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Master‘s Thesis

Is the Single Cone Obturation Technique the Future of Root Canal Filling?

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1. Abstract

OBJECTIVE: This review aims to address the current status of the single cone technique, to clarify whether the single cone technique will be the future of endodontics and if the single cone technique is showing the same obturation quality as other obturation techniques.

METHODS: Narrative literature review.

CONCLUSIONS: The single cone technique shows as good results as other obturation techniques. With the ongoing development of new materials, the single cone technique has a promising future. It is less time-consuming; inexperienced clinicians can achieve good results in a shorter time and are less likely to tend to failures than conventional techniques. The narrative review revealed that bioceramic and calcium silicate-based sealers, combined with the single cone technique, showed highly satisfactory outcomes. Meanwhile, the removal of these fillings and retreatability of obturated root canals using this technique is possible and successfully performed when indicated. However, further investigations and new studies are required to assess if the single cone technique is still as good as other obturation techniques.

2. Introduction

In dentistry endodontic treatment is one of the most challenging fields and often the last option to retain a tooth of a patient. A good outcome of the treatment and prognosis of the tooth is the main goal and an important basis for further planned treatments, such as prosthodontics. The first arising question before starting the endodontic treatment is which root canal preparation should be used ? The dentist can choose at first between different root canal preparation techniques. After a proper root canal preparation, final rinsing, and drying, the next question arises 'Which obturation technique should be used?'. Obturation plays an important role in ensuring the prognosis of the tooth as it is responsible for the prevention of bacterial penetration into the periapical tissues and blocking nutrients from the periapical tissues to reach the remaining bacteria intracanally (1). Within the last decades the lateral condensation, vertical compaction and thermoplasticized gutta-percha techniques have been used for root canal obturation. As new instruments, such as rotary instrumentation systems were invented and introduced to clinical practice, this led to new possibilities and improvement of the performance and efficiency of old techniques which did not have a good prognosis before (3). The introduction of bioceramic materials, better known as calcium silicate-based root canal sealers, and the new rotary instrumentation systems brought the single cone obturation technique back into the consideration of possible obturation techniques due to its simplicity. Studies have shown that 65.3% of mistakes were made during obturation in the whole process of root canal treatment (RCT). In the multistep techniques such as lateral cold compaction, errors such as overfilling, underfilling or voids were very common (2). The single cone obturation is a technique which uses only one tapered master GP cone. Thus makes it easy to operate, saves time for the operator as you don't have to use additional gutta-percha points and decreases the risk factors of errors during the steps of obturation (3). Additionally this technique is easier to learn, execute and inexperienced operators are less prone to make errors (8). More recently the single cone obturation technique has regained its popularity. With the introduction of new endodontic files we gained the ability to prepare the root canal with larger taper instruments and to match the final master cone to the size of the apical master file facilitates the use of the single cone obturation technique. This makes the single cone technique less technique sensitive, requires less equipment, is easier to perform, and is cheap, and as such is gaining popularity among many dentists. Since bioceramic sealers chemically bind to the dentine, the single cone technique is recommended to use only with bioceramic materials. Studies have shown that if the master gutta-percha cone is matched

to the size of the canal preparation it can provide similar quality of obturation compared to the warm vertical compaction (39). As the single cone technique consists proportionally of more sealer than other techniques the properties of sealers need to be reviewed as well and are as important. Hence, the following narrative literature review will address the current status of the single cone technique, will clarify whether the single cone technique will be the future of endodontics and if the single cone technique is showing the same obturation quality as other obturation techniques.

3. Review

3.1 Literature search methodology

A comprehensive literature search to identify related studies in PubMed, Web of Science, and google scholar between 1 January 2017 and 17 April 2023. The following search strategy was used to find relevant studies: (single cone obturation or single cone filling) OR (calcium silicate based root canal sealer or calcium silicate based sealer) OR (bioceramic root canal sealer or bioceramic sealer) AND (root canal OR endodontics OR root canal treatment) OR (root canal filling OR root canal obturation OR gutta-percha). The references list of the included studies and previously published reviews were searched. Laboratory and clinical studies investigating at least one of the single cone properties/outcome were included in the review. The studies performed on animal teeth were excluded.

3.2 Single cone obturation

In the 1960s the single cone technique was invented with the standardization of endodontic instruments and filling points. The general consensus was that a gutta-percha, silver, or titanium point/cone should be selected after preparing the apical stop. Then the filling material should ensure sealing of the prepared canal at the border of the root canal and block the penetration of microorganisms. To have better sealing properties the clinician should use a thin and uniform layer of the sealer. Later on studies have shown that the cement layer of sealer allows leakage due to non dimensional stability, resulting in fluid penetration of the periradicular areas and oral environment. This led into endodontic treatment failure due to cement degradation and implantation of pathologic microorganisms (3). Nowadays the single-cone obturation is newly emerging, as it is time-saving and easy-to-operate especially when it's combined with the new bioceramic

root canals sealers which have improved their physicochemical and biological properties. Also the single cone obturation technique showed, in combination with the new materials, a highly satisfactory short-term outcome in clinical observations (4). To have a good outcome of endodontically treated teeth the chemomechanical preparation is one of the most important steps in root canal treatment. Chemomechanical preparation consists of the removal of vital and necrotic tissues, removal of infected dentin and the elimination of microorganisms in order to eliminate the infection (7). The role of bacteria in periradicular infections is well documented in the literature. Endodontic treatment is more likely to fail if microorganisms remain in the root canals at the time of root canal filling. Bacteria can remain in areas such as isthmuses, dentinal tubules and ramifications and may contaminate disinfectants (46). A study from Lin et. al. showed the correlation between the presence of bacterial infection inside the canals and periradicular thinning in endodontic treatment failures (47).

3.2.1 Sealing ability/Leakage

One of the most common causes of failure of endodontic treatment is the apical leakage. Many factors can influence the apical sealing such as the obturation technique and also the sealing ability of the root canal sealer. To have a good outcome of the endodontic treatment the sealing ability of the obturation technique and sealer plays a crucial role (12). Analyzing the sealing ability of the single cone obturation technique we have to take the first look onto the access cavity preparation and if different designs have an impact on it. According to a study by Farheena Ustad et al. (2021), the traditional or the contracted access cavity preparation, the single cone obturation showed a significantly higher glucose leakage compared to the others (lateral compaction, thermoplastic obturation). But all three obturation techniques used failed in preventing the glucose leakage. The traditional endodontic access cavity showed in all three techniques less leakage than compared to the contracted endodontic access (11). Using the single-cone technique with conventional sealer showed to be less effective in sealing the root canals compared to vertical compaction with warm gutta-percha. Nevertheless, single cone fillings without compaction have been revived with the introduction of greater taper master cones which match the geometry of NiTi- instrumentation systems very closely (5). The sealing properties of two contemporary single cone obturation systems were assessed by Montocelli et. al. (2007). As a control group the warm vertical compaction was used with AH Plus sealer. The authors stated that the two single cone techniques used were as effective as the warm vertical compaction. Further the authors hypothesized that the inferior coronal seal of these

single cone techniques is improving the placement of accessory cones to reduce the thickness of the sealer or an immediate coronal adhesive restoration (83).

Wu et. al. (2009) reviewed and evaluated the quality of single cone and laterally compacted gutta-percha fillings in small curved root canals by using bidirectional radiographs and fluid transport measurements by using epoxy resin-based or zinc-oxide-eugenol sealers. In root canals with small curvatures the study showed that the quality of root canal fillings was similar. As many mesial canals in mandibular molars are irregular shaped and/or oval shaped the coating of the gutta-percha is important to seal the gap between the gutta-percha and the root canal. For applying sufficient amount of sealer into the canal, lentulo or bidirectional spirals can be used (6). Another study from Chauhan et. al. (2021) compared the apical sealing ability of gutta-percha by using three different obturation techniques. The commonly used lateral condensation technique, single cone root canal obturation technique and the injectable thermoplasticized gutta-percha technique. The authors concluded that non significant results were obtained and all three techniques are equally effective as root canal obturation regarding the sealing ability (9). However it is striking that the lateral compactions show with 78,1% the lowest value of overall the fillings. This is due to the fact that the lateral compaction does not produce a homogenous mass and it is very common that it will leave small spaces between the gutta-percha and dentinal walls or accessory cones. Occasionally this space is filled with sealer which creates a denser obturation. Another critical point for endodontic success is the morphology of the root canal and consequently the adaptability of the single cone (13). The most effective techniques for canals with more than 25 degree curvature are the lateral compaction and core carrier technique in the apical area which means 2mm and 5mm away from the apex. In the coronal part all techniques have the same quality as long as good condensation is achieved. The clinician should keep in mind to use a plugger with an optimal size according to the canal diameter and the localisation of root canal curvature in warm filling techniques (14). Another study from Shetty et. al. (2018) revealed similar results in the apical area 2mm and 4mm away from the apex. Here were sixty-six mandibular single rooted premolar teeth reviewed and obturated with the single-cone, injectable gutta-percha and lateral condensation technique. The lateral condensation showed again the maximum mean apical leakage. The single cone obturation exhibited more gutta-percha filled areas in the canals. Leading to decreased apical leakage compared to the other two methods (19). Assessing the bacterial sealing ability of two different bioceramic sealers using the single cone technique a study from Al Eraky et. al (2023) the bioceramic sealers showed comparable results to the resin-based sealer with lateral cold

compaction against the *Enterococcus faecalis*. Additionally the MTA Fillapex Bioceramic sealer provided better results and sealing ability than CearSeal Bioceramic sealer (62). Another important role in preventing microleakage and strengthening the remaining tooth structure is the coronal restoration. Elsherief et. al (2019) investigated the bacterial leakage of the root canal obturated using the single cone technique with three different root canal sealers and three different coronal restorative materials. They concluded that the group using composite and bioceramic sealer showed the lowest means of bacterial leakage. Highest leakage was found in the group with MTA and Glass Ionomer (63).

3.2.2 Apical sealer adaptability

The long term success of endodontic treatment is influenced and based on the complete filling after root canal obturation. Insufficient contact between sealer and gutta-percha, sealer and dentin or voids inside the sealer can result in microleakage which is one of the most common causes for failure of the endodontic treatment (16). Apical periodontitis develops due to the bacterial infection spreading from coronal direction or/and from the apical direction. Further through the complexity of the root canals systems which enables inorganic debris and pulp tissues to remain in areas where instruments and irrigation solutions can not enter easily and is influenced by the amount of surviving microorganisms in the infected area as they are growing and spreading throughout the periradicular areas between sealer and dentin (15,16). Endotoxins such as from *Actinobacillus actinomycetemcomitans* can infect the entire canal length within 20-30 days resulting in apical periodontitis (16). Choosing an adequate filling material is crucial in prevention of the invasion of bacteria into the root canals, as well as the correct decision of the apical sealer to avoid the invasion through the apical foramen (15,16). To evaluate and review the sealer adaptability of the single cone technique the most commonly used sealers need to be reviewed. Palanivelu et. al. (2019) used thirty freshly extracted mandibular premolars which were single rooted and had a single canal. The teeth were divided into three groups. The first group used zinc oxide eugenol sealers, second AH Plus and the third NanoSeal-S. AH plus is an epoxy resin based sealer and NanoSeak-S is polydimethylsiloxane based. The results showed that the epoxy resin based and polydimethylsiloxane based sealers had the best sealers distribution compared to zinc oxide eugenol sealers (20). Bioceramic and polydimethylsiloxane sealers are materials which are currently developed with almost the same characteristics. The question arises which material is superior to the other one. The comparison of Amanda et. al. (2018) revealed that the distribution of these two sealers are similar and showing the same amount

of apical leakage. Both sealers can be used and recommended to use as they have low level of apical leakage (21). Zaki et. al. (2022) prepared forty extracted single rooted lower premolars *in-vitro* and used two different sealers and obturation techniques. The results of the study showed that calcium silicate based sealers have a higher adaptability and are superior to epoxy resin based sealers. The cold lateral compaction showed a higher push out strength. But the single cone technique and cold lateral compaction showed similar results in the adaptability of the sealer to the root canal wall (17). Consequently to the studies mentioned above, calcium silicate based sealers can be recommended to clinicians using them in combination with the single cone obturation technique. *In vitro* the results for calcium silicate based sealers mostly showing the same characteristics comparable or in some parts are even prior to the golden standard epoxy resin based sealers. Calcium silicate based sealers have in addition to their good sealing abilities the clinically proven characteristics of providing bioactive surfaces with stimulation of hard tissue formation and better antibacterial properties (22). Kaul et. al. (2021) investigated the sealing ability of Bioceramic Sealer, AH Plus and Gutta Flow in conservatively prepared curved canals. The results showed that the group using AH Plus sealer showed higher leakage values than GuttaFlow and the two groups of Bioceramic sealer (64). Another study from Asawaworarit et. al (2020) is coming to the same result, that EndoSequence BC Sealer had significantly better sealing ability than AH Plus in all test periods. Under the scanning electron microscopy EndoSequence BC showed also better penetration into the dentinal tubules (65).

As the enlarging weakens the tooth and has a striking impact on the tooth survival which can lead as well to an endodontic treatment failure, it is important to have an eye on the impact of the root canal taper to the apical sealing adaptability. Sfeir et. al. (2018) assessed that the amount of voids was not less in the group with 6% taper than compared with the group of 4% taper. Bioceramic sealers showed reduced voids while still maintaining the characteristics of conventional resin sealers (18).

As ultrasonic activation of the endodontic sealers has been suggested to improve the root filling quality. El-Mal et. al (2023) investigated the influence of ultrasonic activation of Bioceramic sealers on the sealing ability with single cone obturation. They concluded that whenever a Bioceramic Sealer is used in combination with the single cone technique, ultrasonic activation should be applied. Thus helping to reduce microleakage and also obtaining a better outcome of endodontic treatment (66). The study of Bhor et. al. concluded as well that passive ultrasonic activation has a positive impact on the adaptability of the sealer (67).

3.2.3 Bonding strength

As mentioned before the key of a successful root canal treatment is the three dimensional obturation of the canal and it goes along with the instrumentation and disinfection of the canal. That is why we should also have first of all a closer look at the influence of the final irrigation solution and its impact on the push-out bond strength. Do we need to take a different final irrigation solution for the single cone technique ?

To review this question Donnermeyer et. al (2018) assessed the influence of the final irrigation solution (NaOCL, EDTA and CHX) on the push out bonding strength of calcium silicate, epoxy resin-based and silicone-based sealers. AH Plus showed a higher push out bonding strength compared to BioRoot RCS and GuttaFlow. Additionally the push out bonding strength was influenced positively by the use of EDTA and NaOCl. Whereas EDTA had a negative effect on BioRoot RC. GuttaFlow was not influenced (24). Sfeir et.al. reviewed the impact of EDTA, NaOCl and HEDP (activated and non activated by ultrasound) on the push-out bonding strength of AH Plus and Total Fill BC Sealer by using the single cone technique. They concluded that the activation of EDTA solution resulted in comparable push-out bonding strength for Total Fill BC Sealer and AH Plus. The Activation of HEDP had a positive effect on the adhesion quality of AH Plus. Activation of EDTA before the usage of NaOCl could not improve the results of POBS with Total Fill BC Sealer. The usage of HEDP decreased the POBS. Chelating agents prior could improve the adhesion quality of AH Plus (68). So we can take into account that we should adapt our final irrigation protocol to the sealer we are using.

Root canals have different cross-sectional shapes that can vary between round, oval, long oval or flattened root canals. They are measured according to their buccolingual and mesiodistal dimensions. The shape of the canals can be determined by means of microcomputed tomography with mathematical calculation of roundness. The different cross sectional shapes can result in deficient mechanical preparation and root filling procedures. As the single cone technique is using a larger and tapered gutta-percha it is proposed as an easier and faster procedure. But this can affect the bonding strength of the root filling to dentin, as in oval and long oval canals filled with the single cone technique, greater sealer thickness and voids can be found more often. The study of Pereira et. al. (2016) evaluated the bonding strength in single cone fillings of canals with different cross sections. The results of the study showed that in the coronal and middle thirds of the root canals, group 1 (round canals) showed the highest bonding strength. Whereas in the apical part of all three groups were no significant differences visible. In round canals the predominant failures were adhesive (filling material detached from dentine) and mixed

(mixture of adhesive and cohesive). In oval and long oval canals cohesive failures (fracture within the filling material) were more often and predominant compared to round canals. It can be said that the bonding strength is affected by the canal shape and the bonding strength depends on the percentage of gutta-percha filled areas (23).

As bioceramic sealers are the most suitable for the obturation with the single cone technique we lastly need to find out if the single cone technique is superior to the other warm and cold obturation techniques and if the push out bonding strength is less. Mounes et. al. (2022) study concluded that the cold obturation techniques (single cone and lateral cold compaction) showed a reduced bonding strength compared to the warm obturation techniques, such as warm vertical compaction or GuttaCore obturator (25). This disagrees with the study made in 2020 from Putrianti et. al. that concluded that the cold lateral compaction is prior to the others (26). Mounes et. al. (2022) explains that thermoplasticized procedures produce more gutta-percha, have fewer empty gaps and need less sealer than the single cone technique or the lateral cold compaction. The striking point is that we still need to keep in mind that sealers are soluble and shrink slightly, even though the newer materials are less likely to do it. So we need to rely on the gutta-percha as it is not shrinking. Therefore, the reliability of a technique using less sealer in terms of push-out adhesion is higher if we disregard the retreatability (25). Another study from Al-Hiyasat et. al. (2019) disagreed with the results from Mounes et. al. (2022). His team investigated that the warm vertical compaction significantly reduced the bond strength of the resin based AH Plus sealer compared to the lateral cold compaction or single cone technique. Additionally he recognized no significant differences with the use of bioceramic sealers and the influence of different obturation techniques . It is important to mention that in both studies the same materials were used (27). As both studies are in vitro it is quite hard to tell which we can rely on. As there are no clinical studies in vivo available.

After the successful endodontic management the follow-up treatment is generally a radicular post to restore the full function of the tooth with insufficient coronal structure. As creation of the post space can result in a weaker barrier to coronal leakage, maintaining the integrity of remaining filling material is critical. The preparation of this space may result in leakage. The study of Long et. al. (2018) assessed the effect of obturation technique with immediate and delayed post preparation on apical voids and bonding strength of apical gutta-percha. Compared were the single cone and continuous wave condensation. Long et. al. (2018) concluded that volume of voids and bonding strength were similar between these two obturation techniques. It was also not significantly influenced by the obturation technique or timing of preparation (69).

3.2.4 Dentinal tubule penetration

As root canal sealers should provide adherence between gutta-percha and dentinal walls to avoid gap occurrences at the sealer-dentin interface, the sealers should also penetrate into the dentinal tubules by mechanical locking and chemical bonding. Thus minimizes the amount of residual bacteria and forms a physical barrier which improves as well the retention of the root canal filling. Additionally, due to the complexity of the root canal system, sealers need to be used to fill the irregularities and penetrate into dentinal tubules to achieve the hermetic seal of the root canal system (28,29). As the final irrigation can influence the ability of the sealer to penetrate the dentinal tubules, we firstly need to answer the question if the final irrigation procedure has an impact on the different sealers and their penetration ability. The study of Akcay et. al. (2016) investigated the dentinal tubule penetration of AH Plus, iRoot SP, MTA fillapex and Guttaflow Bioseal after different final irrigation procedures. Compared were conventional needle irrigation (CI),the photon induced photoacoustic streaming activation (PIPS) and the passive ultrasonic irrigation (PUI). The study showed that the iRoot SP exhibited a significantly higher penetration area than the other groups. Between the AH Plus, MTA Fillapex and GF Bioseal there were no significant differences. Er.YAG laser activation with PIPS and PUI had significantly higher penetration compared to the CI. Concluded was the study that iRoot with PIPS tip or PUI is advantageous in dentinal tubule penetration (30).

As bioceramic sealers showed again its superiority over the other sealing materials We will review the dentinal tubule penetration of them compared to different obturation techniques. Wang et. al. (2018) compared iRoot SP with single cone obturation technique, the iRoot SP with warm vertical compaction technique. And both obturation techniques mentioned before in combination with AH Plus as sealer. For visualization purposes Rhodamine B dye were mixed with the sealers and analyzed under a confocal laser scanning microscope. Significant was that there were no statistically differences in the density of the root canal filling or on the adaptation to the root canal wall at 2,4 and 6mm to the apex. The dentinal tubule penetration was better with the iRoot SP (bioceramic sealer). iRoot SP was especially better to penetrate and seal more dentinal tubules 2 mm away from the apex. Same results were achieved regardless of the obturation technique which was used (28). Similar results were achieved in the study of Jeong et. al. (2017). The difference in this study was that they prepared 100 extracted anterior teeth and also used CPoint single cone additionally to the gutta-percha single cone and gutta-percha vertical condensation group. As mentioned the results were similar to the study before. Sealer penetration into the dentinal tubules was independent of the obturation technique which

was used. But Jeong et. al. (2017) additionally pointed out in their conclusion that the pressure from hygroscopic expansion of CPoint or warm vertical condensation is not enhancing the penetration depth of the calcium silicate based sealer (31). The study from Hachem et. al. (2019) concluded as well that bioceramic sealer and novel tricalcium silicate sealer showed better dentinal tubule penetration than compared to the golden standard AH Plus sealer (81). Another study from Reynolds et. al. (2020) compared the dentinal tubule penetration of conventional and 'HiFlow' bioceramic with resin-based sealer. The authors used for obturation the single-cone technique and warm vertical obturation. The authors investigated that the dentinal tubule penetration was similar comparing bioceramic sealer, 'HiFlow' bioceramic sealers and resin based sealer by using the single cone technique and warm vertical compaction (80).

Lastly we need to revise how deep the sealer is penetrating into the tubules. The study of Alegre et. al. (2022) compared the intratubular penetration ability in the canal perimeter by using HiFlow bioceramic sealer with warm obturation techniques and single cone obturation technique. The benefit of a higher intratubular penetration is that we promote the micromechanical interlocking and additionally we keep the moisture which is remaining in the dentinal tubules. Through this we can trigger the setting reaction of the remnants and produce hydroxyapatite which creates the aforementioned chemical bonding with the root dentine. Resulting in resistance to separation and strengthening of the root which is preventing the root from fracture. The study used 180 teeth with single rooted teeth. It was concluded that the intratubular penetration showed the highest percentage of penetration at the coronal section compared to the apical, independently of which technique was used. But the warm obturation techniques showed a higher percentage of intratubular penetration in all three sections compared to the single cone technique (32).

3.2.5 Ability to promote healing

The introduction of nickel-titanium (NiTi) files in combination with reciprocating or rotary movements/motion for root canal preparation was an important advance in endodontic therapy as it is not only prolonging the lifespan of the file but also shortens the treatment time. Furthermore it enables filling the canal with a matched-taper single cone which is simpler and less time consuming then other root canal obturation techniques. Due to these and other advantages, such as less procedural errors due to a reduction of technical sensitivity, the single cone obturation technique has become popular by using it combined with a reciprocating single-file system (33,34). As the single cone technique is less time consuming (mainly during the instrumentation) using a reciprocating file or rotary file, it

also can reduce the antimicrobial efficiency of solutions, which is mainly depending on the time and volume of irrigation to disinfect the canal effectively (34). As the proper disinfection of irrigating solutions is crucial and can compromise the reduction of the microbial content in the root canal system it can hinder apical periodontitis healing. De-Figueiredo et. al. (2020) compared reciprocating single files followed by matching taper single cone filling or a hand file with lateral compaction filling. The results of the study showed that there were no significant differences in the first 24 hrs of postoperative pain and flare ups. Furthermore both protocols showed similar healing rates of apical periodontitis and after 12 months the success rate ranged from 73% to 78%. Resulting in the conclusion that endodontic treatment combined with a reciprocating single file and matched taper single cone is showing similar results regarding the clinical effectiveness compared to the treatment using hand file instrumentations and the lateral cold compaction obturation technique (33). Zavattini et. al. (2020) assessed the outcome of root canal treatments using calcium silicate based root canal sealer. In the study they compared the single cone technique with the warm vertical condensation by using 150 teeth. The teeth were filled either with AH Plus or with BioRoot RCS. The authors concluded that the calcium silicate based sealers in combination with the single cone technique showed as good results as the warm vertical condensation and epoxy-resin based sealer (AH Plus). Further, the success rate was within a range from 84% to 90% within the first year of follow-up (79).

Another factor which is influencing the healing ability are irregularities such as fins, isthmuses and lateral canals which are often present inside the root canal system. The inability to fill and seal these anatomical spaces effectively can have a disadvantageous effect on the success of the endodontic treatment. As bioceramic sealers have gained popularity in the modern practice of dentistry due to their physicochemical and biological properties it is important to review the clinical outcome of non surgical root canal treatment by using a single cone technique with bioceramic sealers and to review if the extrusion is affecting the healing ability as well. A study from Chybowski et. al. (2018) used 307 teeth, mainly posterior teeth (92,2%) and reviewed the clinical outcome of non-surgical root canal treatment by using a single cone technique with endosequence bioceramic sealer. The patients were monitored by an average follow-up time of 30.1 months. The overall success rate of the study was 90,9%. Only 9,1% were not healed. 83.1% were healed and 7.8% were healing. Striking is that also the retreatment cases showed a success rate of 91.7%. The study concluded as well that there was a statistically significant difference between lesions <5 mm and >5 mm in diameter. Also that younger

Patients (<50 years old) tended to have a higher rate for a successful treatment than older patients. Another important point is that extrusion was found in almost half of the cases but it did not appear to affect the outcome of treatment (35). Another study from Subbiya et. al. (2022) reviewed 223 patients with 261 teeth. The patients were monitored around 39.18 months. Difference in this study was that the clinic outcome non surgical root canal treatment with a matched single-cone obturation technique with a calcium hydroxide-based sealer was reviewed. The results were similar to the study mentioned before. The overall success rate was 89.7%. However, the study showed that the increase in age was associated with increased chances of success. Additionally the success rates are reduced by an increase in the number of roots and negative pulp sensibility status. As well as the study before concluded the sealer extrusion did not affect the clinical outcome significantly (36).

3.2.6 Dimensional stability

An ideal sealer should offer specific properties. The most desirable physical property for root canal sealers is the insolubility, as the insolubility of endodontic sealers can have a negative effect on the successful outcome of the endodontic treatment. Due to the degradation of the sealer, gaps may occur along the sealer/dentin or sealer/gutta-percha wall which can provide a pathway for microorganisms and their toxic products into the periapical tissue. Furthermore, the dissolution of the root canal sealer can release chemical compounds that can trigger inflammatory changes in the periapical tissue. The International Organization for Standardization (ISO) made low solubility of a root canal sealer in 2001 as a requirement for root canal sealing materials. As the low solubility rates maintain the sealing ability and/or avoid reinfection by the formation of gaps. According to these standards root canal sealers should exhibit solubility less than 3% and the change should not exceed 1.0% in contraction or 0.1% in expansion (54,55,56).

Regarding the flowability and film thickness, iRootSP, Endoseal MTA and Endo CPM fit into the requirements laid down in the ISO Norm 6876:2012 of a flow greater than 17mm (58). Only BioRoot RCS slightly failed to reach the threshold (57). The ISO specifications of film thickness were fulfilled from the sealers iRoot SP and Endoseal MTA. They showed film thickness results less than 50 µm in several studies, whereas BioRoot RCS showed contrary results. The only sealer which showed higher film thickness compared to AH Plus was found for iRoot SP. As written in the ISO-norm 4049 it is recommended that sealers should absorb less than 40 mg/mm^3 after 28 days (58). Two studies found out that iRoot SP, BioRoot RCS and Endoseal were close to these limitations (59,60). The ISO 6876 requirements about 3% weight loss were exceeded from BioRoot

RCS and iRoot Sp within 24 hrs. iRoot SP, BioRoot RCS, Endoseal MTA and Endo CPM did not exceed the ISO 6873 requirement. In general the solubility of CSBS was found to be higher than compared to epoxy resin-based sealers (58). A long term investigation from Urban et. al. (2018) about the solubility and pH value of 3 different root canal sealers showed that the solubility of BioRoot RCS was in accordance with the ISO 6876 requirements even over a 6-month period (61).

3.2.7 Obturation quality/Analysis of porosity

As open pores between endodontic sealers and root canal wall present a favorable environment for bacterial growth and migration pathway (70) the assessment of the obturation and root canal treatment is crucial. The evaluation is made clinically, radiographically as it is highly dependent on the specific radiographic findings. For the evaluation we can use the guidelines according to the European Society for Endodontics. The evaluation of the quality of endodontic treatment is made by evaluating the canal obturation in terms of taper, density and apical extension within the limits from 0.5-2 mm of the radiographic apex (38,71). Öztürk et. al. (2023) reviewed the influence of different NiTi systems on the obturation quality. The authors investigated that the reciprocal NiTi-systems were more effective in terms of shaping than the rotational NiTi-systems. Further, the matched single cone technique had significantly better obturation quality compared to the lateral cold compaction (74). As the lateral cold compaction is most widely used and considered a reference in evaluating other obturation techniques, the study from Garrib et. al. (2020) is comparing the lateral cold compaction 0.02 tapered master cone (LC2),lateral cold compaction 0.04 tapered master cone (LC4) with the matched single-cone technique (MS) and matched single cone-mediated ultrasonic activation (MSUA).The study was using 36 mandibular first premolars with mostly round canals. In this study it was outstanding that the MSUA showed a significantly lower percentage of voids compared to the other three groups. The percentage total percentage volume of voids was significantly lower in the MS group compared to the LC4 and LC2 groups (42). Kim et. al (2021) investigated the effects of ultrasonic activation on root canal filling quality of single cone with calcium silicate based sealer. They concluded that the void volume was significantly lower when the single cone technique was used with ultrasonic activation (SCU) compared to the standard single cone (SC) or continuous wave technique (CW). SCU had especially in the coronal and middle third area less voids compared to SC and CW. Additionally the differences in quality of obturation were not found between SC or CW. Resulting in the statement that the ultrasonic activation is enhancing the quality of

obturation (73). Aishuwariya et. al. (2021) investigated the obturation quality of the lateral cold compaction, single cone and continuous wave compaction. In their study the single cone technique showed overall as good results as the lateral cold compaction and continuous wave condensation (82).

The study of Nouroloyouni et. al. (2023) assessed the single cone obturation versus cold lateral compaction techniques with bioceramic and resin sealers regarding their quality of obturation and push out bonding strength. As mentioned previously about the push out bonding strength I will only concentrate on the quality of obturation in this case. To analyze the quality of obturation the teeth were fixed with cyanoacrylate glue and horizontally sectioned in the apical, middle and coronal thirds to receive a maximum thickness of 3mm for a slice. Afterwards the slices were inspected under a stereomicroscope. It revealed that the distribution of AH Plus sealer was more than compared to the sure seal root (SSR). Additionally the percentage of gutta-percha in the different parts of the root were significantly different. The study showed that the distribution was lower in the coronal third than compared to the middle and apical thirds. Voids were significantly less by the usage of lateral cold compaction and AH Plus sealer. With the usage of SSR the result changed. The cold lateral compaction showed less voids in the coronal thirds, but the single cone technique showed better results in the middle and coronal thirds. The authors concluded that SSR has better physical, chemical and sealing properties compared to the AH Plus sealer. As the push-out bonding strength of the lateral cold compaction with SSR was higher than compared to the single-cone obturation the authors are recommending to use lateral cold compaction. But if the clinician is choosing the single cone technique the results with SSR were superior to the ones with AH Plus (37). A further study from Pedullà et. al. (2020) reviewed root fillings with a matched-taper single cone and two calcium silicate-based sealers. For this they used 48 single rooted mandibular premolars and divided them into two groups. The first one was using GuttaFlow Bioseal and the second BioRoot RCS. Afterwards they were inspected under micro-computed tomography. The results showed that less voids compared to BioRoot RCS in all the root-thirds. BioRoot RCS showed significantly greater voids in the coronal third (40).

Another study from Heran et. al. (2019) reviewed the single cone obturation technique with a modified warm filler. Three sealing materials were assessed. AH Plus, BioRoot CS, GuttaFLow and Prototype (TCS-Zr-30). The study concluded that heat is affecting the sealer properties and void volume. In complex anatomy none of the sealers groups were able to completely obturate the isthmuses, even without heat application. AH

Plus was negatively affected by the usage of heat. GuttaFlow and BioRootCS were not affected by heat. The application of heat modifies the sealing properties and could also enhance the quality of obturation, but for complex canal anatomy the single cone obturation is not the most suitable (39). Keleş et. al. (2020) compared the single cone technique with the warm vertical compaction. They concluded that neither the warm vertical compaction or the single cone technique were able to produce a void free root canal filling in the band-shaped isthmuses. Both obturation techniques showed similar results in terms of quality of root canal obturation (72).

3.2.8 Retreatability

As the root canal therapy can fail, the material which were used during the obturation need to be removed so the root canal system can be cleaned and disinfected again. As gutta-percha is the most commonly used material nowadays it can be removed mechanically and also by the use of organic solvents (42,76). Mechanical removal of obturation material can result in overcutting the dentin, so ideally chemical agents that dissolve the obturation material without destroying the dentin should be used. As gutta-percha can be well dissolved by organic solvents, the sealers are more resistant to chemical dissolution (42). When using the single cone technique for obturation mostly hydraulic calcium disilicate-based root canal sealers are used. As known these sealers are interacting chemically with the dentine. Resulting in a larger percentage of sealer present in the root canal system compared to other techniques. These mentioned factors make retreatment more difficult as it is harder to completely remove these materials (77). The study of Garrib et. al. (2020) investigated the retreatment efficacy of hydraulic calcium silicate sealers used with single cone obturation technique. It revealed that 17% EDTA and 10% formic acid applied for 5 min are not damaging the dentin but they affected the structural integrity of the sealer. The most efficient method of removing the obturation material from the root canal system was to use 10% formic acid in conjunction with mechanical instrumentation. The results were achieving over 95% removal for both gutta-percha and the bioceramic coated version. Additionally patency and reestablishment of the working length was achieved (42). Another study from Croteza et. al. (2019) compared the retreatability of BC Sealer and AH Plus root canal sealers combined with the single cone technique. The study investigated that lower values of remnant filling material was found for BC sealer compared to AH Plus. Additionally the usage of an ultrasonic tip showed lower values of remnants compared to XP-endo Finisher R. Concluding that the

usage of an ultrasonic tip can be considered as a good option in retreatment of the single cone technique in combination with bioceramic sealers (52).

Another group of sealers which are often used in combination with the single cone technique, are tricalcium silicate-based sealers due to their antibacterial and stable mechanic properties. Furthermore they are biocompatible. Zhang et. al. (2022) reviewed the long-term porosity and repeatability of oval shaped canals obturated by two different methods with a novel tricalcium silicate sealer. The first method was the single cone obturation technique and second the warm vertical compaction. The study concluded that the efficiency of retreatment was closely related to the storage time of the specimen, rather than the filling technique which was used (43). As 80% of the general dentist are using zinc-oxide eugenol or resin based sealers (44), lastly we will review the retreatment with resin based sealers. A study from Sumit et. al. (2022) examined the retreatability of bioceramic sealers and resin-based sealers and evaluated the results by using cone beam computed tomography. AH Plus combined with the single cone technique showed the best results by the meaning of time. For retreatment a D-Race retreatment file was used. In all specimens, the apical third had the most remaining filling material. The authors concluded that irrespective of the retreatment technique used, the complete removal of both sealers could not be achieved. Nevertheless, the retreatability of AH Plus was superior to that of BioRoot RCS (45).

3.2.9 Simplicity and clinical applicability

As mentioned before, the success rate of an endodontic treatment highly depends on the quality of the root canal shaping, cleaning and elimination of the microorganisms. If the treatment is performed by an endodontic specialist the success rate can reach more than 90 or 95%, in cases where general practitioners are performing an endodontic treatment it can decrease to 40-65% (75). Lower success rates can be seen when endodontic treatment is performed by undergraduate students. Studies have shown that the root canal obturation by undergraduate dental students is commonly poor and unacceptable, but other investigations have shown that only 30.1-47% are under acceptable quality standards (48). Postgraduate students achieved better results than undergraduate students (49). Nevertheless it can be stated, that the simplified single cone root canal obturation technique potentially can be less related to the experience of the clinician. A study from Drukteinis et. al. (2021) assessed the single cone canal fillings performed by undergraduate, postgraduate students and also specialists for endodontics. This in vitro study used 21 standardized 3D plastic models of upper molars and afterwards it was assessed with micro computed tomography.

Hydraulic calcium silicate based sealer was used in combination with the single cone technique. The authors concluded that no operator was able to ensure void free root canal fillings. Voids were found dominantly in the apical third. Homogeneity and quality in the middle and apical third of the single cone root canal fillings remained similar between the three different groups. Only significant differences were found in the coronal third (48). As the lateral condensation is more time consuming, and the use of multiple cones can lead to a production of a less homogenous mass which can have voids, empty spaces between the gutta-percha due to the insertion of the spreader, excessive amount of sealer and a lack of surface adaptation, we need to review the disadvantages of the lateral compaction. In the study of Gound et. al. (2009) they compared graduating dental students ability of filling a root canal using single or multiple cone obturation technique. The study assessed statistically significant differences between the two groups occur. The students were more able to produce adequate length and density in the clinical and proximal views. But the single cone technique was 110 seconds faster than the multiple cone technique. The authors concluded his study that further training and experience are needed to improve the quality of obturation when using the single cone technique, as the students were previously introduced the first time into the single cone technique (50). As the previously mentioned study is 14 years old and the field of endodontic material is changing fast, I would like to take newer studies into account. Gavini et. al. (2021) evaluated the endodontic treatment performed by undergraduate students using reciprocating instrumentation and single cone obturation. 1102 teeth were assessed. The results of the study showed that anterior teeth, maxillary premolars and molars showed better results than mandibular premolars and molars. Mandibular premolars showed a higher incidence of a short length obturation (33.34%), whereas the molars presented a high incidence of overfilling (6.55%). His study concluded and proved that in the majority of the cases performed by undergraduate students the quality of endodontic treatment was acceptable by using NiTi reciprocating instruments with single cone obturation technique (51). Concluding for the clinical applicability we can say that the single cone technique can be used nowadays when the root canal anatomy promises successful cleaning with circular preparation with moderate preparation sizes (53).

4. Conclusion

As stated before this literature research reviewed the current scientific status of the single cone technique and investigated if the single cone technique is showing the same

obturation quality results as compared to other obturation techniques. The sealing ability of the single cone technique showed better results than other techniques when the curvature was less than 25 degree. If the canal anatomy is more complex the single cone technique can not be recommended and the lateral compaction should be used. In terms of sealer adaptability,dentinal tubule penetration and the ability to promote healing the single cone technique showed as good results as other obturation techniques. The review showed that bioceramic and calcium silicate based sealers in combination with the single cone technique showed highly satisfactory outcomes and the retreatability is still given. The simplicity is one of the most favorable points of the single cone technique. Studies have shown that void free obturation can not be assured in all different obturation techniques and none is prior to the other one. The single cone technique is much faster than the lateral compaction, especially for undergraduate students. No significant differences were found in terms of obturation quality. Which leads to the statement that the single cone technique can be used when root canal anatomy promises successful cleaning. Anyways further investigations and new studies are constantly needed to review if the single cone technique is still as good as other obturation techniques.

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