, in his *Book of Optics*, as small particles moving in straight lines, which bounce when they hit objects. In 1665 Robert Hooke described light waves as similar to waves on the surface of water and Isaac Newton (1642-1727) described light as “corpuscles that are emitted

in all directions from a source". The electromagnetic wave theory was proposed by James Clerk Maxwell, who in 1865 demonstrated that electromagnetic waves could move at the same speed as light [Convissar, 2016].

In 1913, Niels Bohr's theory about energy in atoms, describing how electrons move from one energy level to another by either absorbing or emitting energy, resulted in his Nobel Prize for physics in 1922. He described the theory of spontaneous emission as a process in which electrons drop from a higher energy level to a lower by emitting a photon (energy). Albert Einstein published the quantum theory of light and defined stimulated emission in 1917, after several years of study. Einstein described stimulated emission as a process in which electrons emit photons with the same characteristics as external photons, which stimulates the process. Spontaneous and stimulated emission forms the scientific basis for laser technology [Convissar, 2016].

The word laser was used for the first time by the physicist, Gordon Gould. In 1957 he kept a laboratory notebook with the title, "Some rough calculations on the feasibility of a LASER: Light Amplification by Stimulated Emission of Radiation" [Hecht, 2010]. The first laser (a Ruby laser) was invented by Theodore H Maiman, who published an article in the British weekly journal *Nature* [Maiman, 1960]. Leon Goldman was the first scientist to start experimenting with Ruby laser. He used it on his brother, a dentist, and they found that the Ruby laser had a clinical effect on teeth but that the thermal damage it caused meant that it was not safe for clinical use [Goldman et al., 1965]. Myers and Myers introduced the first Nd:YAG laser in the United States in 1990 [Myers, 2000] . Hibst and Keller invented an Er:YAG laser that could be used in dentistry in the early 1990s [Keller et al., 1991].

What is laser?

Laser is a type of technology that creates light with specific properties, which have various uses in industry, medicine and dentistry [Hecht, 2010]. Laser has several applications in diagnostics and dental treatment [Pick, 1993; Coluzzi, 2005]. Laser technology creates high intensity light beams with the same wavelength and direction. Laser light beams follow one direction and have the same wavelength and phase. Unlike laser light, ordinary light has different wavelengths (400-700 nm) and the light beams are disorganized and follow different directions (Fig.1) [Coluzzi, 2004].

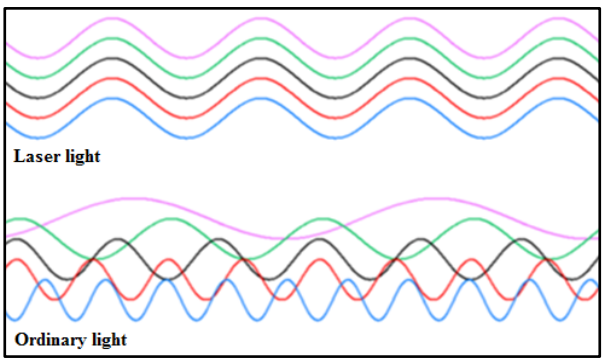

Fig.1 The differences between laser light and ordinary light.
Picture by Kieff,CC-BY-SA-3.0

The laser machine can be described as an energy transformer that transforms low quality energy into high quality energy. A laser machine consists of an optical cavity containing a laser medium (which may be gas, liquid or solid), a pumping energy source and two mirrors [Coluzzi, 2004].

Laser light interacts with tissue in four different ways [Coluzzi, 2005]. It can pass through the tissue without having any effect *(Transmission)*. It can be reflected from the tissue *(Reflection)* or can be absorbed by the cells in the

tissue *(Absorption)*. The absorption effect results in removal of teeth or cut into soft tissue during surgical procedures. Laser light can also spread out into a larger tissue area *(Scattering)*.

Lasers in dentistry

Laser has many applications in dental care. It can replace traditional methods in some treatments or work as a complement to traditional techniques. Depending on the wavelength and the absorption properties of the tissue, the laser light affects the tissue in different ways and so has specific areas of use (Table 1). The lasers used in dental care have wavelengths of between 488 nm (Argon) and 10600 nm (CO_2).

Lasers in dental care can be divided into 4 different categories depending on wavelength [Olivi et al., 2009;Caprioglio et al., 2017].

1. Lasers in the visible spectrum of light with wavelengths between approximately 400 and 700 nm. These lasers are visible, an example being KTP laser with a wavelength of 532 nm, which is used in soft tissue therapy and tooth-whitening.
2. Lasers in the near-infrared spectrum of light with wavelengths between approximately 780 and 2000 nm. Nd:YAG laser (1340 nm) belongs to this group and can be used in endodontics and oral surgery. Diode lasers (800 to1064 nm) which have the same clinical properties as Nd:YAG laser, are more popular than Nd:YAG in dental care due to their lower cost and smaller size.
3. Lasers in the mid-infrared spectrum of light with wavelengths between approximately 2000 and 3000 nm. The Erbium family of lasers (Er:YAG and Er,Cr:YSGG) belong to this group. Er:YAG lasers can be used widely in dental care because their beams are easily absorbed by water and hydroxyapatite.

4. Lasers in the far-infrared spectrum of light with wavelengths over 3000 nm. CO_2 laser belongs to this group and is one of the first lasers developed for use in surgery. Today it is used frequently within soft tissue surgery.

Table 1. Lasers and their applications

Laser	Abberaviation	Wavelength (nm)	Area of use
Argon	Ar	488 and 514	Soft tissue
Carbon dioxide	CO_2	9300, 9600, 10600	Soft tissue
Diode		635-803 and 980-1064	Soft tissue, Tooth-whitening, Caries detection
Erbium-chromium-doped: yttrium-scandium- gallium - garnet	Er,Cr:YSGG	2780	Hard and soft tissue
Erbium-doped: yttrium-aluminium- garnet	Er:YAG	2940	Hard and soft tissue
Neodymium-doped: yttrium- aluminium-garnet	Nd:YAG	1064	Soft tissue
Potassium titanyl phosphate	KTP	532	Tooth-whitening

Dental caries

Dental caries is a disease that is a result from an imbalance in dental biofilm and develops due to the frequent intake of fermentable carbohydrates. A caries lesion is a sign and symptom of caries disease [Fejerskov, 2003]. Dental caries begins with initial lesions in the enamel and advances to superficial, then deep, cavities in the dentin with possible pulpal involvement and tooth loss if not treated. Caries disease can be treated by creating a balance between pathological and protective factors [Featherstone, 2006]. This balance can be achieved through collaboration between the patients and dental team after identifying the risk factors by carrying out a caries risk assessment. The

effective management of caries disease includes the detection of early caries lesions, caries risk assessment and the prevention of new lesions by caries control. Caries control includes plaque control, fluoride supply, dietary advice and the removal of decayed moderate and deep dentin tissue, which is then replaced with filling materials [Banerjee and Domejean, 2013; Walsh and Brostek, 2013].

Excavation of dental caries

Cavitated dentin caries lesions will sometimes be managed by excavation (removal) of caries tissue and replacement of the tooth structure with restorative materials (fillings). The development of adhesive restorative materials and increased understanding of the caries process have led to a paradigm shift, from G.V. Blacks "extension for prevention," to minimal invasive dentistry [Ericson, 2003]. The basic principles of minimal invasive dentistry are disease control, preventing occurrence of new lesions and arresting or controlling of dentin lesions through minimal invasive treatments [Ericson, 2007].

The latest recommendations for removing dentin caries in teeth with sensible, asymptomatic pulp depend on the size of the cavity and whether the tooth is primary or permanent. The total removal of dentin caries to achieve hard dentin pulpally may involve a risk of pulp exposure or pulp inflammation. This is now considered to be overtreatment and is no longer recommended. The latest recommendations include selective removal to firm dentin in moderate cavities and to soft dentin in deep cavities. This applies as long as the peripheral dentin is hard and allows a dense filling [Schwendicke et al., 2016; Banerjee et al., 2017].

Several methods have been developed and used to excavate caries such as rotary bur, plastic and ceramic burs, sono/air abrasion, chemo-mechanical technique, enzymes and lasers [de Almeida Neves et al., 2011].

Conventional rotary bur

The longest used and most widely used method for removing carious tissue is the rotary bur which is considered simple, fast and cost effective by clinicians [Celiberti et al., 2006]. At the same time, the rotary bur has several disadvantages such as unpleasant noise, vibrations and the risk of removing healthy tooth substance. Several studies show that using a high speed bur may lead to pulpal temperature rise and dental tissue cracking [Spierings et al., 1985; Watson and Cook, 1995; Baldissara et al., 1997]. Fear of the rotary bur is also a major cause of dental phobia and avoiding dental care [Kani et al., 2015]. Patients describe the rotary bur method as unpleasant and painful and prefer other more comfortable methods [Kani et al 2015; Ghanei et al 2018].

Er:YAG laser

Light from an Er:YAG laser, with a wavelength of 2940 nm, is absorbed well in water and hydroxyapatite, which means that it is able to remove both tooth and soft tissue. The energy of the Er:YAG laser light is absorbed by the water molecules and converted to heat. The heating process results in the micro explosion of water molecules and increases the internal pressure on dental tissue, which in turn leads to the explosive destruction of enamel and dentine. The process of explosive ablation is also called the thermo-mechanical effect and causes the tissue to be removed (vaporized) [Hibst and Keller, 1989]. The use of water cooling in combination with Er:YAG leads to more effective ablation of dental hard tissue and less increase in pulp temperature [Burkes et al., 1992; Cavalcanti et al., 2003]. The absorption of Er:YAG laser by water molecules is a crucial factor in removing tooth tissue. The more water content,

the faster the tissue can be removed by laser. Enamel contains 12% water, dentin contains more (20%) and the water content in carious dentin may be as high as 54% [Ito et al., 2005]. Therefore, it is much faster to remove dentin, especially carious dentin, than enamel [Parker, 2007].

Er:YAG laser was introduced in the late 1980s.In the mid-1990s, Keller and Hibst´s search for a suitable laser led to further development of Er:YAG laser [Keller et al., 1991]. It was shown that this type of laser was able to remove enamel and dentin using a pulsed laser beam combined with water spray, without noticeable pulp temperature increase [Colucci et al., 2009; Oelgiesser et al., 2003]. To obtain optimal tissue removal and minimal heat development, there are several parameters which are important to consider in addition to water cooling and wavelength. These parameters are pulse duration, pulse energy, repetition rate, beam spot size, delivery method and optical properties of the target tissue [Featherstone, 2000].

Er:YAG laser in the scientific literature

To date (2018) a few authors have reviewed randomised controlled trials (RCT) comparing the rotary bur with Er:YAG lasers in the excavation of caries [Jacobsen et al., 2011; Montedori et al., 2016; Wong, 2018]. No significant differences have been shown in caries removal [DenBesten et al., 2001; Dommisch et al., 2008], cavity preparation [DenBesten et al., 2001] or pulpal damage [Keller et al., 1998; DenBesten et al., 2001] when the methods have been compared. Contradictory results have been shown regarding treatment time, treatment experience and the need for local anaesthesia [Keller et al., 1998; DenBesten et al., 2001; Dommisch et al., 2008].

The time required for the excavation of caries using Er:YAG laser has been evaluated and compared with rotary bur in several RCT studies. In a study by Dommisch et al. [2008] it took three times longer to remove caries with laser. Keller et al. [1998] and Liu et.al. [2006] showed that it took twice as long to excavate caries with laser, while Pelagalli et.al [1997] showed no time difference. In the study by Keller et.al, the patients overwhelmingly found laser treatment to be more comfortable than rotary bur treatment, with 80% of the patients rating the conventional preparation process as more uncomfortable than laser treatment and 82% of the patients indicating that they would prefer Er:YAG laser for future treatments [Keller et al., 1998]. Also, other studies have shown that patients prefer the laser to the rotary bur [Pelagalli et al., 1997; Hadley et al., 2000; Liu et al., 2006;]. In a RCT study by DenBesten et al. [2001] patients reported no significant differences in pain between rotary bur and laser methods. However, there was a greater use of anaesthesia during rotary bur procedures, while Liu et al. [2006] showed that 82% of children felt no pain at all during laser preparation. Several studies showed no differences in marginal integrity, durability and the recurrence of secondary caries [Hadley et al., 2000; Yazici et al., 2010] when the two methods were compared.

Bibliometric analysis of Er:YAG laser research 1985-2015

Bibliometric analysis is used by researchers and scientific communities to explore the impact of a publications, authors or areas of study [Gutierrez-Salcedo et al., 2018]. Using the Web of Science (WOS) database and the computer program Vosviewer (VOS) [van Eck and Waltman, 2017], research into the use of Er:YAG laser in dental care between 1985-2015 was mapped as a part of the author´s postgraduate studies [Sarmadi, 2015]. VOS stands for visualization of similarities and the program is a free science mapping software

tool that was developed by the Centre for Science and Technology Studies at Leiden University. Vosviewer can visualize and construct bibliometric maps using graphical representations (circles and clusters of different colors). Units (articles, authors, scientific journals) are shown as circles and larger circles indicate that the unit has received more attention. The smaller the distance between the circles the greater the strength of the relationship between the units. Co-citation means that two specific publications or authors are cited in the same publication published later. Citation report and co-citation analysis show the impact of publications, researchers or areas of study and the attention they have received.

Two different analyses were performed, a *citation report analysis* in Web of Science and a *co-citation analysis* in Vosviewer. The keyword Er:YAG laser, was selected in the WOS (core collection) database and resulted in 3101 published articles. When the result was limited to categories dentistry, oral surgery and medicine, 847 articles were found. The search was further limited by selecting the type of document (articles and review articles), which resulted in a total of 458 articles. Citation report analysis revealed the ten most cited articles (Table 2) and the ten authors who had published most articles about Er:YAG laser between 1985 and 2015 (Table 3). The analysis showed that the most cited articles in this area were published between 1992 and 2008. The authors in Table 3 are ranked by the number of articles they have published. In this analysis authors did not need to be the first author to be counted, as long as they were included in the author list.

Table 2. The 10 most cited articles about Er:YAG laser (Web of Science category: "Dentistry, Oral surgery, Medicine") 1985-2015.

Title	First author	Publi-cation year	Total cita-tions
Comparison between Er:YAG laser and conventional technique for root caries treatment in vitro	Aoki, A.	1998	183
Shear strength of composite bonded to Er:YAG laser-prepared dentin	Visuri, SR.	1996	182
Bonding to Er-YAG-laser-treated dentin	Ceballos, L.	2002	162
Wet versus dry enamel ablation by Er:YAG laser	Burkes, EJ.	1992	147
Differences in bonding to acid-etched or Er:YAG-laser-treated enamel and dentin surfaces	Martinez-Insua, A.	2000	141
Erbium:YAG laser application in caries therapy. Evaluation of patient perception and acceptance	Keller, U.	1998	137
In-vitro studies on laser scaling of subgingival calculus with an Erbium:YAG laser	Aoki, A.	1994	133
Non-surgical treatment of peri-implant mucositis and peri-implantitis: a literature review	Renvert, S.	2008	128
The effect of lasers on dental hard tissues	Wigdor, H.	1993	127
Lasers in nonsurgical periodontal therapy	Aoki, A.	2004	116

Table 3. The 10 authors who have published most articles about Er:YAG laser (WoS category: "Dentistry, Oral surgery, Medicine") 1985-2015. Total number of articles=458

Author	No. of published articles	% of 458
Schwarz F.	29	6.3
Becker J.	21	4.5
Sculean A.	19	4.1
Aoki A.	18	3.9
Pekora JD.	18	3.9
Ishikawa I.	15	3.2
Corona Sam	13	2.8
Hickel R	12	2.6
Jepsen S	12	2.6
Palma-Dibb RG.	12	2.6

The co-citation analysis showed the impact of, and the relationships between, scientific journals (Fig. 2) and authors (Fig. 3) in published articles about Er:YAG laser from 1985 to 2015. The Journal of Periodontology, Journal of Clinical Periodontology, Clinical Oral Implant Research, Journal of Endodontics and Journal of Dental Research are among the journals with highest attention (Fig. 2).

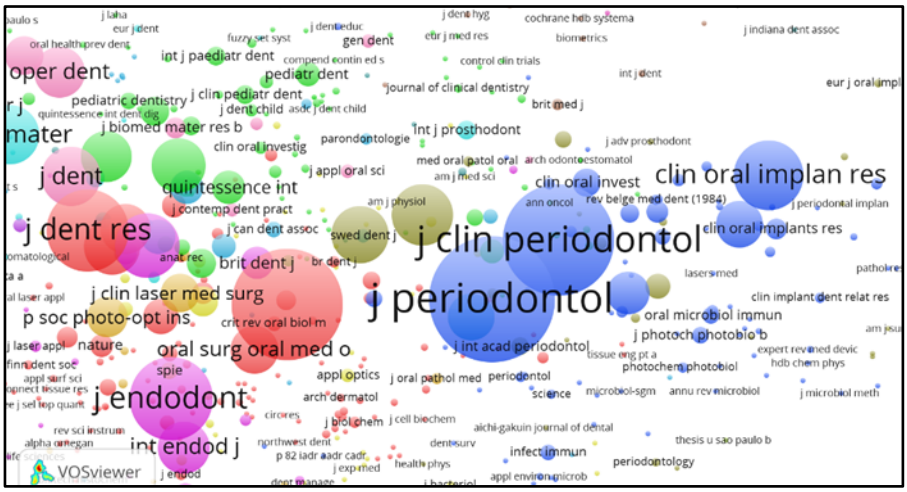

Figure 2. Visualization of journals with most co-citations in Vosviewer 1985-2015

Figure 3. Visualization of authors with most co-citations analysed by Vosviewer from 1985 to 2015.

A comparison between Table 3 and Figure 3 shows that several authors who had published the most articles were not among the most co-cited authors. This indicates that the number of published articles is not as important as the content

of the article. Furthermore, only one of the ten authors who had published most articles (Table 3) is included in the list of the ten most cited articles (Table 2).

Quality of restorations

Dental restorations have a limited life span and several factors affect their durability and quality. A permanent filling needs to be replaced several times during a lifetime and every replacement leads to more extensive destruction of the tooth [Brantley et al., 1995]. Treatment decisions concerning replacement of dental restorations may vary greatly, depending on the clinician's subjective judgment [Bader and Shugars, 1995; Gordan et al., 2009].

The first standardized method for assessing dental restorations was presented in 1960 through the United States Public Health Service (USPHS) [Ryge, 1980]. The USPHS system has been used widely and has been updated to include today's knowledge regarding dental restorations [Cvar and Ryge, 2005]. Studies shows that operator, material and patient factors affect the longevity of restorations [Jokstad et al., 2001]. In a systematic review study an annual failure rate (AFR) of 1.8% over a five- year period has been shown for posterior composite restorations. The main reasons for failure of restorations were fracture and caries [Opdam et al., 2014]. The same study showed that patients' caries activity had a major impact on the durability of restorations and could affect the AFR value up to 3.2% over a five-year period.

A couple of studies have compared the quality of restorations made after excavation of caries lesions using laser technology versus rotary bur [Montedori et al., 2016]. After 24 months, the results show no differences in the durability and quality of the fillings made with these two methods [Yazici et al., 2010].

Postoperative symptoms

The development of adhesive restorative materials in combination with patients' aesthetic and environmental demands have led to the increased use of resin composite in dental cavities [Liew et al., 2011]. However, postoperative sensitivity has been reported to be a problem associated with resin composite restorations [Eick and Welch, 1986; Opdam et al., 1998] with studies showing that 30% of the study population experience postoperative sensitivity after posterior resin composite restoration. Different adhesive systems and the degree of micro-leakage under fillings have been studied in order to identify the causes and reduce patients' postoperative problems [Reis et al., 2015].

No reports are available on postoperative sensitivity after excavation with laser technology. Several studies have compared the degree of micro-leakage in association with Er:YAG excavation with leakage after conventional rotary bur excavation with conflicting results [Lopes et al., 2015]. There have been several studies of how the bond strength of composite fillings with a dentin surface are affected by laser or rotary bur excavation. Some studies report no significant difference [Gutknecht et al., 2001] while other studies report negative results after the laser method [Chinelatti et al., 2006].

Oral soft tissue surgery

The use of lasers in oral soft tissue surgery is well documented. Studies have reported shorter surgery time, faster healing and increased patient comfort when using lasers [Pick and Colvard, 1993; Boj et al., 2011]. Lasers with wavelengths absorbed by water, hemoglobin and melanin can be used in oral soft tissue surgery. Argon (514 nm) and KTP (532 nm) lasers with wavelengths in the visible light spectrum are well absorbed by hemoglobin, and therefore they have a good hemostatic effect and can be used for the treatment of vascular lesions [Romeo et al., 2010; Abukawa et al., 2017]. Lasers with near-

infrared wavelengths such as diode (803-1064 nm), Nd:YAG (1064 nm) lasers are also absorbed well by hemoglobin and have a good coagulation and hemostatic effect and so are ideal for the treatment of vascular lesions [Olivi et al., 2011]. Er:YAG laser (2940 nm) and CO_2 laser (10600 nm) belong to mid and far-infrared wavelengths and are absorbed well by water. For this reason they can be used to remove or cut into soft tissue efficiently, as soft tissue contains a high level of water [Olivi et al., 2010; Pie-Sanchez et al., 2012]. The best results in oral surgery are achieved when the appropriate laser wavelength is selected for the target tissue. In the treatment of inflamed tissue that contains more blood and hemoglobin, lasers with visible or near-infrared wavelengths are more suitable. Vascular lesions such as hemangioma or pyogenic granuloma can be treated better with these lasers. However less vascularized lesions such as fibroma respond better to mid or far-infrared laser treatment with efficient vaporization [Olivi et al., 2007].

Labial frenum & frenectomy

Labial frenum is an anatomical structure made of collagen tissue, elastic and muscle fibers that connect the upper lip to the mucosa of the alveolar process [Edwards, 1977; Delli et al., 2013]. The labial frenum can prevent optimal tooth brushing, or be the cause of gingival retraction or midline diastema if it is too closely attached to the marginal gingiva [Huang and Creath, 1995; Delli et al., 2013].

A frenectomy is a surgical procedure which involves the complete removal of the frenum and its attachment to the periosteum and can be performed with several different techniques such as conventional scalpel technique, electro surgery and laser technique [Devishree et al., 2012]. The surgery can also be performed in different ways depending on the type and shape of the frenum

and its attachment. Different surgery techniques such as Millers technique, Z plastic surgery and VY plastic surgery have been described in the literature [Devishree et al., 2012]. Laser technology using different lasers has been used in oral surgery since the early 1990´s.

Frenectomies performed using different laser wavelengths have been reported in the literature as causing less post-operative discomfort than the conventional scalpel method [Haytac and Ozcelik, 2006a; Cervetto et al., 2011]. The Er:YAG laser has been shown to provide an effective and safe method for performing frenectomies, with high patient acceptance and no postoperative side effects [Olivi et al., 2010; Pie-Sanchez et al., 2012].

Patients' experiences of dental treatment

When treatment or interventions are evaluated the patients' own opinion is valuable. Patient Reported Outcomes (PRO) involve direct reports from the patient without interference from health professionals. PRO includes information about how patients function and feel about their medical condition and care therapy. Data are obtained directly from patients through interviews, self-completed questionnaires, diaries or other data collection tools [Cochrane collaboration, 2018]. Studies shows that use of PRO in clinical practice has a positive impact on diagnosis, treatment and clinicians' communication with patients [Marshall et al., 2006; Valderas et al., 2008].

Questionnaires are the most common method of collecting PRO data. The method is cheap and easily adapted to different circumstances and can be distributed to a large group of people. However, the questionnaire needs a researcher with sufficient knowledge of the subject to be able to ask the right

questions and provide the appropriate response options required to achieve valid and reliable results [Rattray and Jones, 2007]. When knowledge is lacking in an area, qualitative methods, for example interviews with open questions, may be used. Interviews give a deeper understanding of patients' opinions and, at a later stage, knowledge gained from the interviews can be used to construct valid questionnaires.

The intention of this thesis

The Public Dental Service in Uppsala County made a major investment in laser technology in 2009. Several dental clinics bought laser equipment and several dentists underwent training at Aachen University in Germany to start working with the method. The laser method was at that time a new and unknown method for many dentists in Sweden. The investment in laser technology was the major reason for a scientific evaluation of the method.

In this thesis two treatment areas were chosen for study– the excavation of caries and soft tissue surgery – and the outcomes focus on the patient's experiences and the clinical applicability of the methods. The general hypothesis was that patients would prefer laser to conventional methods, that treatment outcomes would be equivalent and that the clinical applicability of treatment would vary.

Aims of the thesis

General aim

The overall aim of this thesis was to study Patients' perceptions and experiences of Er:YAG laser method in excavation of caries and oral soft tissue surgery through qualitative and quantitative studies. In addition the aims were to evaluate the clinical applicability of the method.

Specific aims

Study I

The aim was to obtain a deeper understanding of patients' experiences and perspectives of dental caries treatment with Er:YAG laser technology.

Study II

The aim was to evaluate patients' experiences of two excavations methods, Er:YAG laser and rotary bur and time required by the methods as well as assessments of quality and durability of restorations over a two-year period.

Study III

The aim was to compare frenectomy when performed with Er:YAG laser technology compared with conventional scalpel technique regarding wound healing, patients' experiences, treatment time and bleeding during treatment.

Materials and methods

All studies *(Studies I to III)* were approved by the ethics committee at the Faculty of Medicine, Uppsala University, Sweden. Informed consent was obtained from all participants before the start of the study. For participants younger than 18 years old, consent was also obtained from their legal guardians. *Study I* was a qualitative interview study in which participants were interviewed after caries excavation using a laser method, while *Studies II and III* were prospective, single-blind, randomized and controlled investigations. *Study II* had a split mouth design. Table 4 shows a summary of *Studies I to III.*

Table 4. A summary of *Studies I , II and III.*

Study	Design	Participants Number	Age	Follow-up period	Outcome
I	Qualitative Interviews	12 individuals	15-30 yrs.	---	Subcategories/ categories
II	RCT Single-blind Split mouth	25 individuals 56 cavities	15–37 yrs.	24 mo.	Patients' experiences Treatment time Quality of restorations
III	RCT Single-blind	40 individuals	8–13 yrs.	3 mo.	Patients' experiences Treatment time Bleeding Wound healing

Participants and pretreatment procedures

Study I

Twelve patients aged from 15 to 30 who had undergone at least one caries excavation using a laser method at one of three dental clinics within the Public Dental Service in Uppsala County, Sweden, were strategically selected to participate in this interview study. Participants of both sexes, of different ages and with varying experience of dental care were chosen to obtain variation in the data.

Pretreatment procedures

The interviews were performed by a dentist and a dental hygienist experienced in qualitative studies, but who were not involved in the treatment of the participants, two weeks or more after laser treatment. The participants were given the opportunity to cancel their participation without having to give specific reasons. The interviews took place at a neutral place, such as a library or an office, and the place was chosen by the participants.

Study II

A total of 25 participants were recruited among patients of the Public Dental Service (PDS) in Uppsala County. The patients' dental therapist identified them as appropriate participants when they came for regular dental examinations and fulfilled the inclusion criteria i) age between 15 and 40 years old, ii) two primary caries lesions of equal size, assessed in bite-wing radiographs, in need of treatment, iii) the pairs of cavities located on either occlusal or approximal surfaces, and iv) the cavities not deeper than two-thirds of the outer part of dentin. Patients with severe general diseases (ASA>2), cognitive or intellectual disabilities and patients who required sedation or general anaesthesia, were excluded from the study.

Pretreatment procedures

An experienced dentist responsible for the study examined the bite-wing radiographs of the preliminarily selected patients and took the final decision whether the patient met the inclusion criteria or not. After agreement to participate in the study the cavities were randomly allocated to rotary bur or Er:YAG laser groups. The order in which the methods were to be used was randomized by using 30 sealed envelopes. For each participant, one caries lesion was treated using the rotary bur and one using the Er:YAG laser technique.

Study III

All patients between 7 and 19 years of age who had been referred to a specialist paediatric dentistry clinic and with an assessed need for a frenectomy for the upper labial frenum, were invited to participate in the study. The following criteria for inclusion in the study were used: i) 7 to 19 years of age, ii) referred to specialist clinic, and iii) in need of frenectomy for the upper labial frenum. Patients with severe general diseases (ASA>2), smokers and patients who required general anesthesia during the treatment were excluded from the study.

Pretreatment procedures

After a clinical examination and, if needed, radiographs to exclude pathology in the frenum area, an experienced paediatric dentist took the final decision that the patient could be included in the study. The participants were randomly allocated to either the conventional scalpel group or Er:YAG laser group by opening 40 sealed envelopes divided into four blocks. Prior to surgery the following registrations were recorded: i) distance between the insertion of frenum and the highest point of papilla, ii) size of midline diastema, and iii) photographs of the frenum using a standard photography technique.

Treatment procedures

Study II

Three experienced dentists at the PDS in Uppsala County, trained in the laser technique, performed all treatments. Before the study started the dentists were calibrated as regard to study protocol and laser settings. An Er:YAG laser with a wavelength of 2940 nm was used and, in the rotary bur group, high and low-speed hand pieces for preparation of the tooth. The sensibility of the tooth was tested and an apical radiograph was taken to exclude periapical pathology

before the caries excavation. The duration of the treatment was measured with a timer and included time spent on local anaesthesia and excavation to hard/firm dentin. The definition of excavation time was the point at which the treatment session using the laser or rotary bur started, until the cavity was assessed as free of caries and ready for restoration. Anaesthesia could be chosen before or at any time during the excavation. The time for anesthesia was registered in those cases where anesthesia was requested by the patient during the excavation. The therapists were not allowed to use the rotary bur in the laser group and vice versa. At each visit one tooth was treated and each individual's treatments took place approximately one week apart. The same filling and bonding material was used for all cavities after first being etched using phosphoric acid. A bite-wing radiograph was taken after completion of the filling at the end of the treatment.

Study III

All treatments, irrespective of surgery method, were performed by the main researcher. Administered with a computer injection system, all patients received 0.9 ml local infiltration anesthesia. Er:YAG laser technique (AT Fidelius plus 3, Fotona, Slovenia) with handpiece R014 was used in the laser group (n=20). The settings were in accordance with the manufacturer´s recommendations for use in frenectomy, i.e. pulse length VLP mode (1000 microseconds), pulse energy 150 mj, pulse frequency 10 without supply of air and water. A sterile disposable scalpel was used in the conventional surgery group (n=20). An absorbable suture was used in all cases in the conventional surgery group and in two cases in the Er:YAG laser group. The duration of surgery, defined as the time from when the therapist initiated the procedure with laser or scalpel until the surgery was ended, including suturing and hemostasis, was measured with a stopwatch. Bleeding during surgery was measured with a balance with a high degree of accuracy. Sterile compresses

were weighed before the surgery and, after the compresses had absorbed blood, they were weighed again. After the surgery was completed, the difference in weight before and after surgery was noted. The wounds were photographed with the same camera and settings directly after surgery and on all other occasions. The patient was told to bathe the wound gently with chlorhexidine solution for 10 days postoperatively.

Evaluation of patients' experiences

Study I

Interviews

A semi-structured interview guide was used which allowed the participants to describe the topics in a relaxed manner. The interview guide contained questions about the participants' background, experience of dental care, dental health as well as their experiences of laser treatment and future choice of treatment. The interview guide was adapted to new perspectives when the participants expressed new views during the interview. The interviews were performed, transcribed and analysed in Swedish and translated into English by a professional translator.

Analysis

The transcribed text was analysed using manifest and latent qualitative content analysis as described by Graneheim and Lundman [2004]. The 12 whole interviews, each of which lasted 20 to 30 minutes, formed the *units of analysis*. The units were of adequate size to be considered a whole and, at the same time, serve as a context for the *meaning unit* during the analysis process. To obtain an overall understanding all authors independently read through each interview several times, after which the analysis was continued by two authors further condensing the meaning units to form codes. This can be described as labels

for the meaning units with the purpose to expose new and different aspects. The codes were then sorted into sub-categories and gathered into categories.

Questionnaires

The questionnaires included questions about the patients' views regarding visiting a dentist, their feelings about receiving local anaesthesia, and their experiences of the completed treatment. They marked their agreement, disagreement, using a Visual-Analogue-Scale (VAS), with several statements about the discomfort/pain and the degree of satisfaction associated with the treatments.

Study II

Immediately after treatment the patients responded to a questionnaire for each tooth treated. A second questionnaire was answered one week after each treatment. The questions in both questionnaires were based on patients' views and statements in the earlier interview study *(Study I)*. The questionnaires included questions about the patients' views regarding visiting a dentist, their feelings about receiving local anaesthesia, and their experiences of the completed treatment. They marked their agreement/disagreement, using a Visual-Analogue-Scale (VAS), with several statements about the discomfort/pain and the degree of satisfaction associated with the treatments. In addition, they gave their opinion as to whether they would choose the laser method in future. Furthermore, one week after treatment patients indicated in multiple choice questions whether they had experienced pain or not, and if they had had to take any action because of the pain. Six, 12 and 24 months after the treatment the patients again answered a short questionnaire in which they were asked to mark their agreement/disagreement with statements, using a VAS scale. The participants described how uncomfortable it had been to remove

carious tissue, and which method they would prefer if it became necessary to treat a tooth in the future.

Study III

Immediately after the surgery, patients answered a questionnaire about their experiences in dental care and opinions about the completed treatment. They were asked to consider statements and mark disagreement/agreement on a VAS scale. On the follow-up occasions, five days, twelve days, and three months after surgery, a questionnaire with questions about the patients' opinions of the treatment, and symptoms after treatment, were distributed. The patients answered by responses on a VAS scale, sometimes with assistance from their parents.

Clinical evaluations

Study II

Clinical evaluations were performed six, 12 and 24 months after the treatment. All evaluations were implemented by the main researcher, a dentist specializing in paediatric dentistry. All data was blinded until after the 24-month check-up. At each assessment and for each tooth the following evaluations were performed and the results registered in a protocol: i) sensitivity of the tooth, ii) one clinical photograph of the restoration with occlusal view, iii) one apical and one bite-wing radiograph, exposed after 12 and 24 months, iv) assessments of restorations with regard to retention, marginal integrity, marginal discoloration and secondary caries according to modified Ryge's criteria [Ryge, 1980] after six, 12 and 24 months.

A flow chart of the study from the sampling of participants to 24 months after treatment, is shown in figure 4. Immediately after treatment, and one week after, one questionnaire was collected per treated tooth. At evaluations six, 12

and 24 months after the treatments, one questionnaire was collected per individual on each occasion.

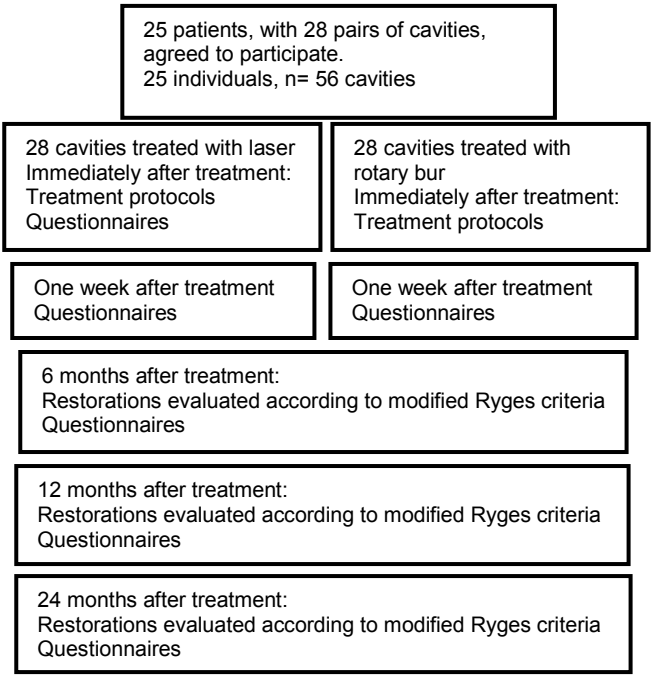

Figure 4. Flow chart of study II.

Study III

The evaluations were performed five days, twelve days and three months after surgery. The sutures were removed at the five-day evaluation. The dentist who performed the surgery implemented the evaluations five and twelve days after treatment, while the evaluation three months after treatment was performed by a specialist in oral and maxillofacial surgery who was not informed of which surgical technique had been used for the individual patient. After three months, the distance between the insertion of frenum and the highest point of papilla, the size of midline diastema and scar formation, were evaluated. Wound healing was evaluated by using photo editing software. The surface that was not covered by epithelium was measured on the standardized photographs and

the size of the area was calculated by the computer program. The measurements taken in ten photos were repeated three weeks after the first measurement. Intra-examiner reliability was calculated from the two measurements. Figure 5 is the flow chart of Study III.

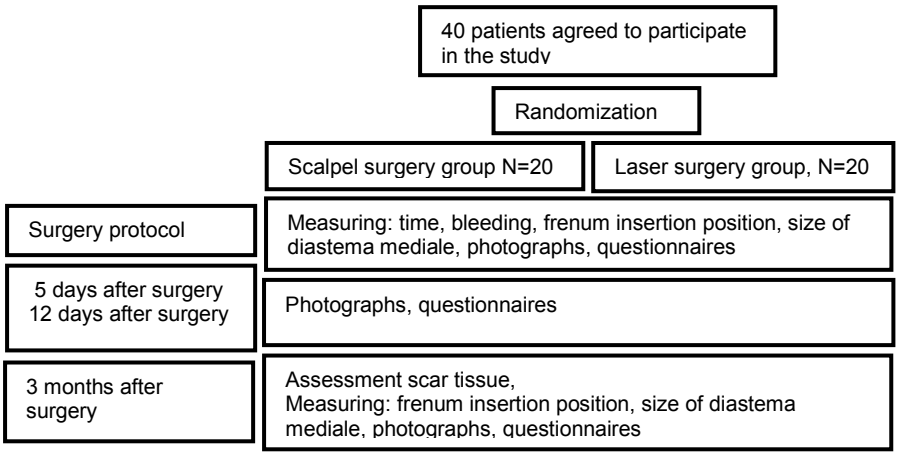

Figure 5. Flowchart of study III

Managing data and statistical analysis

All data in Studies II and III was gathered in protocols designed for the studies. A database was created for each study. The main researcher transferred all data from the protocols to the databases.

Statistical analysis Study II

A power analysis based on a previous study [Keller et al., 1998], indicating that 80 % of the patients would chose laser treatment compared with the null hypothesis of 50 %, showed that 25 patients were needed to keep the power between 80 and 90 per cent and still allow some dropouts. Continuous variables were analyzed using linear and generalized linear mixed models, with

random patient effects and fixed period and treatment effects. Patients' views on the degree of discomfort/pain during treatment included discomfort with local anesthesia, and visiting the dentist in general, as covariates. If normally distributed residuals were not fulfilled, continuous response variables were transformed using natural logarithms and reported as ratios. Statistical comparison for the risk of reaching restoration score Charlie on the modified Ryges criteria was made using a generalized linear mixed model, with random patient effects and fixed period and treatment effects. A t-test with a null hypothesis of 50 on the VAS scale was performed for the question about choosing laser in future. A P-value <0.05 from two-sided tests was considered statistically significant.

Statistical analysis Study III

The power calculation was based on an estimation that the epithelial coverage should be completed three days faster after laser surgery. In total, 40 patients were included since a sample size of 20 in each group was calculated to have 80 % power, with a significance level of 0.05 to detect this difference.

Baseline data was shown as means or medians for continuous variables and percentages for categorical variables. Where appropriate, comparisons between baseline variables were performed using t-tests and Chi-Squared tests. T-tests were used to compare VAS answers, amount of blood, and wound areas. Changes in the distance between frenum attachment and diastema were analysed by linear regression, with the three-month value as a dependent variable and adjusting for the baseline value. Concerning the epithelium coverage, intra-examiner reliability was tested using intra-class correlation. The level of significance was set as $p<0.05$.

Results

Results study I

Seven women and five men between 15 and 30 years of age (median 20.5 years) with experience of laser treatment were interviewed. The majority of the participants had also experienced conventional drilling. The analysis consisted of four categories: choosing laser, understanding laser, encouraging dental care and my oral health. Figure 6 shows the subcategories making up two of these categories.

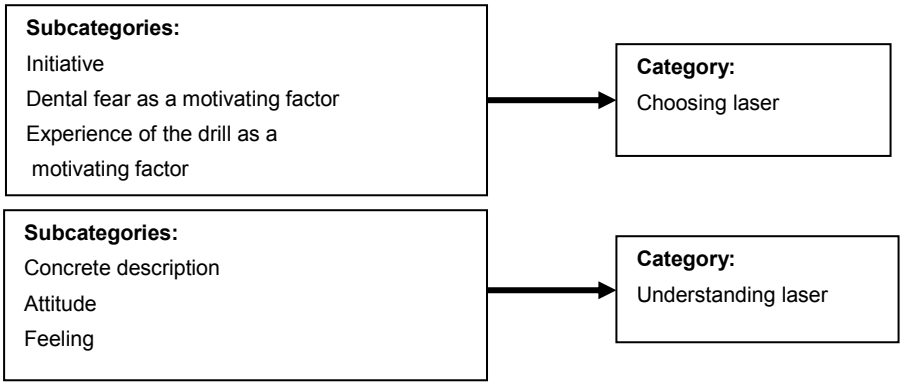

Figure 6. Examples of subcategories forming categories.

Choosing laser

The three subcategories making up this category included: initiative, dental fear as a motivating factor and experience of drilling as a motivating factor. Some participants described how it was the dentist who initiated the laser treatment: *"The dentist was the one who asked me."* Others stated that they found out about laser and asked for laser treatment themselves *"I read about laser in the paper… and it sounded great."*

Dental fear as a motivating factor was common. Both fear of dental treatment in general and specific fear of certain aspects of treatment, were described. Drilling was often mentioned as being unpleasant and was a strong motive for choosing laser treatment, even among those who had never experienced drilling. *"There´s a big drill that sounds a little lower and a sharper drill that sounds higher. I don´t know which I hate more."*

Understanding laser

The three subcategories making up this category included: concrete description, attitude and feeling.

The description of laser treatment was concrete and included many details including perceptions as safety, smell, taste, pain and aesthetics. The sound was described as a ticking, rattling sound like popcorn: "*Well, it is a bit noisy, it kind of shoots right through you, I can't really explain it, but it isn't the kind of thing that scares you, really."* Treatment time was described as both shorter and longer than drilling treatment, but even if the treatment was perceived as longer the participants preferred it.

The attitude to laser treatment was favorable, especially among those who had experienced drilling. The technique was considered more precise, considered and professional. A positive feeling regarding laser treatment were common. The treatment was felt to be safe and allowed the patient to relax during treatment: "*... the next time if there is a next time it will definitely be laser. The results looked a lot better, it took no time at all, and I didn't feel a thing."* Most participants stated that they would spend both time and money in order to have laser treatment.

Encouraging dental care

The two subcategories making up this category were: response and participation and laser in the future.

Participation in the treatment, i.e. receiving information and being able to exert influence, was considered important. The patient needed encouragement and praise during treatment and to feel that the dentist cared. "*I felt secure and calm and they were, like, pedagogical. …They told me what they were doing, and what tools they were using…"* The participants stated that laser would be their choice if they had to get new fillings in the future. Their belief in laser as the technology of the future seemed strong.

My oral health

The subcategories making up this category were: fresh and good-looking, healthy and own responsibility.

Good-looking teeth and fresh breath were very important for the participants' self-esteem. Having healthy teeth and avoiding oral diseases were also considered important. They were aware of the connection between oral hygiene, good diet and dental health – "*Teeth are so important, good teeth are a real sign of how your health is and what your life is like otherwise"*. The participants were also aware of the importance of dental self-care, including daily toothbrushing with fluoride toothpaste, flossing and mouthwash. Some stated that increasing age resulted in individuals taking oral care more seriously and taking a greater responsibility for their own oral health.

Results study II

In total 32 patients were asked to participate in the study. Seven of these patients declined meaning that 25 patients, 12 men and 13 women, were included in the study. The mean age was 22.6 years with a range of between 15 and-37 years old. Three subjects had two pairs of equivalent cavities and 22 had one pair each, making the total of 56 cavities included in this study. Out of these, 28 were treated with laser and 28 with rotary bur. After six, 12 and 24 months a total of 52, 50 and 40 restorations were evaluated (figure 4). One fifth of the cavities were occlusal lesion, the rest were approximal lesions.

Time required

The mean time for excavation by laser was 13.2 min and by rotary bur 4.3 min ($p < 0.0001$). Fewer patients needed local anaesthesia in the laser group (N=10) compared with the rotary bur group (N=15) and thus the mean time for the administration of anaesthesia was shorter in the laser group. The time for anaesthesia and excavation taken together was 15.9 minutes for the laser group and 8.0 minutes for the rotary bur group ($p<0.0001$).

Patients' views

In general, the participants were not uncomfortable about meeting a dentist although the experience of being anesthetised was more problematic for some patients (mean value 38 and 51, respectively, in a VAS-scale, Fig 7).

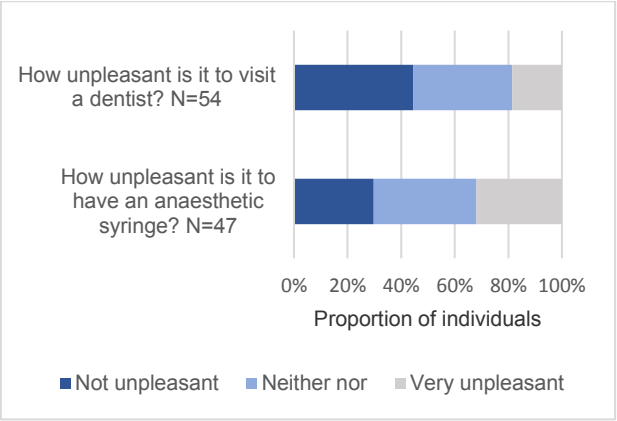

Figure 7. Participants' answers at time of treatment on a VAS-scale. Not pleasant= 0-33 on the VAS-scale, Neither nor= 34- 66, Very unpleasant= 67-100.

Patients assessed the degree of discomfort of the treatment directly afterwards, then one week, six, 12 and 24 months after treatment. Immediately after treatment the two treatment methods were estimated as producing the same amounts of discomfort, but in following evaluations the rotary bur was rated as producing significantly higher levels of discomfort (Fig. 8).

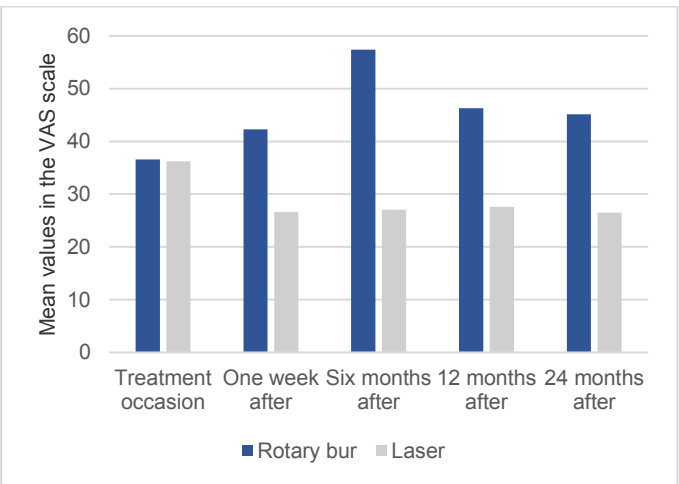

Figure 8. Mean values of marks on a VAS scale showing degree of discomfort during treatment.

Immediately after treatment patients were asked to choose between several different options describing the best of laser and rotary bur methods. Several responses could be selected, and the answers were weighted depending on whether the selection was a first, second or third choice. In Figure 9 the distribution of weighted answers is shown. The main advantages of laser method were that it did not hurt, no anaesthesia was necessary and the drilling sound was avoided. The most common advantage of the rotary bur was that the treatment was faster. However, this result must be interpreted with caution since almost 30 % of participants did not answer the question.

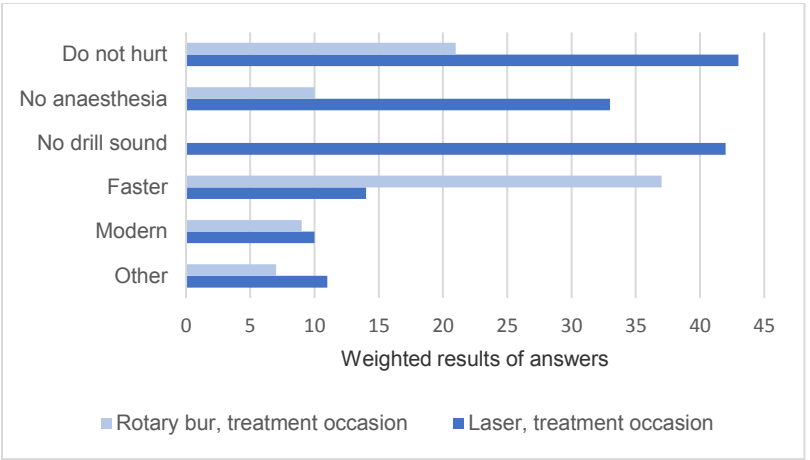

Figure 9. Advantages of the two methods expressed immediately after treatment.

The questionnaire also asked about postoperative symptoms. The differences between the methods were small and not statistically significant (26% for rotary bur and 19% for laser method). The participants also were asked to consider statements about their future choice of treatment method. On all evaluation occasions, participants preferred laser to drill (p=0.001-0.003).

Restorations

The restorations were evaluated after six, 12 and 24 months using Ryges modified criteria. After six months, three of the restorations in the rotary bur group had quality defects. Two restorations in each group showed deficiencies after 12 months and, in addition, two restorations in each group were diagnosed with secondary caries and needed to be redone after being classified at level Charlie according to Ryges criteria. After 24 months, in the laser group two additional restorations were in need of redoing owing to secondary caries. In Figure 10 the registrations of secondary caries in accordance with Ryges criteria are shown. To summarise, four laser treated cavities (14.8%) and two rotary bur treated cavities (7.4%) were redone due to secondary caries at level Charlie (figure 10).

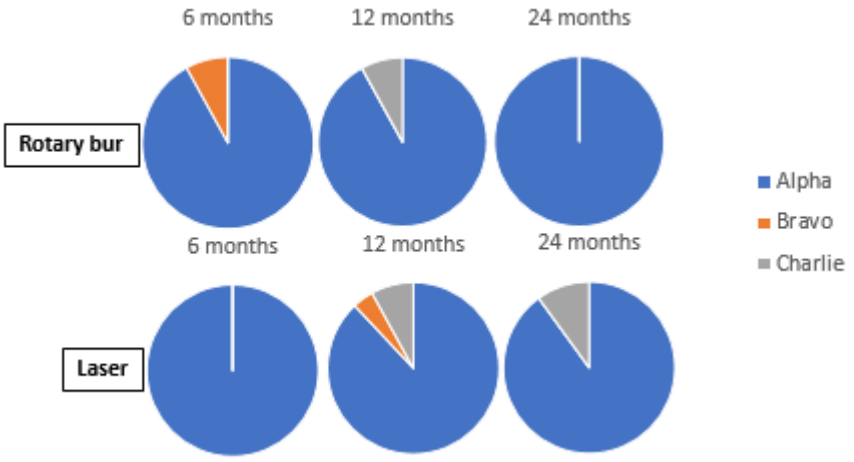

Figure 10. The proportion (%) of registrations of secondary caries shown as Ryges criteria 6 to-24 months after treatment.

Results study III

In total 40 patients met the inclusion criteria, agreed to participate and thus were consecutively included in the study. In addition, nine patients were invited to participate but did not accept and three were excluded due to exclusion criteria. Following the randomization process, 20 patients were allocated to a group to be treated with conventional surgery (scalpel) and 20 to a laser surgery group (Fig. 5). The participants were 7 to -15 years old, with no age difference between the groups. There were more girls in the conventional surgery group (90% vs 60% in laser surgery group). The participants marked on a VAS scale how uncomfortable it was to go to the dentist and to receive local anaesthesia in general. They did not feel uncomfortable visiting the dentist (mean 17.6, on a scale where 0 showed not uncomfortable and 100 very uncomfortable). However, the reported values were higher for local anaesthesia, mean 29.9, but the report still indicated limited discomfort. No differences between the treatment groups could be seen.

Before treatment variations in the distance between the frenum attachment and the highest point of the papilla, between 0 and 3.5 mm, were registered. This distance was longer at the three-month follow-up, but without showing any difference between the treatment groups. A midline diastema between 1.4 and 3.4 mm was noted at baseline, and this diminished by 0.62 to-0.97 mm in the two groups without showing any statistically significant differences between them. The scalpel surgery took on average 10 min 35 sec to perform and laser surgery 6 min 52 sec ($p<0.001$). Bleeding during surgery was limited. In the scalpel group the mean was 1080 mg (1.0 ml) and in the laser group it was 332 mg (0.3 ml), meaning bleeding was three times as high in scalpel surgery ($p = 0.040$). In the scalpel group suturing was done in all cases but in only two cases in the laser group. When scar formation was evaluated after three months, no

differences could be seen between the two techniques. The participants answered questions about discomfort and pain during treatment by marking responses on a VAS scale and also indicated their degree of satisfaction with the treatment. The questions were repeated five and twelve days, and three months, after treatment. On all occasions, and in both treatment groups, the estimation of the discomfort was low (mean 13.5-22.1, scale 0-100, 0 not uncomfortable and 100 very uncomfortable). Satisfaction with the treatments was high (mean 83.5-93.2) with no differences between groups (Fig. 11). The estimation of pain was also low (mean 12.6-27.2). Approximately half of the patients, with no differences between the groups, reported using pain relief drugs after treatment. One patient in the scalpel group had taken antibiotics.

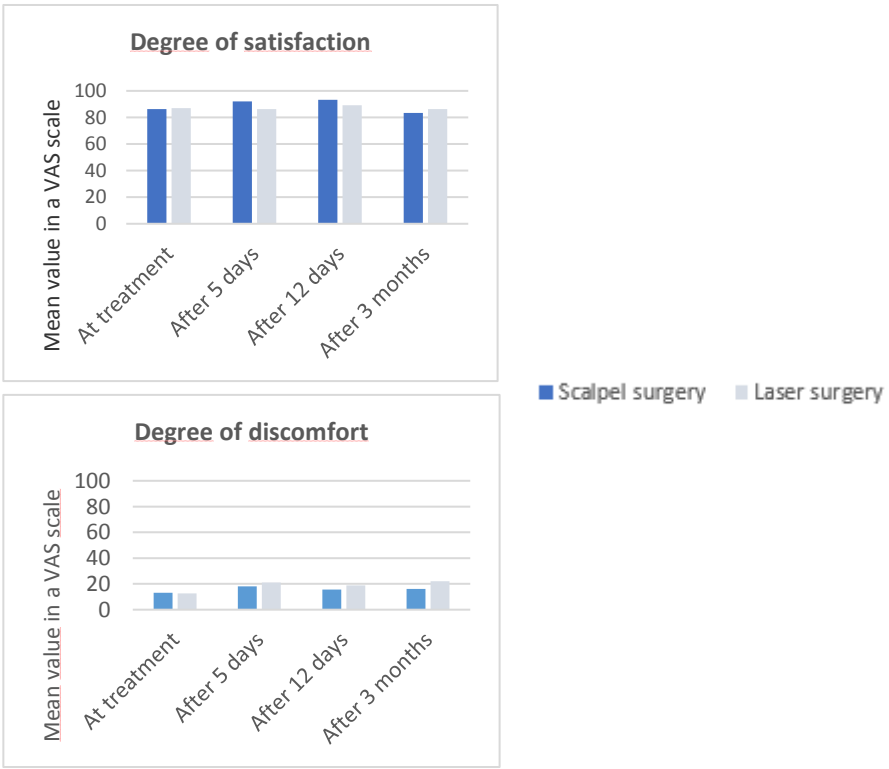

Figure 11. Mean values of marks on a VAS scale showing degree of discomfort during the treatment and degree of satisfaction with the treatment.

Immediately after laser surgery the wound was clearly larger than after scalpel surgery (mean 66.8 and 19.1 square millimetres respectively, $p<0.001$). After five days the area not covered by epithelium was equal in both groups (Fig. 12). Twelve days after surgery, all wounds were covered by epithelium in both groups. Intra-examiner reliability was tested and showed a strong level of agreement directly after treatment and after five days.

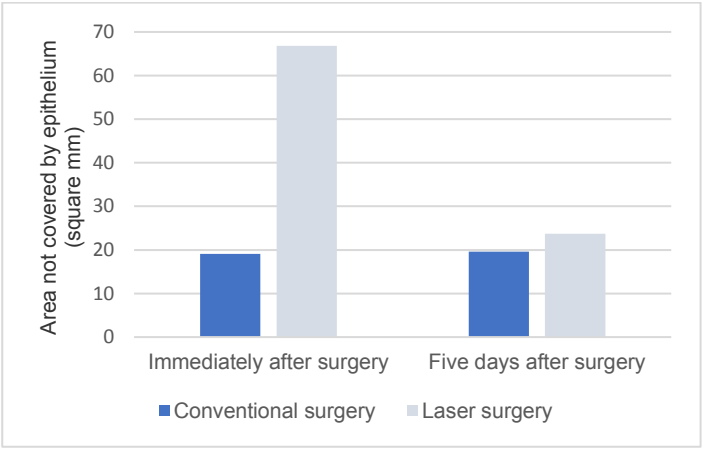

Fig.12 The wound area not covered by epithelium immediately after surgery and after five days.

Discussion

Methodological considerations

In this thesis we have used both qualitative and quantitative data to gain knowledge about the patients' experiences and to understand their perception of dental care. In Study I qualitative data was collected through interviews with open-ended questions, while in Studies II and III, quantitative data was gathered by questionnaires with multiple choice answers and responses to statements on VAS scales. The advantage of combining these two research methods is that they complement each other and lead to a deeper and broader understanding of the aspects being studied [Hallberg, 2002]. Quantitative research methods aims to present a large amount of data which establishes consistency, which in turn makes general conclusions possible. Qualitative research, on the other hand, tries to understand and interpret personal experiences and social phenomena which means that variations and inconsistency is the goal of data collection [Huston and Rowan, 1998]. Thus, the combination of interviews and questionnaires, a triangulation, results in larger variations in opinions and feelings as well as a greater opportunity to make general conclusions from data. In this thesis, the aim was that the studies would together confirm and verify the findings and increase the credibility and validity of the results.

Studies II and III were prospective randomized, controlled and single blind studies. In addition, Study II had a split mouth design with the advantage that the participants were their own controls. On the other hand, the split mouth design may have meant it took longer time to find participants, since they all had to have two primary manifest caries lesions of equal size in need of treatment. The single blind design of Studies II and III resulted in blinded

evaluations of the fillings in Study II and wound healing (three months after surgery) in Study III. It was not possible to design a double-blind study since it was obvious to patients what methods were used in both studies (Studies II and III).

Study population and sample size

In qualitative studies, sample size is determined during the study. In Study I, after 12 interviews saturation was reached, i.e. no new perspectives were found. The participants were of different ages and genders. In addition, they were treated at different locations and had various experiences of dental care. The strategic choice of participants led to gaining varied and complete data. The number of participants in Studies II and III was determined by power calculations based on primary outcomes. In Study II the power calculation of the primary outcome variable, patients' experiences, showed that 25 participants needed to be included. In Study III, the power calculation of the primary outcome, wound healing, was based on three days faster epithelium coverage of the wound in the laser group. A sample size of 20 in each group (a total of 40 patients) was needed to show the differences between the surgical methods.

Interviews in Study I

Individual in-depth interviews were used in Study I. The questions focused on the individuals' own description of actions, feelings and thoughts. Interviews provide a positive experience, allowing the respondents an opportunity to express their thoughts and feelings, as long as they were met with a respectful and humble attitude from the interviewer [Denzin, 2000; Kvale, 2011]. The interview guide was composed of open-ended questions to guide the conversation. The questions were used to keep focus on the chosen subject and

when new ideas were expressed by the participants, the guide was adapted to this new perspective. The interviewer had a dental education, i.e. some pre-understanding of the subject as interviewing without any pre-understanding would make it difficult to ask appropriate follow-up questions. Participants were interviewed two weeks or later after laser treatment in a neutral place and by interviewers who were not involved in the treatments. This allowed participants to describe the treatment openly and honestly. The reason why the interviews were performed after time had passed was that studies have previously shown that patients describe treatments more positively directly after treatment compared to a few weeks later [Kent, 1985].

The analysis method of Study I

Qualitative Content Analysis was selected as the method for analysis. Written, spoken and visual information is described and systematically analysed in this method [Huston and Rowan, 1998]. The content analysis method helps the researcher to structure and understand a large amount of data and can be used with either quantitative or qualitative data in an inductive or deductive way. The inductive approach is recommended when there is not enough knowledge about the studied phenomenon or when there is a lack of theory or hypothesis [Elo and Kyngas, 2008]. In Study I, we used qualitative data and an inductive approach i.e. we had no hypothesis about the laser method. The aim of Study I was to gain a deeper understanding of patients' experiences of the laser method. The analysis focused on describing both the obvious (manifest) and the hidden (latent) meaning or content of the text [Graneheim and Lundman, 2004] and consisted of three main parts: preparation, organizing and reporting [Elo and Kyngas, 2008]. The process stressed the differences between, and similarities within, codes and categories [Graneheim and Lundman, 2004].

The trustworthiness of a qualitative study includes credibility, dependability and transferability [Huston and Rowan, 1998]. Credibility describes how well

data addresses the purpose of the study. In Study I all respondents had experience of the subject being studied. Dependability can be described as how data is persistent over time, and in our case this was achieved by using an interview guide. Dependability was also improved by using an interviewer not involved in the treatment of the informants, which means that informants could more easily talk frankly about the treatment. Transferability, indicating the extent to which research findings can be transferred to a different context, was achieved by carefully describing the research process [Graneheim and Lundman, 2004]. The trustworthiness of the results was enhanced by using respondents' quotes. Quotations also provide evidence for the credibility of the analysis, generating a direct link between the results and the actual data [Graneheim and Lundman, 2004; Morgan, 2010]. The results of Study I were used in designing questionnaires in the later quantitative studies (especially Study II).

Questionnaires in Studies II and III

Patient reported outcomes (PRO) are data obtained from the patient without any interpretation. The patient´s perspective is necessary to determine the efficacy of a treatment. At the same time PRO increases the patient's empowerment and participation in the treatment – the patient's voice in the treatment evaluation is ensured [Deshpande et al., 2011]. A common method for collecting PRO data is questionnaires. When questions are constructed it is important to have enough knowledge of the research area to be able to ask relevant questions and to give patients relevant response options so they can express their perceptions and feelings. In Study II, where PRO (patients' experiences) were the primary outcome of the study, the questions were based on the results from the in-depth interviews in Study I. The participants in the interviews came from the same target population as those in Study II and this probably increased the validity of the questionnaires [Rattray and Jones, 2007;

Calvert et al., 2018]. In Study III the results in the interview study could not be considered as validation of the questions in the same way, since this study described surgery and the participants were significantly younger than those in Study I.

In Studies II and III the questionnaires with similar questions were repeated on several occasions (seven and four times respectively). The reason was to find out if the patient's perception changed over time, something that was true in the excavation study but not in the surgery study. Changes in perception over time can raise questions about what is true – the answers immediately after treatment or those given a week, or even later, after treatment. However, PRO involves seeking reports directly from the patients and without interpretation from health professionals. In this way it is not "the truth" that is sought but the patient's opinion at the moment the question is asked. The time points for assessments should be arranged in line with the trial objectives [Calvert et al., 2018]. In both studies, patients were asked for their opinions about visiting a dentist and getting local anaesthesia in general. These questions were included in the baseline questionnaire which was administered immediately after the treatment. The results may have been affected by the just- completed treatment and it would have been better to have had the participants answer before any treatment had been performed [Calvert et al., 2018]. At the same time, when planning the study protocol we had to consider the demands we were making on the patients, and another questionnaire, although short, could have been too much for them. This may explain the large numbers of respondents who did not respond to the questionnaire one week after treatment in Study II (seven participants in both groups). In addition, internal dropouts occurred since the participants did not answer all questions directly after the treatment. Approximately 30 % left the question about what was best about laser and rotary bur treatment unanswered. Another factor that could have biased the

result is that some participants in Study III were assisted by their parents when answering the questions.

In the questionnaires most data was collected by presenting statements for the participants who were told to mark their responses on a visual analogue scale (VAS scale). The scales are used in research, but also in daily clinical work where their most important field of application is in pain estimation. The scale is linear, has ratio properties but is not always normally distributed. Thus, when dealing with largely skewed distributions, nonparametric statistical tests should be used. Otherwise, the more powerful parametric statistical tests are recommended [Williamson and Hoggart, 2005]. Used as an indicator of pain, the VAS scale has sufficient validity and reliability, taking into account the fact that the pain stimuli would not be the same over time [Lara-Munoz et al., 2004]. However, when indicating low pain levels, VAS scales have been reported to have low validity [Chiarotto et al., 2018]. One limitation of VAS scales could be that patients misunderstand them and use extreme values or do not use parts of the scale at all [Williamson and Hoggart, 2005]. The split-mouth design used in Study II reduces this risk significantly.

Patients' experiences

In the interview study, (Study I), participants were positive to the laser method. They described laser as reliable, comfortable and the method of the future. The results are in line with previous studies [Keller et al., 1998; Liu et al., 2006]. Several participants in Study I had negative experiences of the rotary bur and had developed dental fear. Other studies have also found that noise and vibration from the rotary bur provokes dental fear [Willershausen et al., 1999; Canbek and Willershausen, 2004; Kani et al., 2015]. It is important to note that our intention in Study I was not to recruit participants with negative experiences of rotary bur, However, we found that several participants who

preferred the laser method, had had negative experience of the drill. Some participants in Study I had never experienced the rotary bur but still had a fear of it by having heard stories about unpleasant experiences of the rotary bur from relatives and friends. Studies have shown that dental fear can even come indirectly through exposure to information from others with negative dental experiences [Lundgren et al., 2004]. In Study II the participants did not report dental fear but they still reported reluctance when their dentist used a drill, and thus favouring laser to a conventional bur.

Study II, gave participants the chance to compare methods. All had at least one pair of equal caries lesions in need of treatment and experienced both methods. Directly after treatment, the degree of discomfort was assessed as equal for both methods. One week and six, 12 and 24 months after treatment, the degree of discomfort was assessed as significantly higher for the rotary bur. Studies have previously shown that patients change their description of treatments over time and describe treatments more positively directly after the treatment than a few weeks later [Kyle et al., 2016]. The shift in opinion in our study may be explained by the tendency of the patients to change their opinion with time. When considering statements about the future choice of method, laser was chosen significantly more often on all evaluation occasions. Previous studies confirm the outcome of Study II regarding patient satisfaction with the laser method [Montedori et al., 2016].

In Study III, participants were generally satisfied with the surgical treatments, regardless of method. The estimates of discomfort and pain were low on the VAS scales and the grade of satisfaction was high for both methods. The results of this study conflict with previous studies which have reported less discomfort after frenectomy when laser surgery was used [Haytac and Ozcelik, 2006a ; Cervetto et al., 2011].

Unlike patients, the therapists described laser as a complicated method [Bergholm et al., 2014], but were nevertheless positive about working with it in future because of patients' demands for laser treatment. The therapists' opinion of the laser method may be explained by the fact that use of the method requires knowledge and selection of several parameters such as pulse length, energy per pulse, pulse frequency, amount of water and air, etc. which can make dentists feel it is complicated to work with. However this may also be due to the therapists' uncertainly in using laser. Being able to adjust laser technique to different settings, which was experienced as complicated by therapists, at the same time makes treatment more comfortable for patients.

Treatment time

Most studies report that excavating of caries with laser takes two to three times longer than the rotary bur [Aoki et al., 1998; Keller et al., 1998; Hjertton and Bågesund, 2013]. The result of Study II is in line with the previous studies. It took three times longer to excavate caries with the laser method than the rotary bur, although the total time (local anesthesia and excavation time together) was only twice as long for the laser method. The reason was that fewer patients in the laser group needed local anesthesia, which has previously also been described by Den Besten et al (2001).

Most distal cavities were randomized into the laser group and if we assume that excavation of distal cavities was more time consuming, this could be one explanation of longer treatment times for the laser method. Other reasons for the longer laser treatment times may be the significantly longer time it takes to remove enamel using laser, and the therapists' uncertainty in using the laser method. In addition, an explanation of the longer treatment time may be the absence of tactile sensitivity, which forces the therapist to interrupt the

excavation several times and visually check the status of the cavity. Cavities created by Er:YAG laser in Study II seem, in radiological appearance, to have a more angular and irregular shape than cavities created by rotary bur which have a more rounded and regular shape. This may also be the result of the absence of tactile sensitivity.

For patients who avoid treatment due to fear of the drill, it is a great benefit to receive laser treatment, even if the treatment takes longer. For this group of patients, the opportunity to treat caries lesions before symptoms appear leads to the improvement of oral health, self-esteem and the quality of life [Hakeberg et al., 1993; Moore et al., 2004].

An interesting observation in Study I regarding patients' experiences of treatment time was that some described how laser treatment took less time than the rotary bur. Some of those who felt that laser treatment took more time, expressed the opinion that the dentist was slow because he/she explained every stage carefully. The patients' negative feelings about the drill could explain why the longer treatment time did not influence their positive opinion of laser treatment. However, although the patients in study II stated that laser was superior to conventional bur, the shorter treatment time was ranked as the main benefit of drilling.

Unlike the caries excavation described in Study II, the laser surgery in Study III took a significantly shorter time than conventional scalpel surgery. When various laser methods were compared, time differences in treatment were reported [Pie-Sanchez et al., 2012], which was also found when the scalpel method was compared with a laser method [Medeiros Junior et al., 2015]. However, other studies could not find any time differences [Ize-Iyamu et al., 2013; Suter et al., 2017]. Important reasons for this time gain in Study III,

were that laser surgery group did not need suturation and the bleeding was significantly less during laser surgery. Several studies have compared laser surgery with conventional scalpel surgery and all reported less bleeding when laser was used [Ize-Iyamu et al., 2013; Sobouti et al., 2014; Medeiros Junior et al., 2015].

Quality of restorations

Studies show that operator, material and patient factors affect the quality and longevity of restorations [Jokstad et al., 2001]. Rerestoration of previously restored teeth is a major part of dentists' work and this is expensive [Mjor, 1993]. The main reasons for the failure of restorations is secondary caries and fractures [Opdam et al., 2014].

The two widely used clinical systems for evaluating dental restorations are "Criteria for the clinical evaluation of dental restorative materials"
(Ryge or USPHS criteria) [Ryge, 1980] and "standards of quality of dental care" (CDA criteria). Both evaluation systems evaluate colour, anatomic form and marginal characteristics such as discolouration, adaptation and caries. Both are based on an ordinal scale and on the evaluator's subjective assessment. Several researchers have modified these systems for the assessment of dental restorations [van Dijken, 1986; Allander et al., 1989]. The criticism of these systems is that they describe only the degree of technical excellence of the restorations without taking into account other factors, such as the patient's grade of caries activity. In Study II, the restorations were evaluated according to modified Ryge's criteria which included evaluations of retention, marginal adaptation, marginal discoloration and secondary caries. The split mouth design of the study meant that as to environmental and patient factors, the

restorations were performed and evaluated under the same conditions. The result of Study II is in line with other studies which did not detect statistically significant differences in marginal integrity, durability and secondary caries, between restorations using laser and rotary bur methods [Hadley 2000; Yazici 2010].

Operator factors such as variations in material handling and clinical experience affect the durability of restorations. In a study of 6761 restorations placed in permanent teeth by 243 operators, the durability of restorations was shown to vary according to operators' clinical experience [Mjor et al., 2000]. In Study II the fillings were performed by few dentists of whom one dentist performed 97% of the fillings. The same material was used for both methods. These factors strengthened the reliability of the study.

Regarding secondary caries in study II, twice as many restorations in the laser group were scored Charlie, leading to an annual failure rate (AFR) of 9.1% for the laser group compared with an AFR of 4.5% in the rotary bur group. Examining a larger number of restorations might have detected differences in the durability of restorations, but the number of participants was based on the primary outcome, patients' experiences. Despite the power calculation we aimed to include a larger number of cavities to get a more reliable evaluation of the restorations. However, identifying participants who met the inclusion criteria was difficult and time-consuming. In a previous study [Opdam et al., 2014], 2816 posterior composite restorations treated with rotary bur showed an AFR of 1.8% over a five-year period. The same study showed a variation in AFR from 1.2% to 3.2%, depending on the patients' degree of caries activity. The high degree of caries activity in patients included in Study II can explain the high AFR over a two-year period.

Bonding strength between tooth surface and filling material affects the quality and durability of the restorations. Decreased bonding strength and increased microleakage shorten the durability of restorations and increase the risk of secondary caries. Contradictory results have been published regarding these factors when comparing laser and rotary bur. Some studies reported no difference in bonding strength regardless of the method [Bertrand et al., 2008;], unlike other studies showing a lower bonding strength after laser excavation [Cardoso et al., 2008; Portillo et al., 2015].

Soft tissue surgery and wound healing

The most widely used lasers for oral soft tissue surgery are diode, Nd:YAG, CO_2 and Er:YAG lasers. In Study III, we used an Er:YAG laser. High patient acceptance, less postoperative discomfort and fast healing have been reported as the benefits of Er:YAG lasers in soft tissue surgery [Haytac and Ozcelik, 2006b ; Cervetto et al., 2011]. The hemostatic effect of Er:YAG laser is not as strong as near-infrared lasers (diode and Nd:YAG) and CO_2 lasers, but it offers safe, efficient surgery with low energy levels and a minimal risk of superficial carbonization. After surgery, its hemostatic effect is sufficient to remove the need for sutures, or require only minimal suturation [Olivi et al., 2018]. Lasers' hemostatic effect and its ability to perform precise surgical incisions have been reported previously [Moslemi et al., 2009; Olivi et al., 2009; Ize-Iyamu et al., 2013]. This is in line with our results in Study III, where there was approximately three times less bleeding after using the laser method. A major difference between our study and previous studies is the method of measuring the amount of bleeding during surgery. Previous studies assessed bleeding by using different rating scales while in our study bleeding was accurately weighed on a high precision balance.

A clinical retrospective study of 156 cases of labial frenectomy performed with Er,Cr:YSGG laser showed a reduction in operating time, less use of local anesthesia and no scar tissue [Olivi et al., 2010]. The authors stated the distance between wound margins after laser surgery and the secondary healing to be the reasons for the lack of scar tissue. In Study III, all participants received local anesthesia before surgery and in contrast to Olivi et al. (2010), three months after surgery scar tissue could be seen in all patients except one in laser group.

In Study III, two completely different surgery methods were compared. Immediately after surgery, the wound area was significantly larger in all laser cases but five days later, no difference could be seen between the groups. After twelve days, all wounds were covered by epithelium in both groups. With hindsight, we should have measured the wound surface not covered by epithelium every day between days five and 12 to detect any differences in healing rates between the groups. When comparing CO_2 with Er,Cr:YSGG laser [Pie-Sanchez et al., 2012], the authors presented complete wound epithelization after 14 and 21 days for Er,Cr:YSGG and CO_2 laser respectively, but the method of measuring the wound surface was not described. In Study III, we measured the surface of the wound on standardized, digital photographs using a planimetric software, a method with better precision and reliability than other methods [Khoo and Jansen, 2016]. A marker of known dimension, such as a ruler, is necessary to use for calibration when using the software. In Study III, the edge of tooth 11 was measured and used as a marker to calculate the real size of the wound area. Digital planimetry in measuring chronic wounds has been found to have high intra-examiner reliability [Stacey et al., 2017] as was also found in Study III.

Decreased post-operative pain was reported in a review study of oral soft tissue laser surgery [Seifi and Matini, 2017]. No differences in levels of pain, reported immediately after treatment and on all follow-up occasions, could be detected between the methods used in Study III.

Ethical considerations

In the declaration of Helsinki (WMA 2018) the principles of medical research are stated. In this thesis all studies were approved by the Ethics committee at Uppsala University and thereby followed the declaration. The information given to persons who participate in research should be presented in a simple and clear language to ensure self-determination and voluntariness. Since children were involved in the studies of this thesis the information was adapted to the participants' age and addressed to both the children and their guardians. Regarding caries excavation the patients showed a clear preference for the laser method. At the same time a previous study has shown that dentists found the laser method complicated with high costs and they questioned the benefits for the patients [Bergholm et al 2014]. Caries excavation with the laser method is valuable for patients with dental fear, especially for those who experienced rotary bur frightening. The attitudes from the therapists may lead to that laser technology is not available for patients in need of laser treatment.

Future Considerations

This thesis highlights patients' experiences and clinical applicability of a relatively new method in dentistry and also describes the pros and cons of the method. In the studies, the Er:YAG laser method was compared with conventional methods used in the excavation of caries and oral soft tissue surgery. Patients strongly prefer the Er:YAG laser method to the conventional

rotary bur method in excavating caries, while previous studies indicate that clinicians are not convinced . The Er:YAG laser method is a good complement to the rotary bur but has some limitations. It is not possible to remove metal (amalgam and gold) with a Er:YAG laser. It takes significantly longer to remove enamel and the lack of tactile sensitivity in excavating caries, forces the clinicians to use conventional methods to be able to perform treatments. It is important to point out that the laser machine used in these studies is about ten years old today. The large size of the laser machine we used, the complexity of the method and the need for expensive investment in education and equipment have all been mentioned by clinicians as disadvantages of the method. The rapid development of newer and more modern machines creates the need for investment in new technology after a few years, which is also considered a disadvantage. Regarding oral soft tissue surgery using laser, we observed several benefits and the method was also preferred by clinicians. User-friendly laser machines at a reasonable cost, need to be developed to allow clinicians to use the method to a greater extent in the future.

Conclusions

- Patients experienced less discomfort in connection with caries excavation when the Er:YAG laser method was used.

- Patients expressed a preference for the Er:YAG laser method as an excavation method in the future.

- The Er:YAG laser method is more time-consuming in the excavation of caries than the rotary bur method.

- No statistically significant differences could be seen, either in quality or durability of restorations, between the two methods over a two-year period.

- No differences concerning epithelium coverage of wounds could be identified between the methods used.

- Er:YAG laser surgery is less time-consuming and causes less bleeding than scalpel surgery in frenectomy procedures.

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References

Abukawa H, Kono M, Hamada H, Okamoto A, Satomi T, Chikazu D: Indications of potassium titanyl phosphate laser therapy for slow-flow vascular malformations in oral region. J Craniofac surg 2017;28:771-4.

Allander L, Birkhed D, Bratthall D: Quality evaluation of anterior restorations in private practice. Swed Dent J 1989;13:141-50.

Aoki A, Ishikawa I, Yamada T, Otsuki M, Watanabe H, Tagami J, Ando Y, Yamamoto H: Comparison between Er:Yag laser and conventional technique for root caries treatment in vitro. J Dent Res 1998;77:1404-14.

Bader JD, Shugars DA: Variation in dentists' clinical decisions. J Public Health Dent 1995;55:181-8.

Bagramian RA, Garcia-Godoy F, Volpe AR: The global increase in dental caries. A pending public health crisis. Am J Dent 2009;22:3-8.

Baldissara P, Catapano S, Scotti R: Clinical and histological evaluation of thermal injury thresholds in human teeth: A preliminary study. J Oral Rehab 1997;24:791-801.

Banerjee A, Domejean S: The contemporary approach to tooth preservation: Minimum intervention (MI) caries management in general practice. Prim Dent J 2013;2:30-7.

Banerjee A, Frencken JE, Schwendicke F, Innes NPT: Contemporary operative caries management: Consensus recommendations on minimally invasive caries removal. Br Dent J 2017;223:215-22.

Bergholm A, Ostberg AL, Gabre P: Implementation of laser technology and treatment at county level in the swedish public dental service. Swed Dent J 2014;38:111-20.

Bertrand MF, Brulat N, Lazzarini V, Marcato G, Namour S, Rocca JP: Er:YAG laser cavity preparation and semi-direct composite resin restoration: A microleakage study. Photomed Laser Surg 2008;26:473-7.

Boj JR, Poirier C, Hernandez M, Espassa E, Espanya A: Review: Laser soft tissue treatments for paediatric dental patients. Eur Arch Paediatr Dent 2011;12:100-5.

Brantley CF, Bader JD, Shugars DA, Nesbit SP: Does the cycle of rerestoration lead to larger restorations? J Am Dent Assoc 1995;126:1407-13.

Burkes EJ, Jr., Hoke J, Gomes E, Wolbarsht M: Wet versus dry enamel ablation by Er:YAG laser. J Prosthet Dent 1992;67:847-51.

Calvert M, Kyte D, Mercieca-Bebber R, Slade A, Chan AW, King MT, Hunn A, Bottomley A, Regnault A, Chan AW, Ells C, O'Connor D, Revicki D, Patrick D, Altman D, Basch E, Velikova G, Price G, Draper H, Blazeby J, Scott J, Coast J, Norquist J, Brown J, Haywood K, Johnson LL, Campbell L, Frank L, von Hildebrand M, Brundage M, Palmer M, Kluetz P, Stephens R, Golub RM, Mitchell S, Groves T: Guidelines for inclusion of patient-reported outcomes in clinical trial protocols: The spirit-pro extension. JAMA 2018;319:483-94.

Canbek K, Willershausen B: Survey of the effectiveness of masking noises during dental treatment--a pilot study. Quintessence Int 2004;35:563-70.

Caprioglio C, Olivi G, Genovese MD: Paediatric laser dentistry. Part 1: General introduction. Eur J Paediatr Dent 2017;18:80-2.

Cardoso MV, De Munck J, Coutinho E, Ermis RB, Van Landuyt K, de Carvalho RC, Van Meerbeek B: Influence of Er,Cr:YSGG laser treatment on microtensile bond strength of adhesives to enamel. Oper Dent 2008;33:448-55.

Cavalcanti BN, Lage-Marques JL, Rode SM: Pulpal temperature increases with Er:YAG laser and high-speed handpieces. J Prosthet Dent 2003;90:447-51.

Celiberti P, Francescut P, Lussi A: Performance of four dentine excavation methods in deciduous teeth. Caries Res 2006;40:117-23.

Cervetto S, Villar C, Ellis E: Laser frenectomy postoperatively less uncomfortable than scalpel frenectomy (UT CAT0769). Tex Dent J 2011;128:767.

Chiarotto A, Maxwell LJ, Ostelo RW, Boers M, Tugwell P, Terwee CB: Measurement properties of visual analogue scale, numeric rating scale and pain severity subscale of the brief pain inventory in patients with low back pain: A systematic review. J Pain. 2018 Aug 9.

Chinelatti MA, Ramos RP, Chimello DT, Corona SA, Pecora JD, Dibb RG: Influence of Er:YAG laser on cavity preparation and surface treatment in microleakage of composite resin restorations. Photomed Laser Surg 2006;24:214-18.

Cochrane collaboration. Cochrane handbook for systematic reviews of interventions. Part 3: Special topics. Chapter 17: Patient reported outcomes. Http://handbook-5-1.Cochrane.Org/front_page.Htm; in., 2018.

Colucci V, do Amaral FL, Pecora JD, Palma-Dibb RG, Corona SA: Water flow on erbium:yttrium-aluminum-garnet laser irradiation: Effects on dental tissues. Lasers Med Sci 2009;24:811-18.

Coluzzi DJ: Fundamentals of dental lasers: Science and instruments. Dent Clin North Am 2004;48:751-70.

Coluzzi DJ: Lasers in dentistry. Compend Contin Educ Dent 2005;26:429-35.

Convissar RA: Principles and practice of laser dentistry, 2nd edition. St.Louise, Missouri, Elsevier Mosby, 2016.

Cvar JF, Ryge G: Reprint of criteria for the clinical evaluation of dental restorative materials. 1971. Clin Oral Investig 2005;9:215-32.

de Almeida Neves A, Coutinho E, Cardoso MV, Lambrechts P, Van Meerbeek B: Current concepts and techniques for caries excavation and adhesion to residual dentin. J Adhes Dent 2011;13:7-22.

Delli K, Livas C, Sculean A, Katsaros C, Bornstein MM: Facts and myths regarding the maxillary midline frenum and its treatment: A systematic review of the literature. Quintessence Int 2013;44:177-87.

DenBesten PK, White JM, Pelino JEP, Furnish G, Silveira A, Parkins FM: The safety and effectiveness of an Er:YAG laser for caries removal and cavity preparation in children. Med Laser Appl 2001;16:215-22.

Denzin NK LY: . Handbook of qualitative research. 2nd ed. California: Thousand oaks, Sage publications, inc; 2000., 2000.

Deshpande PR, Rajan S, Sudeepthi BL, Abdul Nazir CP: Patient-reported outcomes: A new era in clinical research. Perspect Clinical Res 2011;2:137 144.

Devishree, Gujjari SK, Shubhashini PV: Frenectomy: A review with the reports of surgical techniques. J Clin Diagn Res 2012;6:1587-92.

Dommisch H, Peus K, Kneist S, Krause F, Braun A, Hedderich J, Jepsen S, Eberhard J: Fluorescence-controlled Er:YAG laser for caries removal in permanent teeth: A randomized clinical trial. Eur J Oral Sci 2008;116:170-76.

Edwards JG: The diastema, the frenum, the frenectomy: A clinical study. Am J Orthod 1977;71:489-508.

Eick JD, Welch FH: Polymerization shrinkage of posterior composite resins and its possible influence on postoperative sensitivity. Quintessence Int 1986;17:103-11.

Elo S, Kyngas H: The qualitative content analysis process. J Adv Nurs 2008;62:107-15.

Ericson D: Minimally invasive dentistry. Oral Health Prev Dent 2003;1:91-92.

Ericson D: The concept of minimally invasive dentistry. Dent Update 2007;34:9-10, 12-14, 17-18.

Featherstone JD: Caries detection and prevention with laser energy. Dent Clin North Am 2000;44:955-69.

Featherstone JD: Caries prevention and reversal based on the caries balance. Pediatr Dent 2006;28:128-132.

Fejerskov O KE: Dental caries. The disease and its clinical management in O SAF (ed): Caries control for populations Copenhagen, Blackwell Munksgaard, 2003;313-26.

Frencken JE, Sharma P, Stenhouse L, Green D, Laverty D, Dietrich T: Global epidemiology of dental caries and severe periodontitis - a comprehensive review. J Clin Periodontol 2017;44 Suppl 18:94-105.

Ghanei M, Arnrup K, Robertson A: Procedural pain in routine dental care for children: a part of the Swedish BITA study.Eur Arch Paediatr Dent. 2018 Sep 7.

Goldman L, Gray JA, Goldman J, Goldman B, Meyer R: Effect of laser beam impacts on teeth. J Am Dent Assoc 1965;70:601-6.

Gordan VV, Garvan CW, Richman JS, Fellows JL, Rindal DB, Qvist V, Heft MW, Williams OD, Gilbert GH: How dentists diagnose and treat defective restorations: Evidence from the dental practice-based research network. Oper Dent 2009;34:664-73.

Graneheim UH, Lundman B: Qualitative content analysis in nursing research: Concepts, procedures and measures to achieve trustworthiness. Nurse Educ Today 2004;24:105-12.

Gutierrez-Salcedo M, Martinez MA, Moral-Munoz JA, Herrera-Viedma E, Cobo MJ: Some bibliometric procedures for analyzing and evaluating research fields. Applied Intelligence 2018;48:1275-87.

Gutknecht N, Apel C, Schafer C, Lampert F: Microleakage of composite fillings in Er,Cr:YSGG laser-prepared class ii cavities. Lasers Surg Med 2001;28:371-4.

Hadley J, Young DA, Eversole LR, Gornbein JA: A laser-powered hydrokinetic system for caries removal and cavity preparation. J Am Dent Assoc 2000;131:777-85.

Hakeberg M, Berggren U, Grondahl HG: A radiographic study of dental health in adult patients with dental anxiety. Community Dent Oral Epidemiol 1993;21:27-30.

Hallberg LR-M: Qualitative methods in public health research. Lund: Studentlitteratur; 2002, pp. 13-34.

Haytac MC, Ozcelik O: Evaluation of patient perceptions after frenectomy operations: A comparison of carbon dioxide laser and scalpel techniques. J Periodontol 2006;77:1815-19.

Hecht J: A short history of laser development. Appl Opt 2010;49:99-122.

Hibst R, Keller U: Experimental studies of the application of the Er:YAG laser on dental hard substances: I. Measurement of the ablation rate. Lasers Surg Med 1989;9:338-44.

Hjertton PM, Bagesund M: Er:YAG laser or high-speed bur for cavity preparation in adolescents. Acta Odontol Scand 2013;71:610-15.

Huang WJ, Creath CJ: The midline diastema: A review of its etiology and treatment. Pediatr Dent 1995;17:171-9.

Huston P, Rowan M: Qualitative studies. Their role in medical research. Can Fam Physician 1998;44:2453-8.

Ito S, Saito T, Tay FR, Carvalho RM, Yoshiyama M, Pashley DH: Water content and apparent stiffness of non-caries versus caries-affected human dentin. J Biomed Mater Res B Appl Biomater 2005;72:109-16.

Ize-Iyamu IN, Saheeb BD, Edetanlen BE: Comparing the 810nm diode laser with conventional surgery in orthodontic soft tissue procedures. Ghana Med J 2013;47:107-11.

Jacobsen T, Norlund A, Englund GS, Tranaeus S: Application of laser technology for removal of caries: A systematic review of controlled clinical trials. Acta Odontol Scand 2011;69:65-74.

Jokstad A, Bayne S, Blunck U, Tyas M, Wilson N: Quality of dental restorations. FDI Commission Project 2-95. Int Dent J 2001;51:117-58.

Kani E, Asimakopoulou K, Daly B, Hare J, Lewis J, Scambler S, Scott S, Newton JT: Characteristics of patients attending for cognitive behavioural therapy at one uk specialist unit for dental phobia and outcomes of treatment. Br Dent J 2015;219:501-6.

Keller U, Hibst R, Geurtsen W, Schilke R, Heidemann D, Klaiber B, Raab WH: Erbium:YAG laser application in caries therapy. Evaluation of patient perception and acceptance. J Dent 1998;26:649-56.

Keller U, Raab WH, Hibst R: [pulp reactions during Erbium YAG laser irradiation of hard tooth structure]. Dtsch Zahnarztl Z 1991;46:158-60.

Kent G: Memory of dental pain. Pain 1985;21:187-94.

Khoo R, Jansen S: The evolving field of wound measurement techniques: A literature review. Wounds 2016;28:175-81.

Kvale S BS: Den kvalitativa forskingsintervjun. 2nd ed. Lund: Studentlitteratur ab. China: Elanders Beijing printing co. Ltd;. 2011.

Kyle BN, McNeil DW, Weaver B, Wilson T: Recall of dental pain and anxiety in a cohort of oral surgery patients. J Dent Res 2016;95:629-34.

Lara-Munoz C, De Leon SP, Feinstein AR, Puente A, Wells CK: Comparison of three rating scales for measuring subjective phenomena in clinical research. I. Use of experimentally controlled auditory stimuli. Arch Med Res 2004;35:43-8.

Liew Z, Nguyen E, Stella R, Thong I, Yip N, Zhang F, Burrow MF, Tyas MJ: Survey on the teaching and use in dental schools of resin-based materials for restoring posterior teeth. Int Dent J 2011;61:12-18.

Liu JF, Lai YL, Shu WY, Lee SY: Acceptance and efficiency of Er:YAG laser for cavity preparation in children. Photomed Laser Surg 2006;24:489-93.

Lopes RM, Trevelin LT, da Cunha SR, de Oliveira RF, de Andrade Salgado DM, de Freitas PM, de Paula Eduardo C, Aranha AC: Dental adhesion to erbium-lased tooth structure: A review of the literature. Photomed Laser Surg 2015;33:393-403.

Lundgren J, Berggren U, Carlsson SG: Psychophysiological reactions in dental phobic patients with direct vs. Indirect fear acquisition. J Behav Ther Exp Psychiatry 2004;35:3-12.

Maiman T: Stimulated optical radiation in ruby masers. Nature 1960;187:493-4.

Marshall S, Haywood K, Fitzpatrick R: Impact of patient-reported outcome measures on routine practice: A structured review. J Eval Clin Pract 2006;12:559-68.

Medeiros Junior R, Gueiros LA, Silva IH, de Albuquerque Carvalho A, Leao JC: Labial frenectomy with Nd:YAG laser and conventional surgery: A comparative study. Lasers Med Sci 2015;30:851-6.

Mjor IA: Repair versus replacement of failed restorations. Int Dent J 1993;43:466-72.

Mjor IA, Dahl JE, Moorhead JE: Age of restorations at replacement in permanent teeth in general dental practice. Acta Odontol Scand 2000;58:97-101.

Montedori A, Abraha I, Orso M, D'Errico PG, Pagano S, Lombardo G: Lasers for caries removal in deciduous and permanent teeth. Cochrane Database Syst Rev 2016;9:Cd010229.

Moore R, Brodsgaard I, Rosenberg N: The contribution of embarrassment to phobic dental anxiety: A qualitative research study. BMC Psychiatry 2004;4:10.

Morgan DL: Reconsidering the role of interaction in analyzing and reporting focus groups. Qual Health Res 2010;20:718-22.

Moslemi M, Fekrazad R, Tadayon N, Ghorbani M, Torabzadeh H, Shadkar MM: Effects of Er,Cr:YSGG laser irradiation and fluoride treatment on acid resistance of the enamel. Pediatr Dent 2009;31:409-13.

Myers TD: The future of lasers in dentistry. Dent Clin North Am 2000;44:971-80.

Norderyd O, Koch G, Papias A, Kohler AA, Helkimo AN, Brahm CO, Lindmark U, Lindfors N, Mattsson A, Rolander B, Ullbro C, Gerdin EW, Frisk F: Oral health of individuals aged 3-80 years in jonkoping, sweden during 40 years (1973-2013). II. Review of clinical and radiographic findings.Swed Dent J 2015;39:69-86.

Oelgiesser D, Blasbalg J, Ben-Amar A: Cavity preparation by Er:YAG laser on pulpal temperature rise. Am J Dent 2003;16:96-8.

Olivi G, Chaumanet G, Genovese MD, Beneduce C, Andreana S: Er,Cr:YSGG laser labial frenectomy: A clinical retrospective evaluation of 156 consecutive cases. Gen Dent 2010;58:e126-33.

Olivi G, Costacurta M, Maturo P, Docimo R: Removal of fibrous epulis with Er,Cr:YSGG laser: Case report. Eur J Paediatr Dent 2007;8:149-52.

Olivi G, Genovese MD, Caprioglio C: Evidence-based dentistry on laser paediatric dentistry: Review and outlook. Eur J Paediatr Dent 2009;10:29-40.

Olivi G, Margolis FS, Genovese MD, Olivi G, Margolis FS, Genovese MD: Laser-soft tissue interaction. Hanover Park, Quintessence Publishing Co Inc, 2011.

Olivi M, Genovese MD, Olivi G: Laser labial frenectomy: A simplified and predictable technique. Retrospective clinical study. Eur J Paediatr Dent 2018;19:56-60.

Opdam NJ, Feilzer AJ, Roeters JJ, Smale I: Class i occlusal composite resin restorations: In vivo post-operative sensitivity, wall adaptation, and microleakage. Am J Dent 1998;11:229-34.

Opdam NJ, van de Sande FH, Bronkhorst E, Cenci MS, Bottenberg P, Pallesen U, Gaengler P, Lindberg A, Huysmans MC, van Dijken JW: Longevity of posterior composite restorations: A systematic review and meta analysis. J Dent Res 2014;93:943-49.

Parker S: Surgical lasers and hard dental tissue. Br Dent J 2007;202:445-54.

Pelagalli J, Gimbel CB, Hansen RT, Swett A, Winn DW, 2nd: Investigational study of the use of Er:YAG laser versus dental drill for caries removal and cavity preparation—phase. I J Clin Laser Med Surg 1997;15:109-115.

Pick RM: Using lasers in clinical dental practice. J Am Dent Assoc 1993;124:37-34.

Pick RM, Colvard MD: Current status of lasers in soft tissue dental surgery. J Periodontol 1993;64:589-602.

Pie-Sanchez J, Espana-Tost AJ, Arnabat-Dominguez J, Gay-Escoda C: Comparative study of upper lip frenectomy with the CO_2 laser versus the Er, Cr:YSGG laser. Med Oral Patol Oral Cir Bucal 2012;17:228-32.

Portillo M, Lorenzo MC, Moreno P, Garcia A, Montero J, Ceballos L, Fuentes MV, Albaladejo A: Influence of Er:YAG and Ti:Sapphire laser irradiation on the microtensile bond strength of several adhesives to dentin. Lasers Med Sci 2015;30:483-92.

Rattray J, Jones MC: Essential elements of questionnaire design and development. J Clin Nurs 2007;16:234-43.

Reis A, Dourado Loguercio A, Schroeder M, Luque-Martinez I, Masterson D, Cople Maia L: Does the adhesive strategy influence the post-operative sensitivity in adult patients with posterior resin composite restorations?: A systematic review and meta-analysis. Dent Mater 2015;31:1052-67.

Romeo U, Palaia G, Del Vecchio A, Tenore G, Gambarini G, Gutknecht N, De Luca M: Effects of KTP laser on oral soft tissues. An in vitro study. Lasers Med Sci 2010;25:539-43.

Ryge G: Clinical criteria. Int Dent J 1980;30:347-58.

Sarmadi R: Visualisering av forskning om användning av Er:YAG laser inom tandvård. Https://ojs.Bib.Hb.Se/vetpub2015/article/view/456. Borås Journal of Science 2015.

Schwendicke F, Frencken JE, Bjorndal L, Maltz M, Manton DJ, Ricketts D, Van Landuyt K, Banerjee A, Campus G, Domejean S, Fontana M, Leal S, Lo E, Machiulskiene V, Schulte A, Splieth C, Zandona AF, Innes NP: Managing carious lesions: Consensus recommendations on carious tissue removal. Adv Dent Res 2016;28:58-67.

Seifi M, Matini NS: Laser surgery of soft tissue in orthodontics: Review of the clinical trials. J Lasers Med Sci 2017;8:S1-s6.

Sobouti F, Rakhshan V, Chiniforush N, Khatami M: Effects of laser-assisted cosmetic smile lift gingivectomy on postoperative bleeding and pain in fixed orthodontic patients: A controlled clinical trial. Progr Orthod 2014;15:66.

Spierings TA, Peters MC, Plasschaert AJ: Thermal trauma to teeth. Endod Dent Traumatol 1985;1:123-9.

Stacey MC, Phillips SA, Farrokhyar F, Swaine JM: Reliability and measurement error of digital planimetry for the measurement of chronic venous leg ulcers. Wound Repair Regen 2017;25:901-5.

Suter VG, Altermatt HJ, Bornstein MM: A randomized controlled clinical and histopathological trial comparing excisional biopsies of oral fibrous hyperplasias using CO_2 and Er:YAG laser. Lasers Med Sci 2017;32:573-81.

Valderas JM, Kotzeva A, Espallargues M, Guyatt G, Ferrans CE, Halyard MY, Revicki DA, Symonds T, Parada A, Alonso J: The impact of measuring patient-reported outcomes in clinical practice: A systematic review of the literature. Qual Life Res 2008;17:179-93.

Walsh LJ, Brostek AM: Minimum intervention dentistry principles and objectives. Aust Dent J 2013;58 Suppl 1:3-16.

van Dijken JW: A clinical evaluation of anterior conventional, microfiller, and hybrid composite resin fillings. A 6-year follow-up study. Acta Odontol Scand 1986;44:357-67.

van Dijken JW, Pallesen U: Fracture frequency and longevity of fractured resin composite, polyacid-modified resin composite, and resin-modified glass ionomer cement class iv restorations: An up to 14 years of follow-up. Clin Oral Investig 2010;14:217-22.

van Eck NJ, Waltman L: Citation-based clustering of publications using CitNetExplorer and VOSviewer. Scientometrics 2017;111:1053-70.

Watson TF, Cook RJ: The influence of bur blade concentricity on high-speed tooth-cutting interactions: A video-rate confocal microscopic study. J Dent Res 1995;74:1749-55.

Willershausen B, Azrak A, Wilms S: Fear of dental treatment and its possible effects on oral health. Eur J Med Res 1999;4:72-7.

Williamson A, Hoggart B: Pain: A review of three commonly used pain rating scales. J Clin Nurs 2005;14:798-804.

WMA Declaration of Helsinki – ethical principles for medical research involving human subjects. https://www.wma.net/policies-post/wma declaration-of-helsinki-ethical-principles-for-medical-research-involving human-subjects/ (2018-09-27)

Wong YJ: Caries removal using lasers. Evid Based Dent 2018;19:45.

Yazici AR, Baseren M, Gorucu J: Clinical comparison of bur- and laser prepared minimally invasive occlusal resin composite restorations: Two-year follow-up. Oper Dent 2010;35:500-7.

Appendix 1

Frågeguide till intervjuerna (studie 1)

Bakgrundsfrågor:

- Hur gammal är du?
- Vad har du för erfarenhet av tandvården? Har du lagat mycket?
- Är du nöjd med din tandhälsa?
- Hur går det att sköta om tänderna hemma?

Om att gå till tandvården:

- Berätta hur det har varit när du gått till tandläkaren och andra inom tandvården.
- Vilka behandlingsmoment är särskilt svåra? Ljud, vibrationer?
- Brukar det göra ont när du går till tandvården?
- Hur brukar du göra med bedövning?
- Hur får du påverka behandlingen när du är hos tandvården?

Om laser:

- Har du varit med om laserbehandling?
- Hur gick det till när ni bestämde att du skulle få prova laser?
- Berätta hur du tycker det är att laga med laser?
- Är det bättre eller sämre än att laga på vanligt sätt?
- Kan du berätta om skillnaderna? (smärta, ljud, vibrationer, glasögonen, stränga rutiner, tidsåtgång)
- Hur har du gjort med bedövning när du lagat med laser?

Om framtid:

- Hur vill laga i framtiden? Varför väljer du så?
- Upplever du att du själv kan göra något åt din tandstatus?
- Drömmer du om att din munhälsa skulle vara annorlunda? Hur skulle du vilja ha det?
- Är tänderna viktiga? Hur tänker du om det?
- Får du komma lagom ofta till tandvården?

Appendix 2

Enkät direkt efter lagning studie 2

Namn och pers. nr…… Tand ….

Ålder ……. □ Kvinna □ Man

1. Hur lagades din tand idag?

□ Med borr

□ Med laser

2. Brukar du välja bedövning då du lagar tänderna?

□ Ja, nästan alltid
□ Ja, ibland
□ Nej, i stort sett aldrig
□ Vet inte

Svara på fråga 3 om du lagade med laser idag. Om du lagade med borr – besvara i stället fråga 4.

3. Vad är bäst med laser? Välj max tre alternativ. Sätt en etta för det viktigaste, en tvåa för det näst viktigaste osv.

□ Det gör inte ont

□ Slipper bedövning

□ Slipper borrljudet

□ Går fortare

□ Är spännande och modernt

□ Annat ……

4. Vad är bäst med vanligt borr? Välj max tre alternativ på samma sätt som du gjorde på fråga 3.

□ Det gör inte ont

□ Slipper bedövning

□ Borrljud bättre än laserljudet

□ Går fortare

□ Känns tryggare på det vanliga sättet

□ Annat ……

Fråga 5 och 6 handlar om hur du brukar uppleva tandläkarbesöken:

5. Hur obehagligt är det att gå till tandläkaren? Sätt ett kryss på linjen.

Inte obehagligt alls	Mycket obehagligt

6. Hur obehagligt är det att få bedövningsspruta? Sätt ett kryss på linjen.

Inte obehagligt alls	Mycket obehagligt

Om dagens behandling:

7. Fick du bedövning idag?
- ☐ Ja
- ☐ Nej

8. Hur obehaglig/smärtsam var dagens behandling? Sätt ett kryss på linjen.

Inte obehaglig, smärtsam alls	Mycket obehaglig, smärtsam

9. Hur nöjd är du med dagens behandling? Sätt ett kryss på linjen.

Mycket missnöjd	Mycket nöjd

10. Svara på fråga 10 om du har fått båda dina fyllningar gjorda.
Jag väljer helst laser om det blir aktuellt att laga fler gånger

Instämmer inte alls	Instämmer helt

Appendix 3

Enkät en vecka efter lagning studie 2

Namn och pers. nr…… Tand …….

Ålder …… □ Kvinna □ Man

1. Hur lagades din tand för en vecka sedan?

□ Med borr
□ Med laser

2. Har det gjort ont i tanden efter lagningen?

□ Det gjorde ont samma dag men försvann sedan
□ Det gjorde ont några dagar men försvann sedan
□ Det gör fortfarande ont i tanden
□ Vet inte

3. Har du haft så svåra besvär att du har behövt vidta några åtgärder?

□ Jag har varit på ett akutbesök p.g.a. den lagade tanden
□ Jag har sökt tandvården för att få råd
□ Jag har tagit smärtlindrande läkemedel
□ Jag har haft ont men inte behövt göra något åt det
□ Jag har inte haft ont

Svara på fråga 4 om du lagade med laser förra veckan. Om du lagade med borr – besvara i stället fråga 5.

4. Vad är bäst med laser? Välj max tre alternativ. Sätt en etta för det viktigaste, en tvåa för det näst viktigaste osv.

□ Det gör inte ont
□ Slipper bedövning
□ Slipper borrljudet
□ Går fortare
□ Är spännande och modernt
□ Annat ……

5. Vad är bäst med vanligt borr? Välj max tre alternativ på samma sätt som du gjorde på fråga 3.

- ☐ Det gör inte ont
- ☐ Slipper bedövning
- ☐ Borrljud bättre än laserljudet
- ☐ Går fortare
- ☐ Känns tryggare på det vanliga sättet
- ☐ Annat ……

6. Hur obehaglig/smärtsam var lagningen förra veckan? Sätt ett kryss på linjen.

Inte obehaglig /smärtsam alls	Mycket behaglig /smärtsam

Appendix 4

Enkät fylls i sex, 12 och 24 månader efter lagning

Namn…….

Ålder …… Kvinna Man

1. Om du jämför lagning med borr och laser, vilket föredrar du då?

 Lika bra
 Laser är bättre
 Vanligt borr är bättre
 Vet ej

2. Vad är bäst med laser? Välj max tre alternativ. Sätt en etta för det viktigaste, en tvåa för det näst viktigaste osv.

 Det gör inte ont
 Slipper bedövning
 Slipper borrljudet
 Går fortare
 Är spännande och modernt
 Annat ……

3. Vad är bra med vanligt borr? Välj max trealternativ på samma sätt som du gjorde på fråga 3.

 Det gör inte ont
 Slipper bedövning
 Borrljud bättre än laserljudet
 Går fortare
 Känns tryggare på det vanliga sättet
 Annat ……

4. Har det gjort ont i tanden som lagades med laser efteråt?

□ Det gjorde ont samma dag men försvann sedan
□ Det gjorde ont några dagar men försvann sedan
□ Det gjorde ont i flera veckor men försvann sedan
□ Det gör fortfarande ont i tanden
□ Kommer inte ihåg

5. Har det gjort ont i tanden som lagades med borr efteråt?

□ Det gjorde ont samma dag men försvann sedan
□ Det gjorde ont några dagar men försvann sedan
□ Det gjorde ont i flera veckor men försvann sedan
□ Det gör fortfarande ont i tanden
□ Kommer inte ihåg

6. Har du haft så svåra besvär att du har behövt vidta några åtgärder?

□ Jag har varit på ett akutbesök p.g.a. den lagade tanden
□ Jag har sökt tandvården för att få råd
□ Jag har tagit smärtlindrande läkemedel
□ Jag har haft ont men inte behövt göra något åt det
□ Jag har inte haft ont

7. Hur obehaglig/smärtsam var det att laga med laser? Sätt ett kryss på linjen.

Inte obehaglig /smärtsam alls — Mycket obehaglig /smärtsam

8. Hur obehaglig/smärtsam var det att laga med borr? Sätt ett kryss på linjen.

Inte obehaglig /smärtsam alls — Mycket obehaglig /smärtsam

9. Jag väljer helst laser om det blir aktuellt att laga fler gånger

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Instämmer inte alls

Instämmer helt

Appendix 5

Enkät fylls direkt efter utförd läppbandsplastik

Namn och pers. nr……
Kirurgisk metod:

Ålder ……. □ Kvinna □ Man

1. Hur obehagligt är det att gå till tandläkaren? Sätt ett kryss på linjen.

Inte obehagligt alls — Mycket obehagligt

2. Hur obehagligt är det att få bedövningsspruta? Sätt ett kryss på linjen.

Inte obehagligt alls — Mycket obehagligt

Om dagens behandling:

3. Tog du värktabletter innan ingreppet idag?
□ Ja
□ Nej

4. Hur obehaglig/smärtsam var dagens behandling? Sätt ett kryss på linjen.

Inte obehaglig /smärtsam alls — Mycket obehaglig /smärtsam

5. Hur nöjd är du med dagens behandling? Sätt ett kryss på linjen.

Mycket missnöjd — Mycket nöjd

Appendix 6

Enkät fylls 5, 12 dagar efter utförd läppbandsplastik

Namn och pers. nr……
Kirurgisk metod:

Ålder ……. □ Kvinna □ Man

1. Hur upplevde du behandlingen för 5/ 12 dagar sedan?

Inte obehagligt alls — Mycket obehagligt

2. Hur mycket smärta har du upplevt under de senaste 5/12 dagarna?

Ingen smärta alls — Hög Smärta

3. Har du behövt ta värktabletter efter ingreppet?
   □ Ja
   □ Nej

4. Hur nöjd är du med förra gångens behandling? Sätt ett kryss på linjen.

Mycket missnöjd — Mycket nöjd

Appendix 7

Enkät fylls i 3 månader efter utförd läppbandsplastik

Namn och pers. nr……
Kirurgisk metod:

Ålder ……. □ Kvinna □ Man

1. Hur upplevde du behandlingen för tre månader sedan?

Inte obehagligt alls — Mycket obehagligt

2. Har du behövt ta antibiotika efter ingreppet?
   □ Ja
   □ Nej

3. Hur nöjd är du med denna behandling? Sätt ett kryss på linjen.

Mycket missnöjd — Mycket nöjd