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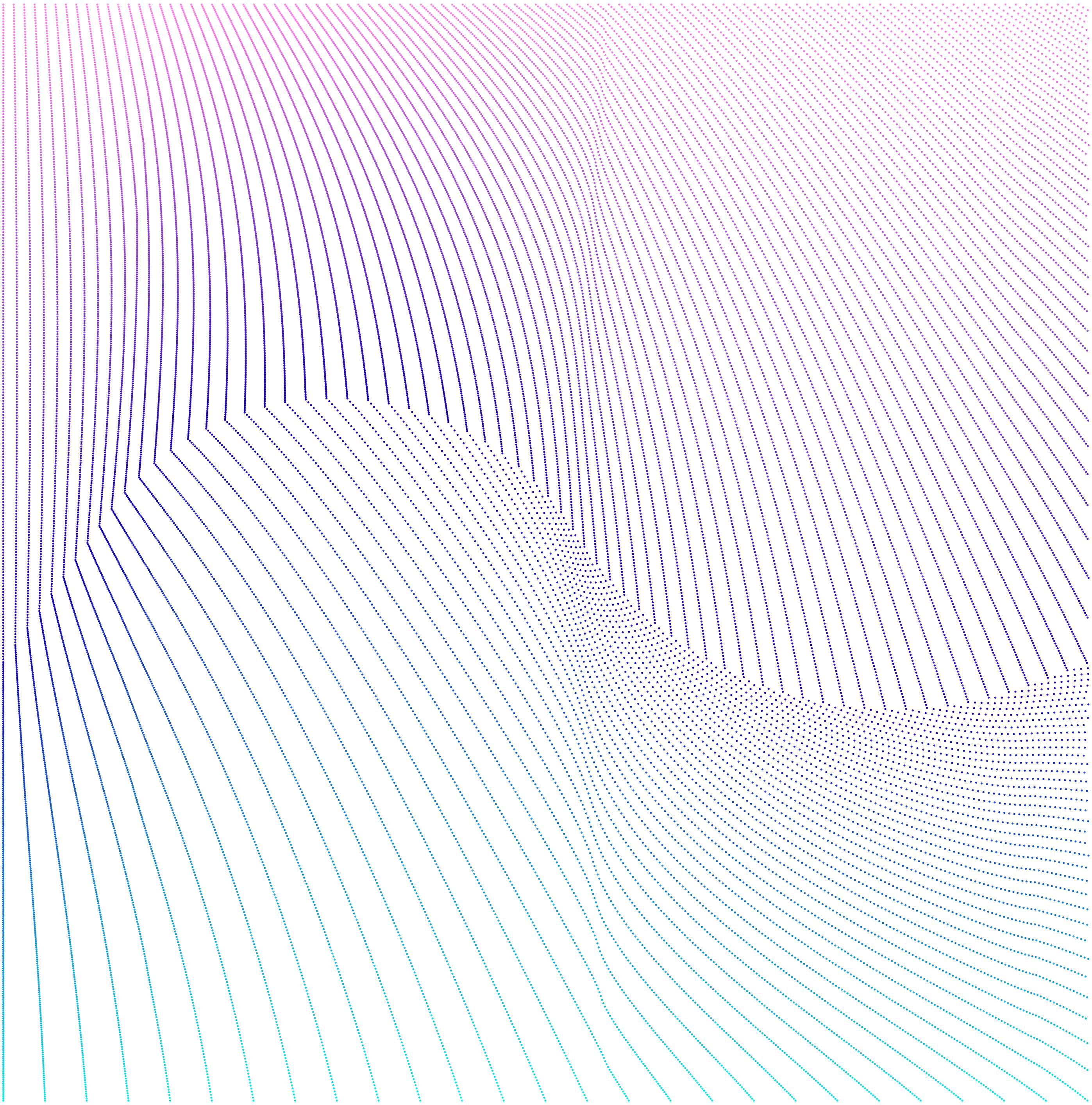

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Contents

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Review

Removal of bacterial biofilm in patients undergoing fixed orthodontic treatment: a literature review

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DISCLOSURE: **ALL AUTHORS REPORT NO CONFLICTS OF INTEREST RELEVANT TO THIS ARTICLE.**

ABSTRACT

Orthodontic treatment is highly popular for restoring functional and facial esthetics in juveniles and adults. However, the prevalence of biofilm-related complications remains high. The objectives of this review are to 1) identify which of the two professional prophylaxis systems analyzed, rubber cup polishing (RCP) and air-powder polishing (APP), is the most effective in removing bacterial biofilm in patients undergoing fixed orthodontic treatment, and 2) the comfort expressed by the patient and any damage caused to the orthodontic device. The search yielded 23 scientific articles, 14 of which were excluded, and 6 met the inclusion criteria. From the studies analyzed, it is, therefore, possible to state that the APP technique is more effective than the RCP technique in removing dental plaque, and treatment is less time-consuming and safer concerning orthodontic devices, as none of the scientific articles examined did APP cause any damage to the orthodontic device or debonding of the brackets.

INTRODUCTION

Fixed orthodontic devices cause objective difficulties in performing daily oral hygiene techniques, which, to be effective, require strong patient motivation. Brackets, bands, bows, ligatures, and elastics represent plaque retention factors, as they offer a greater surface area for adhesion (1, 2) and interfere with toothbrushes and other devices used for plaque control (3, 4). In addition, the orthodontic treatment causes a change in the oral bacterial flora both quantitatively and qualitatively (5, 6). There is a significant increase in the abundance of *Streptococcus mutans* (2, 4) but also of Lactobacilli, Staphylococcus, Candida albicans, motile bacteria, gram-negative bacteria, and the change from an aerobic to an anaerobic population (5, 6).

For the mechanical removal of biofilms at home, either a manual (also orthodontic) or an electric toothbrush can be used. The patient must be instructed to pay particular attention to the cervical third, which must be brushed with roller movements, with a circular technique around each bracket or with the modified Stillman technique, and to brush their teeth at least 20 min after meals (1, 3). Oral hygiene performed with an electric toothbrush (if properly used and timed) is significantly more effective than oral hygiene performed with a manual toothbrush in terms of plaque reduction, bleeding, and gingival inflammation (1, 7). The monobloc toothbrush is particularly indicated for cleansing any spaces created by orthodontic movements, the mesial and distal surfaces of two teeth adjacent to an edentulous area, and/or the distal surfaces of the last molars (1). Another study also stated that combining mono and conventional toothbrushes effectively controlled biofilm formation in orthodontic patients (8).

For mechanical interproximal cleansing, the patient can use dental floss with a stiff end or pipe cleaner (1). In particular, it is necessary to use dental floss because of the presence of orthodontic floss. Furthermore, toothpaste containing fluoride is advisable to reduce the risk of demineralization that can be carried inside the oral cavity with a toothbrush or even in the interdental spaces with toothbrushes, toothpicks, or floss (1).

A 0.05% fluoride mouthwash is suitable for daily use; a low concentration combined with high-frequency results in a remineralizing effect that is useful and indispensable for orthodontic patients. One alternative is a mouthwash containing sodium fluoride and 0.05% chlorhexidine. Combining the two active ingredients has a synergistic effect; it combines the remineralizing action of fluoride with the antibacterial action of chlorhexidine (1).

For professional debridement, dental hygienists can use manual instruments such as scalers and curettes and mechanical instruments such as sonic and ultrasonic scalers (1). Using hand instruments around bands and brackets is difficult, so using sonic and ultrasonic scalers is beneficial (3).

The deployment and polishing of tooth surfaces can be carried out with cups, brushes, and prophy paste (PPI) or with air-polishing and different abrasive powders (1).

During professional oral hygiene sessions to reduce the risk of caries, professional fluoroprophylaxis can be carried out with a high concentration of fluoride gel (1.23%), left on for at least 4 minutes (the minimum time for fluoride uptake), or with amorphous calcium phosphate (ACP). The frequency is determined by the patient's degree of compliance and caries risk and can be either quarterly or half-yearly (5).

OBJECTIVE

The primary objective of this literature review was to identify which of the two professional prophylaxis systems analyzed (RCP and APP) was the most effective in removing bacterial biofilms in patients undergoing fixed orthodontic treatment. In addition to the effectiveness of the two techniques, the time required for each technique was also compared.

Instead, the comfort expressed by the patient and any damage caused to the orthodontic device were considered secondary objectives. Specifically, the occupational prophylaxis techniques considered in this study were as follows:
- polishing with a rubber cup and prophy paste henceforth referred to as rubber cup polishing (RCP);
- air-polishing with abrasive powder, henceforth referred to as APP (air-powder polishing).

MATERIALS AND METHODS

In order to perform a review of the available scientific literature regarding the polishing procedure for tooth surfaces in patients undergoing fixed orthodontic treatment, the PICOs methodology was used (Table I).

Table I. *PICO for search.*

PICO - Effective plaque removal	
P - Patient	M/F patients undergoing fixed metal orthodontic treatment
I - Intervention	Polishing performed with a rubber cup and prophy paste (RCP)
C - Comparison	Air-polishing with abrasive powder (APP)
O - Outcome	Plaque removal
PICO - Time for plaque removal	
P - Patient	M/F patients undergoing fixed metal orthodontic treatment,
I - Intervention	Polishing was performed with a rubber cup and prophy paste (RCP);
C - Comparison	Air-polishing performed with abrasive powder (APP);
O - Outcome	Shorter treatment time
PICO - Patient-expressed comfort	
P - Patient	M/F patients undergoing fixed metal orthodontic treatment
I - Intervention	Polishing performed with a rubber cup and prophy paste (RCP)
C - Comparison	Air-polishing with abrasive powder (APP)

O - Outcome	Patient comfort
PICO - Damage to the orthodontic device	
P - Patient	M/F patients undergoing fixed metal orthodontic treatment
I - Intervention	Polishing performed with a rubber cup and prophy paste (RCP)
C - Comparison	Air-polishing with abrasive powder (APP)
O - Outcome	Damage to the fixed orthodontic device

A literature search was conducted using the PubMed Medline and Cochrane Library databases.

A second in-depth search was carried out in various journals, such as British Medical Dentistry, British Medical Journal, Journal of Dental Hygiene, International Journal of Dental Hygiene, European Journal of Orthodontics, Journal of International Society of Preventive and Community Dentistry, Journal of Indian Society of Periodontology, Dental Press Journal of Orthodontics, The Angle Orthodontist, European Journal of Paediatric Dentistry, Journal of Pharmaceutical Science and Research, Journal of Periodontology and The Journal of Contemporary Dental Practice. Keywords were identified in the search (Table II).

Table II. *Research keywords.*

Objective	Keywords
Effectiveness in plaque removal	*polish, air-polishing, orthodontic, orthodontia, oral hygiene, professional hygiene, polish in orthodontia, fixed orthodontic, polish rubber cup, polish bristle brush, dental hygienist, dental hygiene, cleaning brackets* *Orthodontic AND polishing* *Orthodontic polishing*
Treatment time	*Treatment time, time register*
Comfort expressed by the patient	*Orthodontic polishing comfort, polish comfort, orthodontic air-polish, perception, sensation*
Damage to the orthodontic device	*Damage, debonding, breakage, bracket*

In order to obtain more scientific articles, neither prophy paste (for RCP) nor abrasive powder (for APP) was specified in the search.

Inclusion criteria

The studies covered by the inclusion criteria were clinical trials, RCTs, and systematic reviews, with no limit on the year of publication of the studies and free full text. The sample of patients met the following inclusion criteria:

- Patients of both sexes and all ages
- Patients that were undergoing fixed metal orthodontic treatment.

No limits were set in terms of the initial plaque index and maximum and/or a minimum number of orthodontic brackets.

Exclusion criteria

The exclusion criteria were in vitro studies with extracted teeth. The following types were excluded:

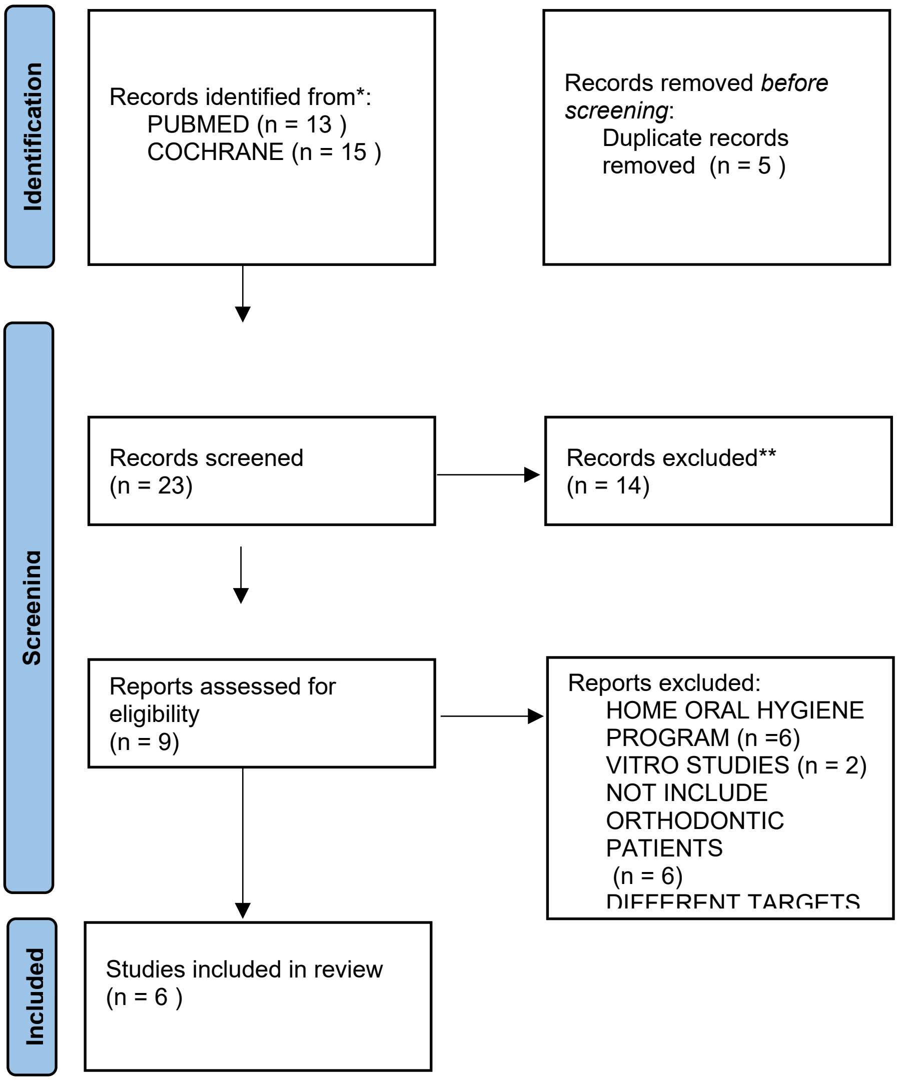
- patients with cardiovascular and blood pressure disorders;

- patients with respiratory diseases;
- haemodialysis patients;
- patients on a low-sodium diet;
- smoking patients.

RESULTS

The search was conducted between October 2019 and August 2020, and the study identification flowchart, according to PRISMA, includes the reasons for excluding articles (Fig. 1).

Fig. 1. *Preferred Reporting Items for Systematic Review and Meta-Analysis flow diagram for studies retrieved through the searching and selection process.*



The search yielded 23 scientific articles,14 of which were excluded because they dealt with home protocols (N=6), were in vitro studies (N=2) or had objectives that were not compatible with those selected (N=6). In addition, of the 9 articles initially included, 3 were excluded because their inclusion criteria did not include orthodontic patients. Six articles met the inclusion criteria (Table III).

Table III. *Included studies.*

Investigators	Year of pubblication	Title	Journal
Barnes et al.(12)	1990	Effects of an Air-Powder Polishing System on Orthodontically Bracketed and Banded Teeth	American Journal of Orthodontics and Dentofacial Orthopedics
Gerbo et al.(13)	1993	Applications of the air-powder polisher in clinical orthodontics	American Journal of Orthodontics & Dentofacial Orthopedics
Gutmann et al.(14)	1998	Air polishing: a comprehensive review of the literature	The Journal of Dental Hygiene
Ramaglia et al.(11)	1999	A clinical comparison of the efficacy and efficiency of two professional prophylaxis procedures in orthodontic patients	European Journal of Orthodontics
Graumann et al.(16)	2013	Air-polishing: a review of a current literature	The Journal of Dental Hygiene
Poormoradi et al.(10)	2018	The comparison of two professional prophylaxis system in plaque removal and debonding of orthodontic brackets	Journal of Indian Society of Periodontology

Effectiveness of APP and RCP in removing plaque from tooth surfaces

For this first objective, the following items were analyzed and are briefly described in table IV (Table IV).

Table IV. *Description of articles included for the objective "effectiveness of RCP and APP in removing plaque from tooth surfaces".*

Article	Prophylaxis paste (CPR)	Abrasive powder (APP)	Plaque index
Barnes et al.(12)	Pumice	Sodium bicarbonate	Plaque Control Record or O'Leary Index of 1972
Ramaglia et al.(11)	Prophy Paste (Smart Practice, USA)	Sodium bicarbonate	Modified 1970 Turesky-Quigley-Hein
Poormoradi et al.(10)	Pumice	Sodium bicarbonate	Plaque Control Record or O'Leary Index of 1972

The effectiveness of plaque removal from the tooth surfaces was evaluated using the plaque index. Each study measured the plaque index of patients sampled before and after treatment with APP and RCP.

The tables below show the average value of the plaque index improvement obtained after APP and RCP treatments, respectively (Table V).

Table. V. *Δ Improvement in plaque index after treatment (Plaque Control Record or O'Leary Index of 1972) in percentage value.*

Method	Barnes et al.(12)	Poormoradi et al.(10)
PLAQUE INDEX (APP)	Δ72.4%	Δ66.2%
PLAQUE INDEX (CRP)	Δ59.9%	Δ30.8%

It should be noted that the data presented in the table for the studies were processed from the values mentioned above provided by the scientific article in question. In contrast, a comparative study conducted by Barnes et al. (12) directly reported the data presented in Table VI (Table VI).

Table VI. *Plaque Index value pre-post treatment.*

Ramaglia et al.(11)	Group I (Chlorhexidine mouthwash 0,12%)	Group II (Chlorhexidine mouthwash 0,12%)
Baseline Plaque Index (APP) Plaque Index (RCP)	 1,88* 1,92*	 1,34 1,27*
Post-treatment Plaque Index (APP) Plaque Index (RCP)	 O,22* 0,31*	 0,05* 0,12*

P value refers to the significance at a level =0,05; the Plaque index of Quigley-Hein was modified by Turesky as reported by Fischman (1988).

Of the three studies selected to address this first objective, two of them, that of Barnes et al. (12) and that of Poormoradi et al. (10), used the same plaque index: the Plaque Control Record or O'Leary Index (11, 9) (Table V).

The study by Ramaglia et al. (11), unlike APP, appeared to be more effective than RCP for dental plaque removal in Group II, and APP was significantly more effective than RCP (Table VII).

Both treatment methods analyzed, APP and RCP, were able to cause a statistically significant reduction in the plaque index; at the same time, however, there was a significant difference between the two methods: by analyzing the percentages, it can be concluded that the improvement in the plaque index is greater for the APP method in all three studies examined. Therefore, the APP technique was more effective than the RCP for plaque removal in patients undergoing fixed orthodontic treatment.

Treatment time is taken by APP and RCP, respectively, to achieve an effective removal of bacterial plaque from the tooth surface

The scientific articles recorded each technique's time spent (treatment time). Table VII shows the average values in minutes taken for the APP and RCP methods presented in the studies analyzed for this objective. The data proposed in the table have been partially reworked; seconds were converted into minutes to allow easy comparison. Ramaglia et al. (11) provided the treatment time for each of the two groups into which the sample was divided. In order to facilitate the comparison with information from the other two studies shown in the table, data from the two groups were averaged. The result was then a single number transformed from seconds to minutes.

Table VII. *Treatment time taken (*calculated value).*

	Minutes		
Method	**Barnes *et al.***	**Ramaglia *et al.***	**Poormoradi *et al.***
APP	4.0 minutes	5.2*minutes	1.8 minutes
CPR	6.8 minutes	8.3*minutes	4.4 minutes
ΔAPP-RCP	-2.8	-3.1	-2.6

It can be deduced from Table VII that the RCP technique required more treatment time than the APP technique in all three studies analyzed.

There was a statistically significant difference in treatment time between the two techniques. On average, the APP method takes 2.8 minutes less than the RCP treatment. Therefore, APP is a faster technique than RCP for effectively removing bacterial plaque from the tooth surface.

Comfort expressed by patients for both professional prophylaxis methods APP and RCP

The scientific articles included in the analysis of patients' expressed comfort with APP and RCP are described in the table below (Table VIII).

Table VIII. *Description of items included per objective "Patient-expressed comfort".*

Article included	Prophylaxis paste (RCP)	Abrasive powder (APP)	Methods used for comfort analysis
Barnes *et al.*	Pumice	Sodium bicarbona te	/
Poormoradi *et al.*	Pumice	Sodium bicarbona te	VAS Visual Analog Scale, the scale ranges from 0 to 100, and each patient assigns a number to each of the two techniques used.

Barnes et al. (12), in their study, consider the aspect of patient comfort with the two techniques analyzed only at the time of the 'discussion', with the following statement: 'patients (...) did not find the APP method unpleasant, but they did find the pressure required used with the RCP method unpleasant or painful'. Unfortunately, the study does not state how the authors arrived at this conclusion; one assumes with questions posed to the patients. Therefore, the conclusion drawn from this study is that the APP method is more comfortable than the RCP method for patients undergoing fixed orthodontic treatment (11).

The study conducted by Poormoradi et al. (10) to understand which technique offers greater comfort uses the VAS Visual Analog Scale, which ranges from a score of 0 to 100, where 0 stands for 'absolute discomfort' (not at all comfortable) and 100 stands for 'absolute comfort' (absolutely comfortable) (9).

The average comfort recorded was 93.04% for the RCP technique and 59.53% for the APP. The value of 93.04% for the RCP method falls within the SEA range, corresponding to 'great convenience, which can be translated as 'very comfortable. On the other hand, 59.53% fall within the "good comfort" range translated as "comfortable". A statistically significant difference was observed between the comfort levels of the two methods. The average comfort level of the RCP technique was higher than that of the APP. The authors of the study pointed out that, in the opinion of most patients, APP is rated less comfortable because of the bitter taste that sodium bicarbonate leaves in the mouth (9).

Damage caused by APP and RCP to the orthodontic device.

The last aspect assessed was the presence or absence of any damage caused by the APP and RCP methods to parts of the orthodontic device, such as orthodontic wires, brackets, and bands.

What can be seen from Table IX is that, taking into consideration the first two articles, that of Barnes et al. (12) and that of Ramaglia et al. (11), damage to the orthodontic wires, brackets and bands is caused in both cases by the RCP technique. In contrast, APP does not cause any damage.

Table IX. *Damage to the orthodontic device.*

Articles	Damage		Debonding	
	APP	RCP	APP	RCP
Barnes et al. (12)	No	Yes, to orthodontic wires and bands	/	/
Ramaglia et al. (11)	No	Yes, minor damage to orthodontic brackets or wires	/	/
Poormoradi et al. (10)	/	/	No	No

Taking the debonding aspect, assessed exclusively by Poormoradi et al. (10), the latter does not occur in any patients with any of the methods analyzed. The authors also state that “there is no objective evidence of fractures and disconnections of the bracket attachment”.

In summary, referring to the three studies in the table, APP did not cause any damage to the orthodontic device or debonding of brackets (9, 10, 11), unlike the RCP method, which caused some damage to orthodontic wires, bands and brackets (9, 2).

DISCUSSION

The objective of this study was to seek an effective method for the professional removal of plaque at a low cost, without damaging the bonding of brackets and teeth, and to provide patients with oral and dental health during orthodontic treatment, in addition to health education and medical aids.

From the studies analyzed, it is possible to state that the APP technique is more effective than the RCP in removing dental plaque in patients undergoing fixed orthodontic treatment (9-14), is less time-consuming (9, 10, 12), and is safer against orthodontic devices, as none of the scientific articles examined whether the APP caused any damage to the orthodontic device or debonding of the bracket (9, 11, 12).

Barnes et al. also showed that APP was very effective for plaque removal, and its advantage over the method was that it required less time and made the patient more comfortable (15). The same conclusions were also reported by Gerbo et al., Gutmann et al., and Graumann et al. in their respective reviews (13, 14, 16). Conflicting opinions were found regarding the comfort expressed by patients.

The discussion of the scientific article by Poormoradi et al. (10), one of the two studies analyzed to compile the results regarding comfort, suggests a reflection. The authors stated that “according to most patients, the cause of this discomfort is associated with the bitter taste of the applied powder”, and again “surely, if other powders had been used, such as glycine, for example, patients would have experienced greater comfort” (9). In this regard, some studies have reported symptoms of respiratory problems during or immediately after gum polishing or damage to the mucus surface of the lower lip following the use of pressurized air (17, 18, 19, 20).

CONCLUSIONS

This literature review aimed to identify which of the two tooth surface polishing techniques, air polishing with abrasive powder (APP) or polishing with a rubber cup and prophy paste (RCP), is more effective in removing biofilms in patients undergoing fixed orthodontic treatment the least expensive in terms of time, the most comfortable for the patient, and the safest concerning the orthodontic device.

From the studies analyzed, it is, therefore, possible to state that the APP technique is more effective than the RCP technique in removing dental plaque in patients. However, conflicting opinions were found concerning the comfort expressed by the patients.

The literature review results suggest that in clinical practice, the dental surfaces of patients with fixed orthodontic appliances performed with air polishing and abrasive powder are recommended while evaluating each patient's case.

REFERENCES

1. Ardizzone V, Bresciano S, Camorali C, Abbinante A, Barone A. Oral Hygienist. Theory and professional practice. First edition Pioltello (MI): Edra, 285-287; 409-415; 611-624.
2. Lombardo G, Signoriello A, Corrocher G, Signoretto C, Burlacchini G, Pardo A, Nocini PF. A Topical Desiccant Agent in Association with Manual Debridement in the Initial Treatment of Peri-Implant Mucositis: A Clinical and Microbiological Pilot Study. Antibiotics (Basel) 2019; 8(2):82. doi:https://doi.org/10.3390/antibiotics8020082.
3. Genovesi AM, Lorenzi C, Lyle DM, et al. Periodontal maintenance following scaling and root planing. A randomized single-center study comparing minocycline treatment and daily oral irrigation with water. Minerva Stomatol 2014; ahead of print.
4. Wilkins E.M. The patient with orthodontic appliances. Clinical Practice of the Dental Hygienist. 13th ed. Philadelphia (PA): Wolters Kluwer 2021; 501-511.
5. Pardo A, Signoriello A, Signoretto C, et al. Detection of Periodontal Pathogens in Oral Samples and Cardiac Specimens in Patients Undergoing Aortic Valve Replacement: A Pilot Study. J Clin Med 2021; 10(17):3874. doi:https://doi.org/10.3390/jcm10173874.
6. Corega C, Vaida L, Festila DG, et al. Dental white spots associated with bulimia nervosa in orthodontic patients. Minerva Stomatol 2014; ahead of print.
7. Antezack A., Monnet-Corti V. Oral and periodontal hygiene in orthodontic patients. Orthod Fr 2018; 89(2):181-190. doi:https://doi.org/10.1051/orthodfr/2018015.
8. Ricci M, Marchisio O, Genovesi AM, et al. comparison between oscillating-twisting rotating of brush head vs a characteristic sweeping bristles motion on reducing oral inflammation. Minerva Stomatol 2014; Epub ahead of print.
9. Cunha LDD, Peruzzo DC, Costa LA, Pereira ALP, Benatti BB. Effect of a single-tufted toothbrush on the control of dental biofilm in orthodontic patients: A randomized clinical trial. Int J Dent Hyg 2018, 16(4):512-518. doi:https://doi.org/10.1111/idh.12360.
10. Poormoradi B, Tamasoki S, Shahbazi A, Hooshyarfard A, Vahdatinia F, Behgozin F, Tapak L. The comparison of two professional prophylaxis systems in plaque removal and debonding of orthodontic brackets. J Indian Soc Periodontol 2018; 22(5):414-418. doi:https://doi.org/10.4103/jisp.jisp_387_17.
11. Ramaglia L, Sbordone L, Ciaglia RN, Barone A, Martina R. A clinical comparison of the efficacy and efficiency of two professional prophylaxis procedures in orthodontic patients. Eur J Orthod 1999; 21(4):423-8. doi:https://doi.org/10.1093/ejo/21.4.423.
12. Barnes CM, Russell CM, Gerbo LR, Wells BR, Barnes DW. Effects of an air-powder polishing system on orthodontically bracketed and banded teeth. Am J Orthod Dentofacial Orthop 1990; 97(1):74-81. doi:https://doi.org/10.1016/S0889-5406(05)81712-3.
13. Gerbo LR, Barnes CM, Leinfelder KF. Applications of the air-powder polisher in clinical orthodontics. Am J Orthod Dentofacial Orthop 1993; 103(1):71-73. doi:https://doi.org/10.1016/0889-5406(93)70109-2.
14. Gutmann ME. Air polishing: a comprehensive review of the literature. J Dent Hyg 1998; 72(3):47-56.

15. Corega C, Vaida L, Festila DG, et al. The benefits of Quercitin for dentistry and maxillofacial surgery: a systematic review. Minerva Stomatol 2014; Epub ahead of print.
16. Graumann SJ, Sensat ML, Stoltenberg JL. Air polishing: a review of current literature. J Dent Hyg 2013; 87(4):173-80.
17. Lombardo G, Pardo A, Signoretto C, Signoriello A, Simeoni E, Rovera A, Nocini PF. Hyperbaric oxygen therapy for the treatment of moderate to severe periodontitis: a clinical pilot study. Undersea Hyperb Med 2020; 47(4):571-580. doi:https://doi.org/10.22462/10.12.2020.6.
18. Hongsathavij R, Kuphasuk Y, Rattanasuwan K. Clinical comparison of the stain removal efficacy of two air polishing powders. Eur J Dent 2017; 11(3):370-375. doi:https://doi.org/10.4103/ejd.ejd_152_17.
19. Pedullà E, Plotino G, Scibilia M, Grande NM, De Santis D, Pardo A, Testarelli L, Gambarini G. Cyclic fatigue comparison among endodontic instruments with similar cross section and different surface coating. Minerva Stomatol 2019; 68(2):67-73. doi:https://doi.org/10.23736/S0026-4970.17.04009-2.
20. Bertossi D, Fiorino P, Corega C, et al. Cone-beam volumetric imaging in craniofacial medicine. Minerva Stomatol 2019; 68(4):200-212. doi:https://doi.org/10.23736/S0026-4970.17.04003-1.
21. Lombardo G, Signoretto C, Corrocher G, Pardo A, Pighi J, Rovera A, Caccuri F, Nocini PF. A topical desiccant agent in association with ultrasonic debridement in the initial treatment of chronic periodontitis: A clinical and microbiological study. New Microbiol 2015; 38(3):393-407.
22. Dental white spots associated with bulimia nervosa in orthodontic patients. Corega C, Vaida L, Festila DG, et al. Minerva Stomatol 2014; ahead of print.
23. Marconcini S, Barone A, Perrini N, et al. Conservative treatment of unicystic odontogenic keratocyst by piezosurgery approach. A case report. Minerva Stomatol 2014; ahead of print.
24. Gelpi F, Romoli L, D'Arienzo D, et al. Lateral periodontal cyst (LPC) mimicking periodontal socket in a young patient: Report of a case and review of the literature. Minerva Stomatol 2014; ahead of print.
25. Genovesi AM, Lorenzi C, Lyle DM, et al.Periodontal maintenance following scaling and root planing. A randomized single-center study comparing minocycline treatment and daily oral irrigation with water. Minerva Stomatol 2014; ahead of print.
26. Marconcini S, Genovesi AM, Marchisio O, et al. In vivo study of titanium healing screws surface modifications after different debridment procedure. Minerva Stomatol 2014; ahead of print.
27. Corega C, Vaida L, Festila DG, et al. Blood levels of interleukins in patients with ameloblastoma. Minerva Stomatol 2014; ahead of print.
28. Nocini PF. De Santis D, Ferrari F, Bertele GP. A Customized Distraction Device for Alveolar Ridge Augmentation and Alignment of Ankylosed Teeth. Int J Oral and Maxillofac Implants 2004; 19(1):133-44.
29. De Santis D, Graziani P, Castellani R, Zanotti G, Gelpi F, Marconcini S, Bertossi D, Nocini PF. A New Radiologic Protocol and a New Occlusal Radiographic Index for Computer-Guided Implant Surgery. J Craniofac Surg 2016; 27(5):e506-10. doi:https://doi.org/10.1097/SCS.0000000000002490.
30. Bertossi D, Nocini R, Luciano U, et al. Piezoelectric surgery inserts vs conventional burst: a clinical investigation. J Biol Regul Homeost Agents 2018; 32(2 Suppl. 2):15-19.
31. Barone A, Toti P, Bertossi D, et al. Gene Expression of Human Mesenchymal Stem Cells Cultured on Titanium Dental Implant Surfaces. Journal Craniofac Surgery 2016; 27(3):712-717. doi:https://doi.org/10.1097/SCS.0000000000002551.
32. De Santis D, Sinigaglia S, Pancera P, et al. An overview of socket preservation. J Biol Regul Homeost Agents 2019; 33(1 Suppl. 1):55-59.
33. De Santis D, Sinigaglia S, Pancera P, et al. An overview of guided bone regeneration. J Biol Regul Homeost Agents 2019; 33(1 Suppl. 1):49-53.

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Review

Air polishing therapy in supportive periodontal treatment: a systematic review

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ABSTRACT

The aim of this study was to analyze tooth surface roughness and clinical parameters by a systematic review of the literature to compare the efficacy of air polishing with hand or ultrasonic instrumentation during supportive periodontal therapy (SPT). This study used a research question based on the PICO method. Bibliographic research was performed using four different databases. For the search of the articles, the work was divided into two parts: the first part analyzed the clinical parameters of air polishing in supportive periodontal therapy, and the second part analyzed the effects of air polishing on hard tissues. Of 164 articles concerning clinical parameters, 49 met the inclusion criteria; from 64 articles concerning hard tissues, it reached 4. Excluding these doubles, 12 were chosen for the literature review: eight RCTs, one retrospective cohort study, and three in vitro studies. The scientific literature has shown that air polishing, scaling, and root planing in supportive periodontal therapy give similar clinical results. However, air polishing seems to preserve the hard tissues of the tooth more than the traditional treatment with ultrasonic or manual instrumentation.

INTRODUCTION

In the era of mini-invasiveness, where every branch of medicine attacks the body as little as possible (1), healing is fast, and side effects can be limited, even in dentistry, and in our case of non-surgical periodontal therapy, we are trying to turn towards greater respect for the tissues, obtaining the same results. Traditionally, non-surgical periodontal therapy and supportive therapy are performed with scaling and root planing (SRP) through the combination of mechanical instruments and manual instruments by performing debridement, biofilm removal, scaling, and calculus removal, and polishing the hard surfaces with rubber cups and abrasive pastes (low granulometry at best), which, if used correctly, embraces the dental element and cleanses the sulcus (2).

Patients with aggressive periodontitis (AgP) require close recall, including SRP, depigmentation with bicarbonate powder, and repolishing (3). In the long term, this can involve the removal of root tissue (4), surface roughening (5), hypersensitivity, and recession (6). Recent literature proposes maintenance of the use of topical desiccant (7), oxygen (8), or low abrasive powders for the control of above and below gingival biofilm (9), which is less time-consuming, more comfortable for the patient (10), and more respectful of hard and soft tissues (11). The clinical and microbiological results were comparable to those obtained with SRP (3, 11).

It is also preferable to apply methods that cause the least possible damage to the hard and soft tissues of the oral cavity (12). Supportive periodontal therapy aims to maintain stability in patients with periodontitis after successful active periodontal therapy. According to Muller et al. (10), the subgingival biofilm may not mineralize to form calculus during maintenance visits; therefore, a treatment modality such as air polishing may be preferable to avoid abrasion of the hard tissues of the tooth (12). The following literature review aims to highlight the effectiveness of air polishing with glycine and erythritol powder compared to traditional scaling and root planing therapy with manual and/or ultrasonic instrumentation in supportive periodontal therapy.

MATERIALS AND METHODS

A research question was previously outlined using the PICO methodology (Table I) to carry out the review.

Table I. *Clinical research question using PICO methodology.*

P	Patient/population/problem	Patients in supportive periodontal therapy (SPT)
I	Intervention	Use of air-polishing with glycine and erythritol powders
C	Comparison	Scaling e root planing (SRP) with manual and / or ultrasonic instrumentation
O	Outcome	Minimally invasive treatment and preservation of hard tissues. The main outcomes are: BoP (bleeding on probing), PI (plaque index), PPD (pocket depth at probing), CAL (clinical attachment level), Rec (gingival recession). The secondary outcomes referred to hard tissues are: loss of substance, mean depth of roughness (Rz) and mean roughness (Ra).

In order to produce this dissertation, bibliographic research was mainly conducted using the following electronic databases: PubMed, Scopus, and Ovid MED LINE. However, only PubMed was used for research on the effects on hard tissues. In addition, Google Scholar was used, and the university accounts for research at the University (University of Verona Search).

The work was divided into two parts to research the articles: the first part analyzed the clinical parameters of air-polishing in supportive periodontal therapy, and the second part analyzed the effects of air polishing on hard tissues. The main MeSH terms for researching clinical parameters included "air-polishing," "subgingival air-polishing," and "supportive periodontal therapy"; while to analyze the effects on hard tissues, were used MeSH terms such as "effects on hard tissues," "root surface roughness," "root cementum," "surface alterations," all united by the boolean operator "AND." Keywords were identified in the search (Table II). Two reviewers (Ale and Sara) screened the handwriting singly, first by their titles and objectification. Second, full-textbook papers that fulfilled the eligibility criteria for the addition were linked according to the study aims. Finally, the diversity of the primary outgrowth across studies was determined according to the following factors: study design, evaluation period, the medical and periodontal status of subjects, number of subjects, mean age and age range of subjects, follow-up of the study, and intervention type of Air polishing in supportive therapy.

Table II. *Keywords for the research.*

Aim	Keywords
Air polishing in supportive periodontal therapy	*(air polishing) AND (supportive periodontal therapy) (subgingival air polishing) AND (supportive periodontal therapy) (subgingival air polishing) AND (periodontal maintenance)*
Air-polishing on hard tissues	*(air polishing) AND (cementum)* *(air polishing) AND (root surface roughness) (air polishing) AND (surface alterations)*

The types of studies that met the inclusion criteria were clinical trials, RCTs, and systematic reviews. The exclusion criteria were publication date over 10 years and language other than Italian or English.

To further narrow the scope of the research, the articles were selected according to the following criteria: publication date: 2011-2021, text availability, free full text; RCT, randomized controlled trials; retrospective cohort trials.

The keywords used were subgingival instrumentation, subgingival air-polishing, glycine and erythritol powder, supportive periodontal therapy, PD ≥ 4 mm, periodontal maintenance therapy, manual and ultrasonic instrumentation, and SRP.

Exclusion criteria: publication date before 2011, systematic reviews and meta-analysis; keywords such as peri-implantitis, peri-implant mucositis, trehalose powder, additional therapy, supragingival instrumentation, non-surgical and surgical periodontal therapy, sodium bicarbonate powder.

RESULTS

The search yielded 228 articles: 164 for the first and 64 for the second research question. Of the 164 articles concerning clinical parameters, 49 met the inclusion criteria; from 64 articles concerning hard tissues, we reached 12. With the exclusion of doubles, 12 of 53 articles were selected for the literature review: eight RCTs (11, 12, 14-19), one retrospective cohort trial (20), and three in vitro studies (21, 22, 15). Eight RCTs and a retrospective cohort study evaluated the clinical parameters, and three 3 in vitro studies evaluated the effects on hard tissues. The procedure for selecting articles to be included in this review is shown in Fig. 1.

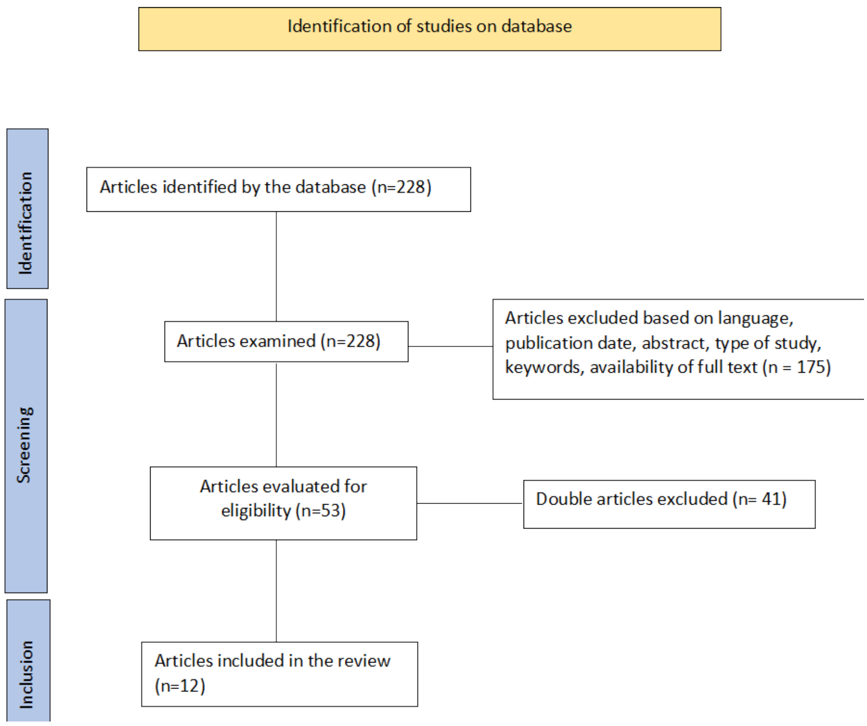

Fig. 1. *Preferred Reporting Items for Systematic Review flow diagram for studies retrieved through the searching and selection process.*

As shown in Table III, in the RCTs and the retrospective cohort study, air polishing was compared with manual instrumentation in six studies (12, 13, 15, 16, 18, 19) and with ultrasound in five studies (11, 14, 16, 18, 19). In addition, one study used air polishing with dust-free water as a control group (19).

Eight RCTs (11-18) and a retrospective cohort study (20) evaluated air polishing in supportive periodontal therapy. In the study by Wennström et al. (11), air polishing was applied in pockets with PPD between 5-8 mm, in two studies (12, 17) in pockets with 4-9 mm and in the remaining studies (13-16, 18, 19) in pockets with PPD≥4 mm. Glycine powder was used in 5 studies (11, 12, 16, 17, 19). Erythritol powder was used in 4 studies (13-15, 18).

All RCT studies used an air-polishing device to remove the subgingival biofilm with a periodontal nozzle, whereas a retrospective cohort study (19) used an air-polishing device with a standard handpiece.

The average age of patients varies between 18 and 80 years; most of the RCT studies had a follow-up of 3, 6, and 12 months; two studies (11, 16) had a 1-2 months follow-up, while the study by Petersilka et al. (19) had a 5-year follow-up, being a long-term retrospective study.

Table III shows the specific characteristics of the RCTs and the retrospective cohort study. In particular, the table includes the intervention, clinical application, parameters, devices used and follow-ups.

Table III. *RCT-specific characteristics and retrospective cohort study.*

STUDIES	INTERVENTION	CLINICAL APPLICATION	PARAMETERS	DEVICES USED	FOLLOW-UP
Wennstrom et al. (2011)	GPAP vs ultrasonic instrumentation	SPT, PPD 5-8 mm	PD, CAL, BOP	Perio-Flow EMS handpiece with periodontal nozzle Ultrasonic instrumentation (Piezon EMS with PerioSlim)	Basal time, 14 and 60 days
Flemmig et al. (2012)	GPAP vs manual instrumentation	SPT, PPD 4-9 mm	PD, Rec, BOP, PI	Perio-Flow EMS handpiece with periodontal nozzle Curette and scaler	Basal time, 10 and 90 days
Hagi et al. (2013)	EPAP vs manual instrumentation	SPT, PPD ≥ 4 mm	PD, BOP, CAL, PI	Perio-Flow EMS handpiece with periodontal nozzle Gracey curette, universal curette	Basal time and 3 months
Müller et al. (2014)	EPAP vs ultrasonic instrumentation	SPT, PPD ≥ 4 mm	PD, PI, BOP, Rec	Perio-Flow EMS handpiece with periodontal nozzle Ultrasonic instrumentation (Piezon LED, EMS)	Basal time, 3, 6, 9 and 12 months
Hagi et al. (2015)	EPAP vs manual instrumentation	SPT, PPD ≥ 4 mm	PD, BOP, CAL, PI	Perio-Flow EMS handpiece with periodontal nozzle Gracey curette, universal curette	Basal time and 6 months
Kargas et al. (2015)	GPAP vs manual / ultrasonic instrumentation	SPT, PPD ≥ 4 mm	PD, PI, GI, Rec, CAL	Perio-Flow EMS handpiece with periodontal nozzle Ultrasonic (Piezon EMS) + Gracey curette	Basal time, 1, 3 e 6 months
Sekino et al. (2020)	GPAP vs air polishing with water without glycine	SPT, PPD 4-9 mm	PD, CAL, PI, BOP	Perio-Flow EMS handpiece with periodontal nozzle	90 and 180 days
Ulvik et al. (2021)	EPAP vs ultrasonic / manual instrumentation	SPT, PPD ≥ 4 mm	PD, BOP, CAL, PI	Perio-Flow EMS handpiece with periodontal nozzle Ultrasonic (Piezon EMS) + Gracey curette	Basal time, 3, 6, 9 e 12 months
Petersilka et al. (2021)	GPAP vs ultrasonic / manual instrumentation	SPT, PPD ≥ 4 mm	PD, PI, BOP	Airflow EMS with standard handpiece Gracey curette + sonic scaler Kavo	5 years

Concerning clinical parameters, in particular the probing depth (PPD), in all the studies, it was shown that air-polishing with glycine or erythritol powder obtained PPD reduction results similar to manual and ultrasonic instrumentation (Tables VI and V), except in the study by Kargas et al. (16), where the GPAP (air-polishing with glycine powder) group showed a significantly higher PPD than manual and ultrasonic instrumentation at 1, 3, and 6 months: a statistically significant reduction at 1 and 3 months compared to the initial values, while at 6 months, there was no significant difference.

Regarding the clinical attachment level (CAL), no statistically significant differences were observed between air-polishing with glycine or erythritol powder and manual or ultrasonic instrumentation in any of the ranges examined, as can always be deduced from Tables VI and V. Almost all studies report an increase or gain in CAL with both treatment procedures.

In the 6 months, Ulvik et al. (18) found a significant difference between treatments of 0.8 mm (± 0.4), comparing manual and ultrasonic instrumentation ($p = 0.032$) to air-polishing with erythritol powder.

In the study by Kargas et al. (16), at 1 month, the GPAP (air-polishing with glycine powder) group showed statistically higher levels of CAL than with manual instrumentation. In contrast, at 3 and 6 months, statistically significant differences were observed in both groups assigned to mechanical and ultrasonic instrumentation. Regarding the gingival recession (Rec), there was no statistically significant difference between the test group (air-polishing with glycine powder or erythritol) and the control group (manual or ultrasonic instrumentation) in follow-ups at 1, 3, and 6 months. (Tables VI and V).

Tables IV and V on the following pages show the main clinical results of the RCTs and retrospective cohort studies included in the review.

Table IV. *Results parameters PPD, CAL and Rec air-polishing with glycine powder.*

PARAMETER		PPD						CAL			REC	
STUDY		Petersika et al. (2021)		Sekino et al. (2020)	Kargas et al. (2015)	Flemming et al. (2012)	Wennstrom et al. (2011)	Sekino et al. (2020)	Kargas et al. (2015)	Wennstrom et al (2011)	Kargas et al. (2015)	Flemming et al. (2012)
Air-polishing	Basic time	1.2**	14.7*	4.6 (1.2)	4.78 ± 0.10	4.3 ± 0.9	5.8 (0.70)	6.2 (2.5)	5.42 ± 0.13	n.r	0.64 ± 0.08	0.5 ± 1.0
SRP		0.0**	10.3*	4.7 (0.9)	4.66 ± 0.10/ 4.50 ± 0.09	4.2 ± 0.5	5.7 (0.62)	6.8 (2.2)	5.12 ± 0.11/ 4.94 ± 0.09	n.r	0.46 ± 0.10/ 0.44 ± 0.08	0.2 ± 0.5
Air-polishing	1/2 months	n.r	n.r	n.r	4.44 ± 0.10	n.r	4.5 (0.87)	n.r	5.42 ± 0.13	- 0.6 (0.69)	0.98 ± 0.13	n.r
SRP		n.r	n.r	n.r	3.88 ± 0.10/ 3.74 ± 0.08	n.r	4.4 (0.93)	n.r	4.98 ± 0.11/ 4.80 ± 0.09	- 0.6 (1.03)	1.10 ± 0.13/ 1.06 ± 0.07	n.r
Air-polishing	3 months	n.r	n.r	4.0 (1.3)	4.40 ± 0.11	4.1 ± 0.8	n.r	5.5 (2.1)	5.38 ± 0.12	n.r	0.98 ± 0.11	0.5 ± 0.9
SRP		n.r	n.r	4.7 (0.9)	3.84 ± 0.07/ 3.70 ± 0.08	4.1 ± 0.5	n.r	7.0 (2.4)	4.76 ± 0.11/ 4.84 ± 0.09	n.r	0.92 ± 0.11/ 1.14 ± 0.08	0.2 ± 0.4
Air-polishing	6 months	n.r	n.r	3.8 (1.4)	4.52 ± 0.09	n.r	n.r	5.4 (2.4)	5.40 ± 0.11	n.r	0.88 ± 0.10	n.r
SRP		n.r	n.r	4.5 (1.2)	4.00 ± 0.08/ 4.06 ± 0.10	n.r	n.r	6.6 (2.2)	4.82 ± 0.11/ 4.82 ± 0.09	n.r	0.82 ± 0.09/ 0.76 ± 0.11	n.r
Air-polishing	5 years	97.2**	33.3*	n.r	n.r	n.r	n.r	n.r	n.r	n.r	n.r	n.r
SRP		100**	33.3*	n.r	n.r	n.r	n.r	n.r	n.r	n.r	n.r	n.r

*3.5≤PPD<6.5 mm with percentage of PPD reduction
** PPD≥6.5 mm with percentage of PPD reduction
Note: ultrasonic treatment / manual instrumentation treatment
n.r: not rilevable

Table V. *Results of PPD, CAL and Rec air-polishing parameters with erythritol powder.*

PARAMETER		PPD				CAL			REC
STUDY		Ulvik et al. (2021)	Hagi et al. (2015)	Muller et al. (2014)	Hagi et al. (2013)	Ulvik et al. (2021)	Hagi et al. (2015)	Hagi et al. (2013)	Muller et al. (2014)
Air-polishing	Basic time	4.8 ± 0.4	4.46 ± 0.07	5.2 (0.4)	4.46 ± 0.07	5.5 ± 0.4	4.90 ± 0.19	4.90 ± 0.19	1.0 (0.9)
SRP		4.6 ± 0.2	4.65 ± 0.09	5.4 (0.6)	4.64 ± 0.09	5.0 ± 0.2	5.07 ± 0.21	5.07 ± 0.21	0.9 (1.0)
Air-polishing	3 months	n.r	n.r	n.r	3.72 ± 0.12	n.r	n.r	4.43 ± 0.22	n.r
SRP		n.r	n.r	n.r	4.16 ± 0.14	n.r	n.r	4.57 ± 0.25	n.r
Air-polishing	6 months	4.0 ± 0.4	3.78 ± 0.13	n.r	n.r	5.2 ± 0.4	4.43 ± 0.24	n.r	n.r
SRP		3.5 ± 0.3	3.92 ± 0.15	n.r	n.r	4.4 ± 0.3	4.37 ± 0.26	n.r	n.r
Air-polishing	12 months	3.7 ± 0.4	n.r	4.5 (1.0)	n.r	5.1 ± 0.4	n.r	n.r	1.0 (1.0)
SRP		3.4 ± 0.3	n.r	4.4 (1.1)	n.r	4.5 ± 0.3	n.r	n.r	0.8 (1.1)
n.r: not rilevable									

Regarding bleeding on probing, all studies highlight that air polishing and manual or ultrasonic instrumentation reduce bleeding. In particular, in the study of Petersilka et al. (19), the percentage of sites showing improvement was higher in the GPAP (air-polishing with glycine powder) cohort than in the scaling cohort.

In a study by Sekino et al. (17), there was a tendency for less bleeding on days 90 and 180 in the glycine powder air-polishing group and more bleeding in the powder-free water air-polishing group on the same days, but these differences were not statistically significant.

No statistically significant differences were highlighted regarding the plaque index (PI): air polishing and manual or ultrasonic instrumentation led to the reduction of bacterial plaque.

Taking into consideration the retrospective cohort study of Petersilka et al. (19), although there was a more significant reduction in the plaque index in favor of the test group with GPAP, air polishing with glycine powder led to a reduction in the plaque index as much as manual or ultrasonic instrumentation with no statistically significant differences.

In a study by Ulvik et al. (18), air polishing with erythritol powder reduced the plaque index to the same extent as manual or ultrasonic instrumentation without statistically significant differences. Tables VI and VII on the following pages highlight the values of the BoP and PI parameters of the various studies.

Table VI. *Results BoP parameters, PI air-polishing with glycine powder.*

PARAMETER		BOP					PI			
STUDY		Petersika et al. (2021)	Sekino et al. (2020)	Kargas et al. (2015)	Flemming et al. (2012)	Wennstrom et al. (2011)	Petersika et al. (2021)	Sekino et al. (2020)	Kargas et al. (2015)	Flemming et al. (2012)
Air-polishing	Base time	18.5*	77.8*	0.70*	26.8± 27.9	100*	18.8*	0.4 (0.6)	1.12*	47.4± 42.2
SRP		6.7*	77.8*	0.72*/0.48*	33.6± 17.9	100*	9.3*	0.3 (0.6)	0.96*/0.88*	49.6± 38.2
Air-polishing	1/2 months	n.r	n.r	0.38*	n.r	25*	n.r	n.r	0.48*	n.r
SRP		n.r	n.r	0.40*/0.20*	n.r	30*	n.r	n.r	0.56*/0.32*	n.r
Air-polishing	3 months	n.r	33.3*	0.50*	14.0± 20.6	n.r	n.r	0.4 (0.5)	0.52*	33.4± 28.5
SRP		n.r	55.6*	0.28*/0.24*	16.8± 16.3	n.r	n.r	0.3 (0.5)	0.44*/0.54*	36.1± 40.5
Air-polishing	6 months	n.r	38.9*	0.58*	n.r	n.r	n.r	0.3 (0.6)	0.64*	n.r
SRP		n.r	50.0*	0.38*/0.40*	n.r	n.r	n.r	0.3 (0.6)	0.50*/0.44*	n.r
Air-polishing	5 years	14,9*	n.r	n.r	n.r	n.r	10,9*	n.r	n.r	n.r
SRP		5,7*	n.r	n.r	n.r	n.r	6,3*	n.r	n.r	n.r

Note: ultrasonic treatments/manual instrumentation treatment
*without standard deviation
n. r: not rilevable

Table VII. *Results bop parameters, PI air-polishing with erythritol powder.*

PARAMETER		BOP				PI			
STUDY		Ulvik et al. (2021)	Hagi et al. (2015)	Muller et al. (2014)	Hagi et al. (2013)	Ulvik et al. (2021)	Hagi et al. (2015)	Muller et al. (2014)	Hagi et al. (2013)
Air-polishing	Base time	100*	31.70± 2.31	22± 10	31.70± 2.31	63*	31.95± 3.79	0.4 (0.2)	31.95± 3.79
SRP		100*	36.45± 2.84	21± 10	36.45± 2.84	54*	34.45± 4.81	0.4 (0.2)	34.45± 4.81
Air-polishing	3 months	n.r	n.r	n.r	26.10± 2.45	n.r	n.r	n.r	29.20± 3.96
SRP		n.r	n.r	n.r	30.89± 2.84	n.r	n.r	n.r	23.89± 3.03
Air-polishing	6 months	70*	26.11± 2.90	n.r	n.r	40*	20.53± 3.86	n.r	n.r
SRP		90*	27.89± 2.52	n.r	n.r	45*	21.78± 3.06	n.r	n.r
Air-polishing	12 months	68*	n.r	15± 6	n.r	50*	n.r	0.3 (0.1)	n.r
SRP		55*	n.r	14± 6	n.r	43*	n.r	0.3 (0.1)	n.r

*without standard deviation
n.r: not rilevable

In regards to the in vitro studies, the parameters taken into consideration were the following:
a. loss of substance (in micrometres, µm)
b. average depth of roughness (Rz), in micrometres
c. average roughness (Ra), in micrometres.

Hägi et al. (13) analyzed the loss of substance, mean roughness (Ra), and mean roughness depth (Rz) of dentin, which was higher when curettes were used (128 ± 40 µm) compared to ultrasonic (14 ± 12 µm) and air polishing with erythritol powder (6 ± 7 µm). After five treatments, Ra was higher after applying ultrasonic ($p = 0.037$) and curettes ($p = 0.030$), and Rz was higher after using curettes ($p = 0.028$).

Bozbay et al. (20) analyzed the loss of cementum thickness after various treatments: air-polishing with glycine powder, ultrasonic, ultrasonic followed by air-polishing with glycine, and manual instrumentation. After subgingival instrumentation, the percentages of coronal cementum remaining were 94%, 84%, 80%, and 65% for air-polishing, ultrasonic, ultrasonic, ultrasonic, and manual instrumentation, respectively.

The results showed that smoother root surfaces were produced by manual instrumentation followed by air polishing, whereas the ultrasound-instrumented root surfaces had grooves and scratches.

Air polishing yielded the most favourable results for the enamel's average roughness depth (Rz). Air polishing alone was the only group that did not reveal any significant changes in Rz compared to the untreated cementum. Other approaches have significantly reduced the surface roughness of cementum.

DISCUSSION

This literature review evaluated air-polishing efficacy with glycine and erythritol powder compared to traditional scaling and root planning treatment with manual and/or ultrasonic instruments in supportive periodontal therapy.

Subgingival air polishing in supportive periodontal therapy has shown promising results as an alternative treatment approach to the traditional method performed with manual or ultrasonic instrumentation. The studies selected for this review show that the results obtained with air polishing are similar to those obtained in the study of Badersten et al. (21), who compared the traditional method with manual instruments to the ultrasonic method.

According to the eight RCTs and retrospective cohort study, no significant differences existed between the compared clinical parameters. Therefore, air polishing aims to reduce probing pocket depth (PPD), gingival recession (Rec), bleeding () and plaque accumulation (PI). In addition, studies have confirmed that clinical attack level (CAL) gain is also possible with air polishing. Regarding pocket depth reduction (PPD), the study by Kargas et al. (16) is the only one to state that a reasonably high PPD was reached compared to the control group, but without statistically significant differences.

For the clinical attachment level (CAL), the study of Ulvik et al. (18) observed a statistically significant difference in favor of the manual or ultrasonic instrumentation group, presumably due to the selection of the sites; in fact, the study takes into consideration the involvement of furcations, and it seems that air polishing does not achieve the same results obtained in the sites without defects.

Air polishing also seems to obtain more satisfactory results regarding gingival recession (Rec), and in the study by Kargas et al. (16), it was shown that air polishing, if repeated over time, causes a lesser extent of the side effect of gingival recession. However, it has been shown that both manual and ultrasonic instrumentation, if repeated over time, cause a greater gingival recession (22, 24). Both powders, glycine and erythritol, yielded similar results as manual and/or ultrasonic instrumentation. A long-term study by Petersilka et al. (19) highlighted that glycine powder might have a better result in reducing bleeding on probing (BoP) and, therefore, periodontal inflammation, a sign of disease progression. This result may be due to glycine powder's immunomodulatory, anti-inflammatory, and cytoprotective effects on periodontal tissue (25). In the study by Hagi et al. (17), erythritol powder improved the clinical parameters BOP, PI, PPD, and CAL to a similar extent as SRP.

What can be deduced from the results of the studies considered corresponds to what was stated in the systematic review by Nascimento et al. (24): air polishing, manual instrumentation, and ultrasound instrumentation are clinically efficient in controlling biofilms to levels compatible with the reduction of periodontal inflammation measured by plaque accumulation, bleeding, pocket depth, and clinical attachment level.

A comparison of the results from in vitro studies shows that air-polishing with glycine or erythritol powder minimizes damage to hard-tooth tissues (15, 21, 22). In addition, air polishing with erythritol powder involves less dentin loss and surface roughness than manual and mechanical instruments (15). According to Bozbay et al. (22), air polishing with glycine powder causes less loss of cementum and less surface roughness than traditional treatment. In the study by Arefnia et al. (23), air polishing alone did not cause enamel loss and resulted in less cementum loss than all other groups.

On the other hand, manual and ultrasonic instrumentation cause excessive loss of hard root tissue during SPT, as discussed in the literature (25, 26, 28, 29).

Based on the results obtained through this literature review, it can be stated that both air-polishing with glycine and erythritol powder and manual or ultrasonic instrumentation are two effective treatment modalities for achieving the subgingival biofilm removal in patients in supportive periodontal therapy: both treatments obtain comparable clinical results. Furthermore, it has been shown that repeated manual or ultrasonic instrumentation in supportive therapy can cause greater damage to the tooth's hard tissues. Instead, the risk of excessive removal of the root substance was shown to be negligible with the use of air polishing with glycine and erythritol powder.

In general, the need for subgingival tartar removal in SPT is relatively low compared with the need for causal therapy. Therefore, air polishing is a promising tool for supportive periodontal therapy because, given the same results, it causes the least possible damage to the hard tissues of the oral cavity.

RESULTS

This literature review shows that air polishing with glycine and erythritol powder is advantageous in supportive periodontal therapy, as it has obtained clinical results similar to manual or ultrasonic instrumentation. Today, the concept of minimally invasive surgery is increasing, and the choice of tools and treatments that cause the least possible damage to the body is preferred. Air polishing has been shown to preserve the tooth's hard tissues compared to the "gold standard" treatment. In supportive periodontal therapy, in which patients come for recalls every 3/4 months, the goal is to obtain good results with the least possible damage. During maintenance visits, the need for calculus removal is low; therefore, treatment modalities such as air polishing are preferable to avoid tooth surface loss.

REFERENCES

1. Pardo A, Signoriello A, Signoretto C, et al. Detection of Periodontal Pathogens in Oral Samples and Cardiac Specimens in Patients Undergoing Aortic Valve Replacement: A Pilot Study. J Clin Med 2021; 10(17):3874. doi: 10.3390/jcm10173874.
2. Genovesi AM, Lorenzi C, Lyle DM, et al. Periodontal maintenance following scaling and root planing. A randomized single-center study comparing minocycline treatment and daily oral irrigation with water. Minerva Stomatol 2014; Epub ahead of print.
3. Mensi M, Feres M, Calza S, Sordillo A, Scotti E, Garzetti G. One-Stage Full Mouth Instrumentation (OSFMI): Clinical Outcomes of an Innovative Protocol for the Treatment of Severe Periodontitis. J Int Acad Periodontol. 2020; 22(3):129-136.
4. Petersilka GJ. Subgingival air-polishing in the treatment of periodontal biofilm infections. Periodontol 2000 2011; 55(1):124-42. doi: 10.1111/j.1600-0757.2010.00342.x.
5. Flemmig TF, Petersilka GJ, Mehl A, Hickel R, Klaiber B. The effect of working parameters on root substance removal using a piezoelectric ultrasonic scaler in vitro. J Clin Periodontol 1998; 25(2):158-63. doi: 10.1111/j.1600-051x.1998.tb02422.x.
6. Draenert ME, Jakob M, Kunzelmann KH, Hickel R. The prevalence of tooth hypersensitivity following periodontal therapy with special reference to root scaling. A systematic review of the literature. Am J Dent 2013; 26(1):21-7.
7. Lombardo G, Signoriello A, Corrocher G, Signoretto C, Burlacchini G, Pardo A, Nocini PF. A Topical Desiccant Agent in Association with Manual Debridement in the Initial Treatment of Peri-Implant Mucositis: A Clinical and Microbiological Pilot Study. Antibiotics (Basel) 2019; 8(2):82. doi: 10.3390/antibiotics8020082.
8. Lombardo G, Pardo A, Signoretto C, Signoriello A, Simeoni E, Rovera A, Nocini PF. Hyperbaric oxygen therapy for the treatment of moderate to severe periodontitis: a clinical pilot study. Undersea Hyperb Med. 2020; 47(4):571-580. doi: 10.22462/10.12.2020.6.
9. Sculean A, Bastendorf KD, Becker C, et al. A paradigm shift in mechanical biofilm management? Subgingival air polishing: a new way to improve mechanical biofilm management in the dental practice. Quintessence Int 2013; 44(7):475-7. doi: 10.3290/j.qi.a29615.
10. Kruse AB, Wölki BJ, Woelber JP, Frisch E, Vach K, Ratka-Krüger P. Subgingival air polishing with trehalose powder during supportive periodontal therapy: use of a conical shaped tip during a randomized clinical trial. BMC Oral Health. 2022; 22(1):70. doi: 10.1186/s12903-022-02109-1.
11. Wennström JL, Dahlén G, Ramberg P. Subgingival debridement of periodontal pockets by air polishing in comparison with ultrasonic instrumentation during maintenance therapy. J Clin Periodontol 2011; 38(9):820-7. doi: 10.1111/j.1600-051X.2011.01751.x.
12. Flemmig TF, Arushanov D, Daubert D, Rothen M, Mueller G, Leroux BG. Randomized controlled trial assessing efficacy and safety of glycine powder air polishing in moderate-to-deep periodontal pockets. J Periodontol 2012; 83(4):444-52. doi: 10.1902/jop.2011.110367.
13. Hägi TT, Hofmänner P, Salvi GE, Ramseier CA, Sculean A. Clinical outcomes following subgingival application of a novel erythritol powder by means of air polishing in supportive periodontal therapy: a randomized, controlled clinical study. Quintessence Int. 2013; 44(10):753-61. doi: 10.3290/j.qi.a30606.
14. Müller N, Moëne R, Cancela JA, Mombelli A. Subgingival air-polishing with erythritol during periodontal maintenance: randomized clinical trial of twelve months. J Clin Periodontol 2014; 41(9):883-9. doi: 10.1111/jcpe.12289.
15. Hägi TT, Hofmänner P, Eick S, Donnet M, Salvi GE, Sculean A, Ramseier CA. The effects of erythritol air-polishing powder on microbiologic and clinical outcomes during supportive periodontal therapy: Six-month results of a randomized controlled clinical trial. Quintessence Int 2015; 46(1):31-41. doi: 10.3290/j.qi.a32817.
16. Kargas K, Tsalikis L, Sakellari D, Menexes G, Konstantinidis A. Pilot study on the clinical and microbiological effect of subgingival glycine powder air polishing using a cannula-like jet. Int J Dent Hyg 2015; 13(3):161-9. doi: 10.1111/idh.12104.

17. Sekino S, Ogawa T, Murakashi E, Ito H, Numabe Y. Clinical and microbiological effect of frequent subgingival air polishing on periodontal conditions: a split-mouth randomized controlled trial. Odontology 2020; 108(4):688-696. doi: 10.1007/s10266-020-00493-0.
18. Ulvik IM, Sæthre T, Bunæs DF, Lie SA, Enersen M, Leknes KN. A 12-month randomized controlled trial evaluating erythritol air-polishing versus curette/ultrasonic debridement of mandibular furcations in supportive periodontal therapy. BMC Oral Health 2021; 21(1):38. doi: 10.1186/s12903-021-01397-3.
19. Petersilka G, Koch R, Vomhof A, Joda T, Harks I, Arweiler N, Ehmke B. Retrospective analysis of the long-term effect of subgingival air polishing in supportive periodontal therapy. J Clin Periodontol 2021; 48(2):263-271. doi: 10.1111/jcpe.13392.
20. Bozbay E, Dominici F, Gokbuget AY, Cintan S, Guida L, Aydin MS, Mariotti A, Pilloni A. Preservation of root cementum: a comparative evaluation of power-driven versus hand instruments. Int J Dent Hyg 2018; 16(2):202-209. doi: 10.1111/idh.12249.
21. Badersten A, Nilvéus R, Egelberg J. Effect of non-surgical periodontal therapy. I. Moderately advanced periodontitis. J Clin Periodontol. 1981; 8(1):57-72. doi: 10.1111/j.1600-051x.1981.tb02024.x.
22. Arefnia B, Koller M, Wimmer G, Lussi A, Haas M. In Vitro Study of Surface Changes Induced on Enamel and Cementum by Different Scaling and Polishing Techniques. Oral Health Prev Dent 2021; 19(1):85-92. doi: 10.3290/j.ohpd.b927695.
23. Schaumann T, Kraus D, Winter J, Wolf M, Deschner J, Jäger A. Potential immune modularly role of glycine in oral gingival inflammation. Clin Dev Immunol 2013; 2013:808367. doi: 10.1155/2013/808367.
24. Nascimento GG, Leite FRM, Pennisi PRC, López R, Paranhos LR. Use of air polishing for supra- and subgingival biofilm removal for treatment of residual periodontal pockets and supportive periodontal care: a systematic review. Clin Oral Investig 2021; 25(3):779-795. doi: 10.1007/s00784-020-03762-y.
25. Pedullà E, Plotino G, Scibilia M, Grande NM, De Santis D, Pardo A, Testarelli L, Gambarini G. Cyclic fatigue comparison among endodontic instruments with similar cross section and different surface coating. Minerva Stomatol. 2019; 68(2):67-73. doi: 10.23736/S0026-4970.17.04009-2.
26. Ricci M, Marchisio O, Genovesi AM, et al. Comparison between oscillating-twisting rotating of brush head vs a characteristic sweeping bristles motion on reducing oral inflammation. Minerva Stomatol 2014; Epub ahead of print.
27. Corega C, Vaida L, Festila DG, et al. The benefits of Quercitin for dentistry and maxillofacial surgery: a systematic review. Minerva Stomatol 2014; Epub ahead of print.
28. Corega C, Vaida L, Festila DG, et al. Dental white spots associated with bulimia nervosa in orthodontic patients. Minerva Stomatol 2014; Epub ahead of print.
30. Bertossi D, Fiorino P, Corega C, et al. Cone-beam volumetric imaging in craniofacial medicine. Minerva Stomatol 2019; 68(4):200-212. doi: 10.23736/S0026-4970.17.04003-1.

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Review

Investigation on the accuracy of implant surgery in dynamic navigation: metanalysis and systematic review of literature

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ABSTRACT

The object of this study was to compare, through meta-analysis, the accuracy in implant placement obtained in Dynamic Navigation (DN) with Static Navigation (SN) and with conventional free-hand surgery (CS) and to provide some useful clinical parameters to consider during the planning phase of the intervention. A meta-analysis was performed, dividing the selected studies into two groups based on the statistical technique adopted: DN vs CS and DN vs SN. The heterogeneity between the various studies was assessed with the homonymous test and quantified with I2. The results were graphically represented using a forest plot. Egger's test and funnel plot were used to investigate the "small study effect". The search was performed through the PubMed database, and the Cochrane Library database identified 448 articles. After applying the inclusion criteria, 14 articles were selected and used for quantitative synthesis (meta-analysis). From the results obtained from this meta-analysis, it can be stated that the Dynamic Navigation mode allows for better accuracy than conventional surgery, the most used type of surgery, and is comparable to Static Navigation, the gold standard for accuracy.

INTRODUCTION

The rehabilitation of partial and total edentulism using osteointegrated implants is a method that has proven to be highly effective and predictable, with success rates reported in the literature that are also high in the long-term follow-up (1, 2). In order to obtain these results, the diagnostic phase of pre-surgical planning is fundamental and if carried out correctly, reduces complications connected to implant malposition, such as an occlusal overload of the implant that can lead to a preterm failure, unsatisfactory aesthetics, in particular in the anterior sectors, and prosthetist difficulty in creating a prosthetic product (3). Complications of greater interest always linked to a malposition of the implant can be cortical perforations, lesions of adjacent teeth and damage to particular anatomical structures, such as the inferior alveolar nerve or the maxillary sinus (4).

Once the planning has been carried out, i.e. once the ideal implant position has been identified on the software, the clinician's objective is to transfer it with maximum reproducibility to the real site (transition to the surgical phase); in order to do this, there are 2 methods available:

• Analogical: Conventional surgery, also called Free Hand or Mental Navigation

• Digital: Computer Assisted Surgery (CAS), also known as Computer Guided Surgery or Surgery in Navigation

This last method is divided into two modalities:

• Surgery in Static Navigation

• Surgery in Dynamic Navigation

A distinction can be made between static navigation using templates (dime) and direct dynamic navigation using optical transmission systems (5). The last frontier in the field of implant surgery is represented by Dynamic Navigation, a practical aid to minimise the discrepancies between the virtually planned implant position (using special software) and the real position of the dental implant. This technique is therefore added to the other two already available in implantology: conventional free-hand surgery and static navigation. The following discussion will compare the accuracy of these three surgical modalities through a systematic review and meta-analysis of what is currently reported in the literature.

MATERIALS AND METHODS

The guidelines in the *Cochrane Handbook for Systematic Reviews of Interventions (the Handbook)*, version 5.1.0 of March 2011, were followed for this systematic review of the literature accompanied by meta-analysis. Furthermore, the PRISMA Statement (2015) Guidelines for reporting systematic reviews and meta-analyses were followed to realise the Materials and methods section. (6) To search for scientific publications, the online databases most used in Italy, "PubMed" and "Cochrane Library", were used. The bibliographic research was carried out from February 2021 until the end of June of the same year by a single author (M.B.).

The following filters were applied to search for publications in the online databases mentioned above: 1) publication date included in the period from 01/01/2000 to 31/06/2021; 2) articles published exclusively in English. In addition, the research was carried out to select studies that compared the accuracy obtained from implant surgery in Dynamic Navigation (DN) with the one obtained from other types of implant placement, such as Static Navigation (SN) and/or free-hand conventional surgery (CS). The search strategy was based on the following terms: "Oral Implant", OR "Endosseous Implant", OR "Dental Implant", OR "Implant Placement", AND "Navigation surgery", OR "Image-guided surgery" OR "Dynamic Navigation" OR "Dynamic surgery" AND "Free-hand" OR "Conventional surgery "OR" Computer-Aided Design "OR" Static Navigation "OR" Static surgery "OR" Template " AND "Mesh " OR "custom titanium mesh" OR "custom mesh" OR "titanium mesh".

Eligibility criteria

Regarding the articles potentially includable in the review, randomised-controlled clinical trials (RCT), controlled clinical trials (CCT), cohort studies, comparative cadaver studies and comparative model studies were considered. Cadaver and model studies were included to compensate for the reduced availability of articles regarding implant placement in Dynamic Navigation due to the recent introduction of this technique, and this was possible as no Patient-centered outcomes or other data requiring a follow-up period were assessed but only those relating to the accuracy of the system, which can also be measured in this type of studies. Studies involving pterygoid implants, zygomatic implants, orthodontic mini-screws, studies with no control and Case reports were not included in the review.

As indicated by the *Cochrane Handbook for Systematic Reviews of Interventions*, the protocol for the formulation of the PICO question was adopted to outline the criteria for the inclusion of the articles, as shown below (7):

- **Population:** Only articles regarding patients, models and cadavers with partial or total edentulism to be rehabilitated with the placement of dental implants preceded by virtual planning were considered. Furthermore, the number of total implants had to be greater than or equal to 10 in the test and control groups.
- **Intervention:** The test group had to be composed of Dynamic Navigation implant placement.
- **Comparison:** The control group had to consist of implant placement with Static Navigation surgery, the gold standard for accuracy, or with conventional surgery, the most used procedure.
- **Outcomes:** The outcomes searched for in the articles were divided into primary and secondary outcomes. The primary outcome searched was the accuracy measured by superimposition between the virtual plan and the real position of the implant and reported as one of the following parameters:
    - *angular deviation,*
    - *total apical deviation*
    - *total coronal deviation*.

In addition, the following accuracy parameters were considered secondary outcomes:

- *apical depth deviation*
- *coronal depth deviation*
- *lateral apical deviation* and *lateral coronal deviation.*

Data characteristics

Coronal and apical deviations were assessed in individual clinical trials as follows: a first CBCT is executed to allow the digital pianification of the ideal implant position. After the surgery, a second CBCT is performed to evaluate the actual implant position. Then a superimposition of the first and second CBCT is performed to evaluate the accuracy of the surgery technique adopted (Fig. 1).

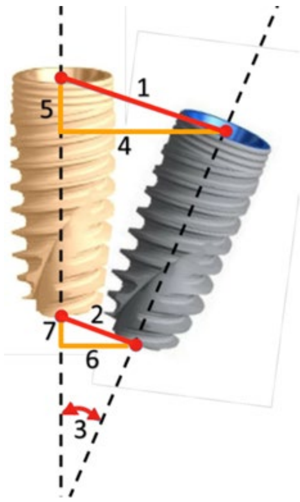

Fig. 1. *The primary outcomes are shown in red, and the secondary outcomes are shown in orange. Angular deviation (3): evaluates the amplitude of the angle formed by the axis of the positioned implant and the insertion axis of the virtual implant, expressed in degrees (°). Total apical deviation (2): it is the overall distance between the center of the positioned implant apex and the center of the virtual implant apex, expressed in mm. This variable, considering also the depth and the angular deviation, is reported, in some articles, as a 3D apical distance. Total coronal deviation (1): this is the total distance between the center of the platform of the positioned implant and the center of the virtual implant platform, expressed in mm. This variable, considering also the depth and the angular deviation is reported, in some articles, as 3D coronal distance. Apical depth deviation (7): it is the distance between the center of the positioned implant apex and the center of the virtual implant apex, measured along the Z axis. It is expressed in mm. Coronal depth deviation (5): it is the distance between the center of the placed implant platform and the center of the virtual implant platform, measured along the Z axis. It is expressed in mm. Lateral apical deviation (6): it is the distance between the center of the positioned implant apex and the insertion axis of the virtual implant, measured perpendicular to the latter. It is expressed in mm. Lateral coronal deviation (4): it is the distance between the center of the platform of the positioned implant and the insertion axis of the virtual implant, measured perpendicular to the latter. It is expressed in mm.*

Study selection

The PRISMA 2009 flow diagram guidelines were followed to select the articles (6). The titles obtained through the generic research previously explained were subsequently reviewed one by one (identification) by a single author (M.B.). At this point, the articles were selected by analysing the title and reading the abstract. In this second phase (screening), the full satisfaction of the inclusion criteria by the article in question was assessed. Therefore, studies that did not meet the inclusion criteria were excluded at this stage. Instead, the publications in which the abstract reading was insufficient to understand if the inclusion criteria were met were included in the next phase (reading the full text (eligibility). In this way, it was possible to include (*included*) only the studies that met all the criteria set out above.

Data collection process

The data of interest were extrapolated and grouped in data collection tables. The following parameters were analysed: 1) authors, year of publication, type of study; 2) test surgery modality and machinery used, comparison surgery modality; 3) the total number of patients, cadavers, models, number of test patients, cadavers, models, number of control patients, cadavers, models; 4) number of test implants, number of control implants; 5) type of edentulous test, type of edentulous control; 6) primary outcomes, secondary outcomes.

Statistical analysis

A meta-analysis was performed, dividing the selected studies into two groups based on the statistical technique adopted: DN vs CS and DN vs SN.

The meta-analysis results were expressed as standardised mean difference (SMD = Standardized Mean Difference) for the quantitative variables (Total Coronal Deviation, Coronal lateral D., Coronal depth D., Total apical D., Lateral apical D., Apical Depth D., Angular Axes D.). The extent of SMD was interpreted as mild, SMD = 0.2; medium, SMD = 0.5; and high, SMD = 0.8.

The heterogeneity between the various studies was assessed with the homonymous test and quantified with I2. The Higgins heterogeneity index (I2) describes the proportion of heterogeneity of the individual studies that cannot be explained by the sampling error and has the advantage of being intrinsically independent of the number of studies. Since the heterogeneity test was significant and/or the I2 was> 30% (8) for all the variables considered, a "random" effects statistical model was used. The combined (pooled) estimates and the related confidence intervals were calculated using Der Simonian and Laird (9). Finally, the results were graphically represented using a forest plot.

Egger's test and funnel plot were used to investigate the "small study effect" (10). As a general rule, funnel plot asymmetry tests should only be used when at least 10 studies are included in the meta-analysis because when there are fewer studies, the tests' power is insufficient to distinguish randomness from true asymmetry. The level of statistical significance was set at 5%, and the confidence intervals (CI) were calculated at 95%. All data were analysed with the STATA Software (Version 15).

RESULTS

Study selection and description

The search through the PubMed database identified 437 articles; instead, the search through the Cochrane Library database identified 21 articles. After eliminating the duplicates, 448 publications were obtained. A single operator (M.B.) viewed all these 448 titles and selected 347 abstracts to be read to assess whether or not they comply with the topic of interest. After the screening phase, 320 articles were removed. The 27 papers that tested positive for eligibility were investigated by reading the full text to assess whether they adhered to the inclusion criteria and, consequently, their possible use in the systematic review and meta-analysis. After reading the text, it was possible to exclude 13 jobs (Table I). From the initial research, 14 articles were selected: 14 were used for the qualitative synthesis (systematic review of the literature), and 14 were used for quantitative synthesis (meta-analysis). Following the *PRISMA 2009 guidelines*, a flow chart was constructed summarising the study selection procedure (Fig. 2). It is always important to mention and consider the possibility and the risk of bias in the included studies. The general characteristics of the 14 studies included in the quantitative synthesis were collected and summarised in the following table (Table II). Five clinical studies were identified (11-15), 1 study on the anatomical specimen (16) and 8 in vitro studies (4, 17-23).

Table I. *Articles excluded with motivation.*

Author	Year Reason for exclusion
Pellegrino et al.	2019 Absence of control
Stefanelli L. et al.	2019 Absence of control
Widmann et al.	2010 Absence of control
Kim et al.	2015 Absence of control
Golob Deeb J. et al.	2019 Absence of control
Emery et al.	2016 Absence of control
Sun et al.	2019 Absence of control
Ma L. et al.	2019 N. implants test/control < 10, DS not reported
Jokstad A. et al.	2018 Accuracy not reported or not comparable
Herklotz I. et al.	2017 Accuracy not reported or not comparable
Mischkowski R. et al	2016 Accuracy not reported or not comparable
Kramer F. et al.	2004 Accuracy not reported or not comparable
Sießegger M. et al.	2001 Accuracy not reported or not comparable

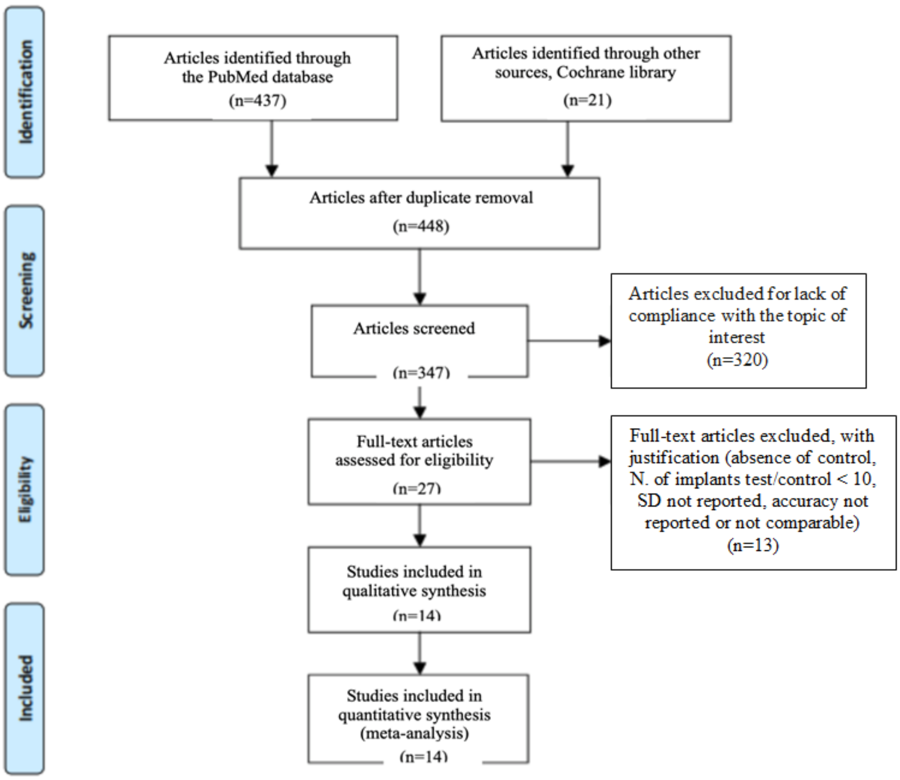

Fig. 2. *PRISMA flow chart.*

Table II. *General characteristics of the included studies.*

Author, Year	Study type	Surgical technique adopted		N(patients)		N(implants)		Edentulous type	
		Test	Control	Test	Control	Test	Control	Test	Control
HUMAN (VIVO)									
Kaewsiri, 2019	Human RCT	DN (IRIS-100)	SN	30	30	30	30	PE	PE
Block, 2017	Human CT	DN(X-Guide, full guide) DN(X-Guide, partial guide)	CS	tot 478		219 373	122	PE PE	PE PE
Yimarj P 2020	RCT parallel	DN(Iris-100)	SN (VisiJet MP200)	Tot 30		30	30	Partial (two neighboring implants)	Partial (two neighboring implants)
Sun 2020	Non-RCT	DN(AqNavi)	- sCAIS - d+sCAIS Freehand	NR		32	32 32 32	NR	NR
Aydemir 2020	Split-mouth RCT	DN(Navident)	Freehand	15	15	43	43	Partial (posterior bilateral edentulism)	Partial (posterior bilateral edentulism)
EX VIVO (CADAVER)									
Ruppin, 2008	Ex Vivo (human cadaver mandibles)	DN (RoboDent) DN (Artma Virtual Patient)	SN	tot20 (20 human cadaver mandibles)		40 40	40	TE-PE TE-PE	TE-PE
VITRO (MODEL)									
Mediavilla Guzman 2019	in vitro study (Polyurethane model)	DN(Navident)	SN(NemoStudio® / ProJet 6000)	10 models	10 models	20	20	Total	Total
Zhou 2020	in vitro study (Resin 3D printed model)	DN (Yizhimei)	sCAIS (VisiJet M3)	10 models	10 models	40	40	Partial	Partial
Jorba-Garcia 2019	in- vitro study (Resin model)	DN (NaviDent)	CS	3 models	3 models	18	18	PE	PE
Chen CK, 2018	In vitro study (Plaster model)	DN (AQ Navi SNS)	SN CS	10 models	10 models 10 models	50	50 50	PE	PE PE
Somogyi-Ganss, 2014	In vitro study	DN (NaviDent)	CS SN (Strauman GS) SN (Simplant SG) SN (Nobel Guide)	50	50 50 50 50	400	400 400 400 400	PE	PE PE PE PE
Kang, 2014	In vitro study	DN (CBYON Suite System), zona canini DN (CBYON Suite System), zona molari	SN	10	10	20 20	20 20	TE TE	TE TE
Hoffmann, 2005	In vitro study	DN (Vector Vision Compact)	CS	8	8	112	112	TE	TE
Brief, 2005	In vitro study	DN (RoboDent) DN (DenX IGI System)	CS	5 5	5	15 15	15	PE PE	PE

DN: Dynamic Navigation, SN: Static Navigation, CS: Conventional Surgery PE: partially edentulous TE: totally edentulous
NR: not reported, dCAIS dynamic computer – aided implant surgery, sCAIS static computer – aided implant surgery

All the studies included analysed the implant positioning in Dynamic Navigation (DN) as a test intervention; in particular, 1 of these studies used and evaluated two DN systems as a test; 1 divided the test group based on the site of insertion in canine and molar position and 1 study divided the test group, based on the method of insertion, between Full and Partial Guide. If control intervention is considered, only 6 studies represented implant placement in Static Navigation (SN), 5 studies by conventional surgery alone (CS), and 3 by SN and CS.

Considering the total number of implants inserted and divided into the 3 groups used in the subsequent meta-analysis, the data concerning 1517 implants in the DN test group, 1482 implants in the SN control group and 792 implants in the CS control group were collected.

In almost all the articles considered, the type of edentulism treated was exclusive of the partial type, with the exception of 3 in vitro studies which performed the insertion of implants in models characterised by total edentulism. In the remaining studies, it was not possible to separate the number of partial edentulous ones from the total edentulous ones.

Results of the individual studies

This paper examined the following primary outcomes resulting from the implant placement: Total coronal deviation, Total apical deviation and Angular deviation. The secondary outcomes considered are Coronal lateral deviation, Coronal depth deviation, Apical lateral deviation and Apical depth deviation.

Primary outcomes

The Total Coronal Deviation parameter was analysed in 8 studies, 4 clinical (11-13, 15) and 4 in vitro (4, 17, 18, 19). The total apical deviation was analysed in 11 studies, 5 clinical (11-15) and 6 in vitro (4, 17, 1-20, 23).

The Angular Deviation parameter was analysed in all included studies (4, 11-23). The primary outcomes were grouped in the table below (Table III).

Table III. *Primary Outcomes.*

Author, Year	Study Type	Surgery type		N(implants)		Mean Total Coronal Deviation (SD); mm		Mean Total Apical Deviation (SD); mm		Mean Angular Deviation (SD); °	
		Test	Control	Test	Control	Test	Control	Test	Control	Test	Control
HUMAN (VIVO)											
Kaewsiri, 2019	Human RCT	DN	SN	30	30	1,05 (0,44)	0,97 (0,44)	1,29 (0,5)	1,28 (0,46)	3,06 (1,37)	2,84 (1,71)
Block, 2017	Human CT	DN f DNp	CS	219 373	122	1,16 (0,59) 1,31 (0,68)	1,78 (0,77)	1,29 (0,65) 1,52 (0,78)	2,27 (1,02)	2,97 (2,09) 3,43 (2,33)	6,5 (4,21)
Yimarj P 2020	RCT parallel	DN	SN	30	30	1,24 (0,39)	1,04 (0,67)	1,58 (0,56)	1,54 (0,79)	3,78 (1,84)	4,08 (1,69)
Sun 2020	Non-RCT	DN	- sCAIS - d+sCAIS Freehand	32	32 32 32			1,25 (0,09)	1,49 (0,08) 0,98 (0,19) 1,89 (0,09)	3,24 (0,36)	4,54 (0,29) 2,20 (0,38) 6,12 (0,12)
Aydemir 2020	Split-mouth RCT	DN	Freehand	43	43	1,01 (0,07)	1,70 (0,13)	1,83 (0,12)	2,51 (0,21)	5,59 (0,39)	10,04 (0,83)
EX VIVO (CADAVER)											
Ruppin, 2008	Ex Vivo (human cadaver mandibles)	DN DN	SN	40 40	40					8,1 (4,6) 8,1 (4,9)	7,9 (5)
VITRO (MODEL)											
Mediavilla Guzman 2019	in vitro study (Polyurethane model)	DN	SN	20	20	0,85 (0,48)	0,78 (0,43)	1,18 (0,60)	1,20 (0,48)	4,00 (1,41)	2,95 (1,48)
Zhou 2020	in vitro study (Resin 3D printed model)	DN	sCAIS	40	40	0,4 (0,41)	1,15 (0,34)	0,34 (0,33)	1,37 (0,38)	0,97 (1,21)	2,6 (1,11)
Jorba-Garcia 2019	in- vitro study (Resin model)	DN	CS	18	18	1,29 (0,46)	1,50 (0,58)	1,33 (0,5)	2,26 (1,11)	1,6 (1,3)	9,7 (5,2)
Chen CK, 2018	In vitro study (Plaster model)	DN	SN CS	50	50 50	1,07 (0,48)	1,02 (0,46) 1,44 (0,56)	1,35 (0,55)	1,5 (0,79) 2,00 (0,79)	4,45 (1,97)	6,02 (3,71) 9,26 (3,62)
Somogyi-Ganss, 2014	In vitro study	DN	CS SN 1 SN 2 SN 3	400	400 400 400 400			1,71 (0,61)	2,32 (1,18) 1,71 (0,86) 1,46 (0,76) 1,91 (0,94)	2,99 (1,68)	8,95 (4,65) 3,31 (1,86) 3,09 (1,9) 4,24 (2,66)
Kang, 2014	In vitro study	DNc DNm	SNc SN m	20 20	20 20					12,37 (4,18) 8,97 (3,83)	6,72 (3,41) 3,9 (2,44)
Hoffmann, 2005	In vitro study	DN	CS	112	112					4,2 (1,8)	11,2 (5,6)
Brief, 2005	In vitro study	DN 1 DN 2	CS	15 15	15			0,6 (0,2) 0,94 (0,4)	1,89 (0,8)	2,12 (0,78) 4,21 (4,76)	4,59 (2,84)

DN: Dynamic Navigation, SN: Static Navigation, CS: Conventional Surgery PE: partially edentulous TE: totally edentulous; NR: not reported, dCAIS dynamic computer – aided implant surgery, sCAIS static computer – aided implant surgery, c: canines, m: molars

Secondary outcomes

The Lateral Coronal Deviation parameter was analysed in a total of 6 studies, 1 clinical (12), 1 on an anatomical piece (16) and 4 in vitro (18, 20, 21, 23). The Coronal Depth Deviation parameter was analysed in 2 studies, 1 clinical (12) and 1 in vitro (21).

The apical lateral deviation parameter was analysed in 4 studies, 1 clinical (12) and 3 in vitro (20, 21, 23). The Apical Depth Deviation parameter was analysed in a total of 7 studies, 2 clinical (12, 14), 1 on an anatomical piece (16) and 4 in vitro (18, 20, 21, 23). The secondary outcomes were grouped in the table below (Table IV).

Table IV. *Secondary Outcomes.*

Author, Year	Study Type	Surgery type		N(implants)		Mean coronal lateral deviation (SD); mm		Mean coronal depth deviation (SD); mm		Mean apical lateral deviation (SD); mm		Mean apical depth deviation (SD); mm	
		Test	Control	Test	Control	Test	Control	Test	Control	Test	Control	Test	Control
HUMAN (VIVO)													
Kaewsiri, 2019	Human RCT	DN	SN	30	30								
Block, 2017	Human CT	DN f DNp	CS	219 373	122	0,74 (0,43) 0,8 (0,49)	1,19 (0,68)	0,76 (0,6) 0,89 (0,73)	1,12 (0,83)	0,9 (0,55) 1,01 (0,65)	1,84 (1,05)	0,78 (0,6) 0,9 (0,74)	1,1 (0,82)
Yimarj P 2020	RCT parallel	DN	SN	30	30								
Sun 2020	Non-RCT	DN	- sCAIS - d+sCAIS Freehand	32	32 32 32							0,73 (0,13)	1,00 (0,15) 0,52 (0,20) 1,42 (0,25)
Aydemir 2020	Split-mouth RCT	DN	Freehand	43	43								
EX VIVO (CADAVER)													
Ruppin, 2008	Ex Vivo (human cadaver mandibles)	DN DN	SN	40 40	40	1,0 (0,5) 1,2 (0,6)	1,5 (0,8)					0,6 (0,3) 0,8 (0,7)	0,6 (0,4)
VITRO (MODEL)													
Mediavilla Guzman 2019	in vitro study (Polyurethane model)	DN	SN	20	20								
Zhou 2020	in vitro study (Resin 3D printed model)	DN	sCAIS	40	40								
Jorba-Garcia 2019	in- vitro study (Resin model)	DN	CS	18	18	0,85 (0,41)	1,26(0,66)					0,88 (0,47)	0,57(0,33)
Chen CK, 2018	In vitro study (Plaster model)	DN	SN CS	50	50 50								
Somogyi-Ganss, 2014	In vitro study	DN	CS SN 1 SN 2 SN 3	400	400 400 400 400	1,14 (0,55)	1,14 (0,68) 0,9 (0,48) 0,76 (0,54) 0,81 (0,55)			1,18 (0,56)	1,74 (1,07) 1,19 (0,62) 0,99 (0,64) 1,24 (0,8)	1,04 (0,71)	0,73 (0,71) 1,05 (0,86) 1,1 (0,79) 1,27 (0,86)
Kang, 2014	In vitro study	DNc DNm	SNc SN m	20 20	20 20	2,06 (1,43) 3,03 (1,81)	0,73(0,41) 0,68 (0,44)	1,14 (1,25) 0,76 (0,84)	0,47(0,34) 0,32 (0,25)	2,76 (1,03) 3,31 (2,07)	2,03(0,97) 1,08 (0,77)	1,42 (1,01) 1,96 (0,93)	1,52(1,31) 0,52 (0,52)
Hoffmann, 2005	In vitro study	DN	CS	112	112								
Brief, 2005	In vitro study	DN 1 DN 2	CS	15 15	15	0,35 (0,17) 0,65 (0,58)	1,35 (0,56)			0,47 (0,18) 0,68 (0,31)	1,62 (0,68)	0,32 (0,21) 0,61 (0,36)	0,84 (0,65)

DN: Dynamic Navigation, SN: Static Navigation, CS: Conventional Surgery PE: partially edentulous TE: totally edentulous NR: not reported, dCAIS dynamic computer – aided implant surgery, sCAIS static computer – aided implant surgery, c: canines, m: molars

Clinical outcomes

Before dealing with the section regarding quantitative synthesis to extrapolate clinical data that can be valid as a reference during the planning phase of an intervention in Dynamic Navigation, a further investigation was made where the overall mean and standard deviation of all studies included in the systematic review were calculated. The overall mean and standard deviation of Dynamic Navigation is shown in the following table, divided into primary and secondary outcomes. (Table V).

Table V. *Accuracy of Dynamic Navigation.*

Primary outcomes	Mean (SD)
Total Coronal Deviation	1,04 (0,44)
Total apical deviation	1,25 (0,45)
Axis angular deviation	4,7 (2,27)
Secondary outcomes	Mean (SD)
Lateral coronal deviation	1,18 (0,7)
Coronal depth deviation	0,89 (0,86)
Lateral apical deviation	1,47 (0,76)
Apical depth deviation	0,91 (0,56)

Quantitative synthesis of the results

A quantitative comparison for the accuracy of implant placement was performed through a meta-analysis of each of the 7 primary and secondary outcomes evaluated.

Forest plot graphs were extrapolated from the meta-analysis to allow a simpler graphical interpretation. In addition, where possible, or where the number of studies allowed their realisation, the Egger test was also performed accompanied by the graphical representation through a funnel plot to investigate the "small study effect".

The results of the statistical tests accompanied by the reference graphs are shown in the section below, divided by parameter. In order to facilitate the interpretation, the results relating to the comparison between Dynamic Navigation and conventional surgery (DN vs CS) were highlighted in blue, and those between Dynamic Navigation vs Static Navigation (DN vs SN) in yellow.

Total coronal deviation

For the total coronal deviation, the statistical analysis shows that there is a high difference (SMD = -1.650), statistically significant ($p < 0.001$), in favor of Dynamic Navigation in comparison with conventional surgery. From the comparison of Dynamic Navigation vs Static Navigation, a slight difference emerges (SMD = -0.234) in favor of Dynamic Navigation, but this difference does not reach statistical significance ($p = 0.576$) (Table VI).

Table VI. *Total Coronal Deviation.*

Study	SMD	[95% Conf.	Interval]	% Weight
DN vs CS				
Aydemir (2020)	-6.609	-7.694	-5.524	8.00
Chen CK (2018)	-0.709	-1.114	-0.305	10.40
Jorba-Garcia (2019)	-0.401	-1.061	0.259	9.63
Block (2017)	-0.668	-0.877	-0.460	10.78
Block (2017)	-0.940	-1.172	-0.707	10.75
Sub-total				
D+L pooled SMD	-1.650	-2.509	-0.791	49.56
DN vs SN				
Chen CK (2018)	0.106	-0.286	0.499	10.43
Zhou (2020)	-1.991	-2.530	-1.453	10.03
Mediavilla (2019)	0.154	-0.467	0.774	9.76
Yimarj P (2020)	0.365	-0.146	0.875	10.11
Kaewsiri (2019)	0.182	-0.325	0.689	10.12
Sub-total				
D+L pooled SMD	-0.234	-1.055	0.586	50.44
Overall				
D+L pooled SMD	-0.933	-1.527	-0.339	100.00

Test(s) of heterogeneity:

	Heterogeneity statistic	degrees of freedom	P	I-squared**	Tau-squared
DN vs CS	113.91	4	0.000	96.5%	0.8741
DN vs SN	52.99	4	0.000	92.5%	0.8074
Overall	192.50	9	0.000	95.3%	0.8400

** I-squared: the variation in SMD attributable to heterogeneity)

Note: between group heterogeneity not calculated;
only valid with inverse variance method

Significance test(s) of SMD=0

DN vs CS	z= 3.77	p = 0.000
DN vs SN	z= 0.56	p = 0.576
Overall	z= 3.08	p = 0.002

Total coronal deviation: forest plot

Observing the forest plot, of which the upper portion concerns the DN vs SN comparison and the lower portion the DN vs CS comparison, it can be seen that the test, the DN, is favoured in comparison with the CS and comparable to the SN, although presenting a very slight difference, however not significant (Fig. 3).

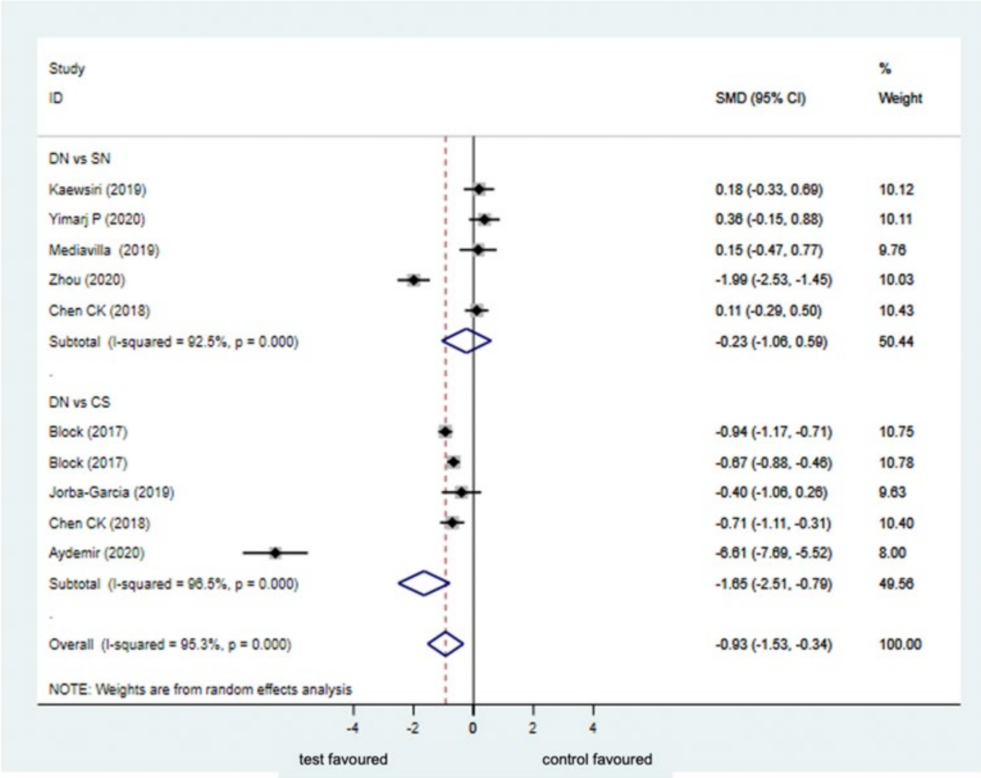

Fig. 3. *Total Coronal Deviation, forest plot.*

Total apical deviation

For the total apical deviation, the statistical analysis shows that there is a high difference (SMD = -1.919), statistically significant (p <0.001), in favor of Dynamic Navigation in comparison with conventional surgery. From the comparison of Dynamic Navigation vs Static Navigation, a moderate difference emerges (SMD = -0.556) in favor of Dynamic Navigation, reaching statistical significance (p = 0.008) (Table VII).

Table VII. *Total Apical Deviation.*

Study	SMD	[95% Conf.	Interval]	% Weight
DN vs CS				
Block (2017)	-1.222	-1.462	-0.982	6.17
Block (2017)	-0.887	-1.099	-0.676	6.20
Sun (2020)	-7.111	-8.455	-5.767	3.53
Aydemir (2020)	-3.976	-4.711	-3.241	5.12
Jorba-Garcia (2019)	-1.080	-1.782	-0.378	5.20
Chen CK (2018)	-0.955	-1.369	-0.541	5.88
Somogyi-Ganss (2014)	-0.649	-0.792	-0.507	6.27
Brief (2005)	-2.212	-3.133	-1.291	4.61
Brief (2005)	-1.502	-2.319	-0.685	4.90
Sub-total				
D+L pooled SMD	-1.919	-2.482	-1.355	47.88
DN vs SN				
Kaewsiri (2019)	0.021	-0.485	0.527	5.69
Yimarj P (2020)	0.058	-0.448	0.565	5.69
Sun (2020)	-2.819	-3.516	-2.121	5.22
Mediavilla-Guzman (2	-0.037	-0.657	0.583	5.41
Zhou (2020)	-2.894	-3.525	-2.263	5.39
Chen CK (2018)	-0.220	-0.614	0.173	5.92
Somogyi-Ganss (2014)	0.000	-0.139	0.139	6.27
Somogyi-Ganss (2014)	0.363	0.223	0.503	6.27
Somogyi-Ganss (2014)	-0.252	-0.392	-0.113	6.27
Sub-total				
D+L pooled SMD	-0.556	-0.969	-0.143	52.12
Overall				
D+L pooled SMD	-1.220	-1.601	-0.840	100.00

Test(s) of heterogeneity:

	Heterogeneity statistic	degrees of freedom	P	I-squared**	Tau-squared
DN vs CS	177.38	8	0.000	95.5%	0.6313
DN vs SN	181.71	8	0.000	95.6%	0.3465
Overall	560.92	17	0.000	97.0%	0.5960

** I-squared: the variation in SMD attributable to heterogeneity)

Note: between group heterogeneity not calculated;
only valid with inverse variance method

Significance test(s) of SMD=0

DN vs CS	z= 6.67	p = 0.000
DN vs SN	z= 2.64	p = 0.008
Overall	z= 6.29	p = 0.000

Total apical deviation: forest plot

Observing the forest plot, of which the upper portion concerns the DN vs CS comparison and the lower portion the DN vs SN comparison, it can be seen that the test, the DN, is favoured in comparison with the CS and also favoured in comparison with the SN, with statistical significance in both comparisons (Fig. 4).

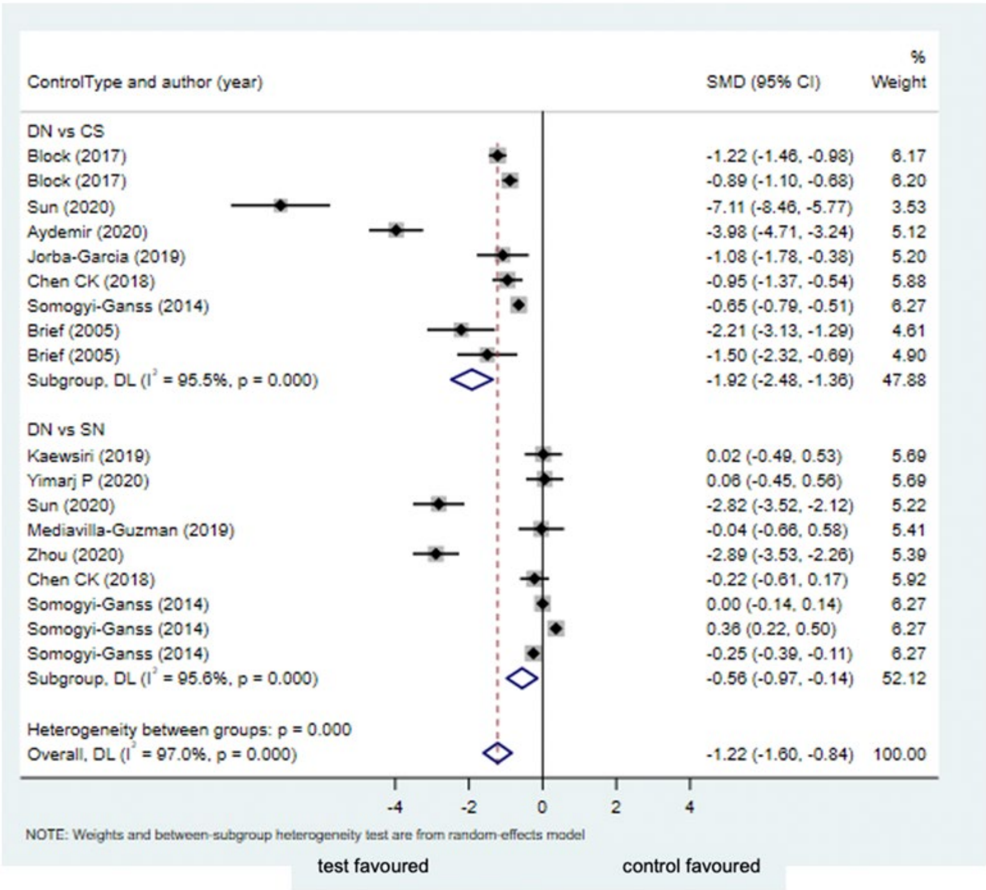

Fig. 4. *Total Apical Deviation, forest plot.*

Axis angular deviation

For the angular deviation of the axes, the statistical analysis shows that there is a high difference (SMD = -2.269), statistically significant (p <0.001), in favor of Dynamic Navigation in comparison with conventional surgery. From the comparison of Dynamic Navigation vs Static Navigation, a slight difference emerges (SMD = -0.199) in favor of Dynamic Navigation, but this difference does not reach statistical significance (p = 0.239) (Table VIII).

Table VIII. *Axis Angular Deviation.*

Study	SMD	[95% Conf.	Interval]	% Weight
DN vs SN				
Kaewsiri (2019)	0.142	-0.365	0.649	4.50
Yimarj P (2020)	-0.170	-0.677	0.337	4.50
Sun (2020)	-3.977	-4.831	-3.123	3.94
Ruppin (2008)	0.042	-0.397	0.480	4.58
Ruppin (2008)	0.040	-0.398	0.479	4.58
Mediavilla Guzman (2	0.726	0.085	1.367	4.30
Zhou (2020)	-1.404	-1.894	-0.913	4.52
Chen CK (2018)	-0.529	-0.927	-0.130	4.63
Somogyi-Ganss (2014)	-0.181	-0.319	-0.042	4.84
Somogyi-Ganss (2014)	-0.056	-0.194	0.083	4.84
Somogyi-Ganss (2014)	-0.562	-0.703	-0.421	4.84
Kang (2014)	1.481	0.778	2.185	4.20
Kang (2014)	1.579	0.865	2.293	4.18
Sub-total				
D+L pooled SMD	-0.199	-0.529	0.132	58.44
DN vs CS				
Block (2017)	-1.168	-1.406	-0.930	4.78
Block (2017)	-1.056	-1.271	-0.842	4.80
Sun (2020)	-10.733	-12.685	-8.781	2.17
Aydemir (2020)	-6.862	-7.983	-5.742	3.46
Jorba-Garcia (2019)	-2.137	-2.965	-1.310	3.98
Chen CK (2018)	-1.651	-2.106	-1.196	4.56
Somogyi-Ganss (2014)	-1.705	-1.867	-1.543	4.83
Hoffmann (2005)	-1.683	-1.988	-1.378	4.73
Brief (2005)	-1.186	-1.966	-0.406	4.07
Brief (2005)	-0.097	-0.813	0.619	4.17
Sub-total				
D+L pooled SMD	-2.269	-2.850	-1.688	41.56
Overall				
D+L pooled SMD	-1.073	-1.460	-0.686	100.00

Test(s) of heterogeneity:

	Heterogeneity statistic	degrees of freedom	P	I-squared**	Tau-squared
DN vs SN	186.57	12	0.000	93.6%	0.3069
DN vs CS	223.40	9	0.000	96.0%	0.7433
Overall	800.09	22	0.000	97.3%	0.7992

** I-squared: the variation in SMD attributable to heterogeneity)

Note: between group heterogeneity not calculated;
only valid with inverse variance method

Significance test(s) of SMD=0

DN vs SN	z= 1.18	p = 0.239
DN vs CS	z= 7.65	p = 0.000
Overall	z= 5.44	p = 0.000

Axis angular deviation: forest plot

Observing the forest plot, of which the upper portion concerns the DN vs SN comparison and the lower portion the DN vs CS comparison, it can be seen that the DN test is favoured in comparison with the CS and comparable to the SN, although presenting a very slight difference, however not significant. Furthermore, it can be observed that the difference between DN and SN remains minimal and negligible both by analysing the data as a whole and in individual studies, except for the data reported by Kang et al. and Sun et al. which differ considerably from the other data reported (Fig. 5).

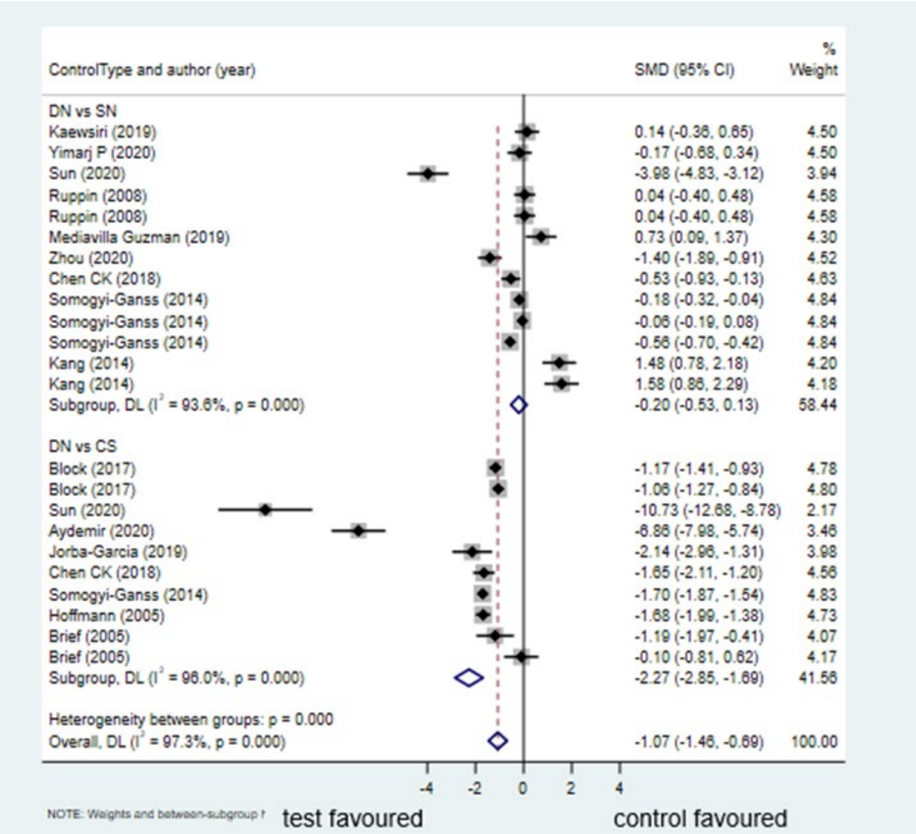

Fig. 5. *Axis Angular Deviation, Forest Plot.*

The presence of the “small study effect” was investigated using the funnel plot and the Egger test:

- Funnel Plot Axis Angular Deviation, DN vs CS comparison (Fig. 6).
- Funnel Plot Axis Angular Deviation, DN vs SN comparison (Fig. 7).
  - Since the p = 0.148, the presence of “small-study effects” is excluded from the comparison between DN and CS. (Table IX).
  - Since p = 0.840, the presence of “small-study effects” is excluded from the comparison between DN and SN. (Table X).

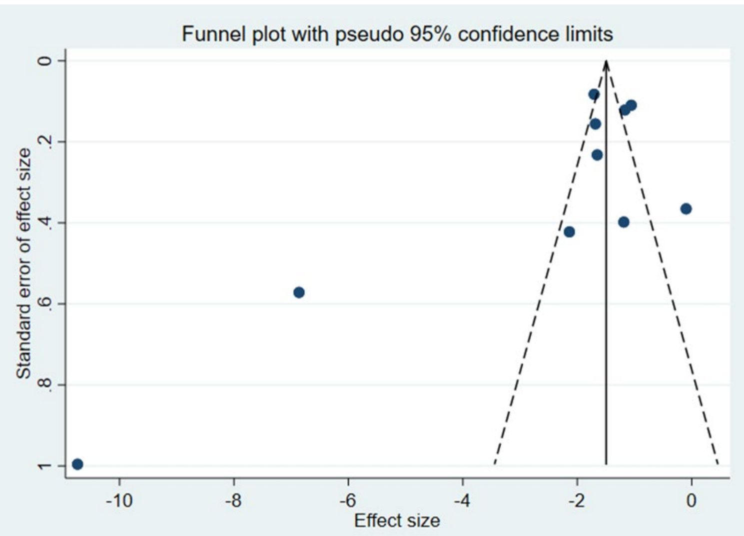

Fig. 6. *Funnel Plot Axis Angular Deviation, DN vs CS comparison.*

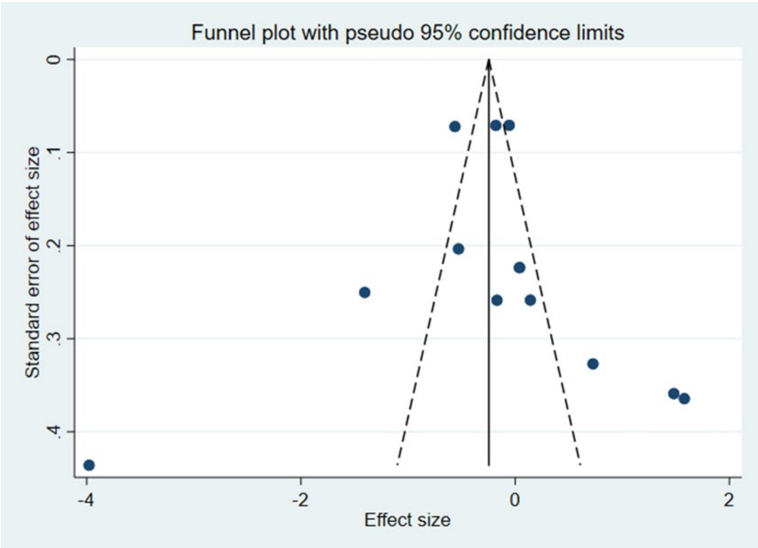

Fig. 7. *Funnel Plot Axis Angular Deviation, DN vs SN comparison.*

Table IX. *Since the p = 0.148, the presence of "small-study effects" is excluded in the comparison between DN vs CS.*

```
. ***CHECKING PUBLICATION BIAS WITH EGGER'S TEST FOR DN vs CS
. *table (P VALUE)
. metabias _ES _seES if ControlType=="DN vs CS",  egger

Note: data input format theta se_theta assumed.

Egger's test for small-study effects:
Regress standard normal deviate of intervention
effect estimate against its standard error

Number of studies =  10                         Root MSE      =   4.598
```

Std_Eff	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
slope	-.9547596	.4109467	-2.32	0.049	-1.902405	-.0071148
bias	-4.062364	2.53608	-1.60	0.148	-9.910575	1.785846

```
Test of H0: no small-study effects          P = 0.148
```

Table X. *Since p = 0.840, the presence of "small-study effects" is excluded in the comparison between DN vs SN.*

```
. ***CHECKING PUBLICATION BIAS WITH EGGER'S TEST FOR DN vs SN
. *table (P VALUE)
. metabias _ES _seES if ControlType=="DN vs SN",  egger

Note: data input format theta se_theta assumed.

Egger's test for small-study effects:
Regress standard normal deviate of intervention
effect estimate against its standard error

Number of studies =  13                         Root MSE      =    4.11
```

Std_Eff	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
slope	-.2887218	.2567526	-1.12	0.285	-.8538305	.2763869
bias	.3977745	1.925844	0.21	0.840	-3.840979	4.636528

```
Test of H0: no small-study effects          P = 0.840
```

Coronal lateral deviation

For the lateral coronal deviation, the statistical analysis shows a high difference (SMD = -0.867), statistically significant (p = 0.001), in favor of Dynamic Navigation compared to conventional surgery. From the comparison of Dynamic Navigation vs Static Navigation, a moderate difference emerges (SMD = 0.449) in favor of Static Navigation, reaching statistical significance (p = 0.006) (Table XI).

Table XI. *Coronal Lateral Deviation.*

Study	SMD	[95% Conf.	Interval]	% Weight
DN vs CS				
Block (2017)	-0.844	-1.075	-0.614	8.57
Block (2017)	-0.718	-0.928	-0.509	8.62
Jorba-Garcia (2019)	-0.746	-1.423	-0.069	6.84
Somogyi-Ganss (2014)	0.000	-0.139	0.139	8.75
Brief (2005)	-2.416	-3.372	-1.461	5.58
Brief (2005)	-1.228	-2.012	-0.443	6.34
Sub-total				
D+L pooled SMD	-0.867	-1.358	-0.376	44.70
DN vs SN				
Ruppin (2008)	-0.750	-1.203	-0.296	7.82
Ruppin (2008)	-0.424	-0.868	0.019	7.86
Somogyi-Ganss (2014)	0.465	0.324	0.605	8.75
Somogyi-Ganss (2014)	0.697	0.554	0.840	8.75
Somogyi-Ganss (2014)	0.600	0.458	0.742	8.75
Kang (2014)	1.264	0.583	1.946	6.82
Kang (2014)	1.784	1.046	2.522	6.55
Sub-total				
D+L pooled SMD	0.449	0.129	0.768	55.30
Overall				
D+L pooled SMD	-0.133	-0.503	0.238	100.00

Test(s) of heterogeneity:

	Heterogeneity statistic	degrees of freedom	P	I-squared**	Tau-squared
DN vs CS	77.56	5	0.000	93.6%	0.3037
DN vs SN	70.89	6	0.000	91.5%	0.1437
Overall	352.23	12	0.000	96.6%	0.4030

** I-squared: the variation in SMD attributable to heterogeneity)

Note: between group heterogeneity not calculated;
only valid with inverse variance method

Significance test(s) of SMD=0

DN vs CS	z= 3.46	p = 0.001
DN vs SN	z= 2.75	p = 0.006
Overall	z= 0.70	p = 0.483

Coronal lateral deviation: forest plot

Observing the forest plot, of which the upper portion concerns the DN vs CS comparison and the lower portion the DN vs SN comparison, it can be seen that the test, the DN, is very favored in comparison with the CS but disadvantaged when compared to the SN, with statistical significance in both comparisons (Fig. 8).

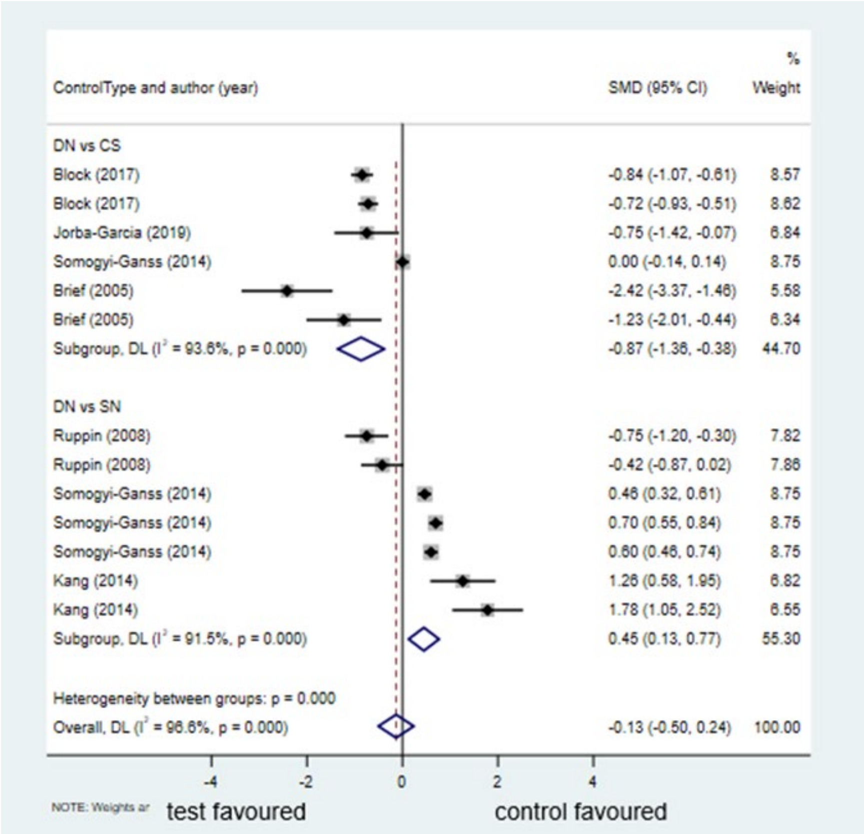

Fig. 8. *Coronal Lateral Deviation, Forest Plot.*

Coronal depth deviation

For the coronal depth deviation, the statistical analysis shows that there is a moderate difference (SMD = -0.408), statistically significant (p <0.001), in favor of Dynamic Navigation in comparison with conventional surgery. From the comparison of Dynamic Navigation vs Static Navigation, a moderate difference emerges (SMD = 0.721) in favor of Static Navigation, and this difference reaches statistical significance (p = 0.002) (Table XII).

Table XII. *Coronal Depth Deviation.*

Study	SMD	[95% Conf.	Interval]	% Weight
DN vs CS				
Block (2017)	-0.521	-0.746	-0.296	29.68
Block (2017)	-0.304	-0.510	-0.099	30.01
Sub-total				
D+L pooled SMD	-0.408	-0.620	-0.195	59.69
DN vs SN				
Kang (2014)	0.731	0.090	1.373	20.14
Kang (2014)	0.710	0.070	1.350	20.17
Sub-total				
D+L pooled SMD	0.721	0.268	1.174	40.31
Overall				
D+L pooled SMD	0.045	-0.431	0.520	100.00

Test(s) of heterogeneity:

	Heterogeneity statistic	degrees of freedom	P	I-squared**	Tau-squared
DN vs CS	1.95	1	0.163	48.6%	0.0114
DN vs SN	0.00	1	0.963	0.0%	0.0000
Overall	23.20	3	0.000	87.1%	0.1851

** I-squared: the variation in SMD attributable to heterogeneity)

Note: between group heterogeneity not calculated;
only valid with inverse variance method

Significance test(s) of SMD=0

DN vs CS	z= 3.77	p = 0.000
DN vs SN	z= 3.12	p = 0.002
Overall	z= 0.18	p = 0.854

Coronal depth deviation, forest plot

Observing the forest plot, of which the upper portion concerns the DN vs CS comparison and the lower portion the DN vs SN comparison, it can be seen that the test, the DN, is favoured in comparison with the CS but disadvantaged if compared to SN, with statistical significance in both comparisons (Fig. 9).

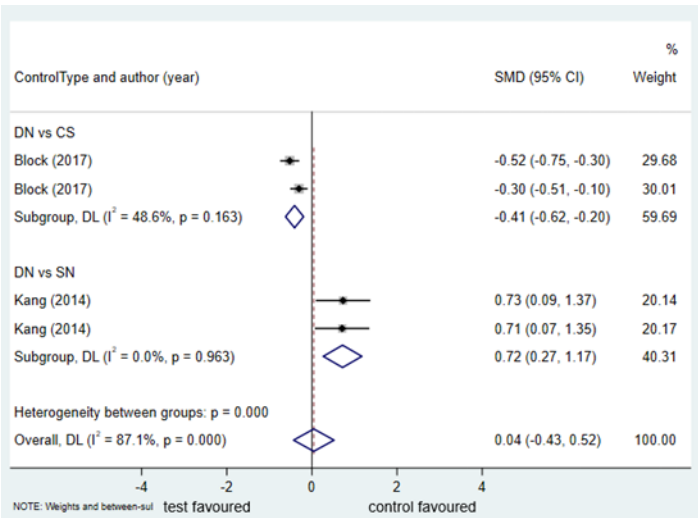

Fig. 9. *Coronal Depth Deviation, Forest Plot.*

Lateral apical deviation

For the lateral apical deviation, the statistical analysis shows that there is a high difference (SMD = -1.216), statistically significant (p <0.001), in favor of Dynamic Navigation in comparison with conventional surgery. From the comparison of Dynamic Navigation vs Static Navigation, a slight difference emerges (SMD = 0.289) in favor of Static Navigation, and this difference reaches statistical significance (p = 0.048) (Table XIII).

Table XIII. *Lateral Apical Deviation.*

Study	SMD	[95% Conf.	Interval]	% Weight
DN vs CS				
Block (2017)	-1.226	-1.466	-0.986	11.10
Block (2017)	-1.081	-1.296	-0.866	11.19
Somogyi-Ganss (2014)	-0.656	-0.798	-0.513	11.40
Brief (2005)	-2.312	-3.250	-1.375	7.07
Brief (2005)	-1.779	-2.633	-0.925	7.57
Sub-total				
D+L pooled SMD	-1.216	-1.603	-0.829	48.32
DN vs SN				
Somogyi-Ganss (2014)	-0.017	-0.156	0.122	11.41
Somogyi-Ganss (2014)	0.316	0.177	0.455	11.40
Somogyi-Ganss (2014)	-0.087	-0.226	0.052	11.41
Kang (2014)	0.730	0.089	1.371	8.91
Kang (2014)	1.428	0.730	2.126	8.55
Sub-total				
D+L pooled SMD	0.289	0.003	0.576	51.68
Overall				
D+L pooled SMD	-0.419	-0.818	-0.019	100.00

Test(s) of heterogeneity:

	Heterogeneity statistic	degrees of freedom	P	I-squared**	Tau-squared
DN vs CS	33.90	4	0.000	88.2%	0.1402
DN vs SN	36.53	4	0.000	89.1%	0.0773
Overall	293.37	9	0.000	96.9%	0.3596

** I-squared: the variation in SMD attributable to heterogeneity)

Note: between group heterogeneity not calculated;
only valid with inverse variance method

Significance test(s) of SMD=0

DN vs CS	z= 6.16	p = 0.000
DN vs SN	z= 1.98	p = 0.048
Overall	z= 2.05	p = 0.040

Lateral apical deviation: forest plot

Observing the forest plot, of which the upper portion concerns the DN vs CS comparison and the lower portion the DN vs SN comparison, it can be seen that the test, the DN, is favoured in comparison with the CS but disadvantaged if compared to SN, with statistical significance in both comparisons (Fig. 10).

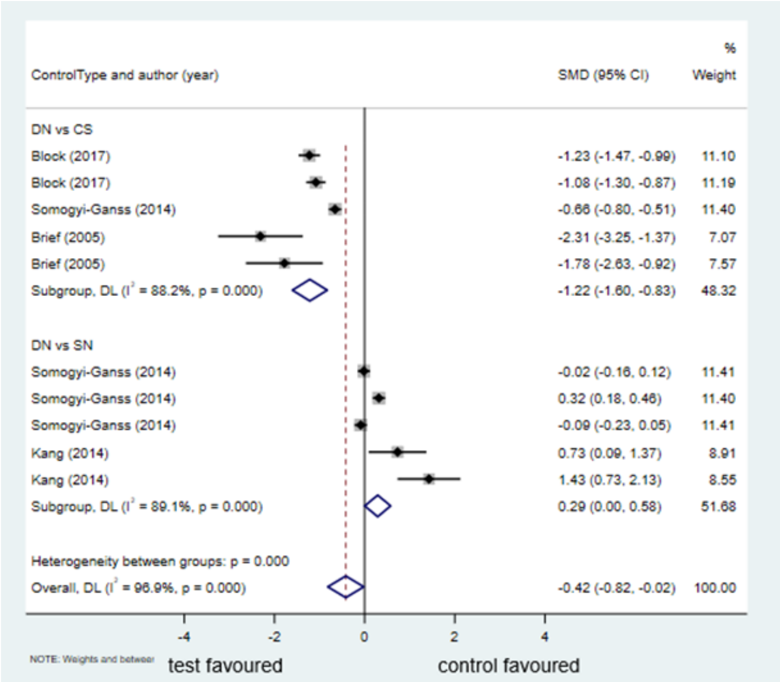

Fig. 10. *Lateral Apical Deviation, Forest Plot.*

Apical depth deviation

For the apical depth deviation, the statistical analysis shows a moderate difference (SMD = -0.577) with borderline statistical significance (p = 0.055) in favor of Dynamic Navigation compared to conventional surgery. From the comparison of Dynamic Navigation vs Static Navigation, a slight difference emerges (SMD = -0.065) in favor of Dynamic Navigation, and this difference does not reach statistical significance (p = 0.673) (Table XIV).

Table XIV. *Apical Depth Deviation.*

Study	SMD	[95% Conf.	Interval]	% Weight
DN vs CS				
Block (2017)	-0.466	-0.690	-0.242	7.88
Block (2017)	-0.263	-0.468	-0.058	7.94
Sun (2020)	-3.463	-4.245	-2.681	5.00
Jorba-Garcia (2019)	0.763	0.085	1.441	5.55
Somogyi-Ganss (2014)	0.437	0.296	0.577	8.13
Brief (2005)	-1.077	-1.846	-0.307	5.06
Brief (2005)	-0.438	-1.163	0.287	5.30
Sub-total				
D+L pooled SMD	-0.577	-1.167	0.013	44.85
DN vs SN				
Sun (2020)	-1.924	-2.519	-1.328	6.00
Ruppin (2008)	0.000	-0.438	0.438	6.88
Ruppin (2008)	0.351	-0.091	0.793	6.86
Somogyi-Ganss (2014)	-0.013	-0.151	0.126	8.14
Somogyi-Ganss (2014)	-0.080	-0.219	0.059	8.14
Somogyi-Ganss (2014)	-0.292	-0.431	-0.152	8.13
Kang (2014)	-0.085	-0.706	0.535	5.86
Kang (2014)	1.911	1.157	2.665	5.14
Sub-total				
D+L pooled SMD	-0.065	-0.366	0.236	55.15
Overall				
D+L pooled SMD	-0.260	-0.537	0.017	100.00

Test(s) of heterogeneity:

	Heterogeneity statistic	degrees of freedom	P	I-squared**	Tau-squared
DN vs CS	149.27	6	0.000	96.0%	0.5567
DN vs SN	76.21	7	0.000	90.8%	0.1429
Overall	228.90	14	0.000	93.9%	0.2406

** I-squared: the variation in SMD attributable to heterogeneity)

Note: between group heterogeneity not calculated;
only valid with inverse variance method

Significance test(s) of SMD=0

DN vs CS	z= 1.92	p = 0.055
DN vs SN	z= 0.42	p = 0.673
Overall	z= 1.84	p = 0.066

Apical depth deviation: forest plot

Observing the forest plot, of which the upper portion concerns the DN vs CS comparison and the lower portion the DN vs SN comparison, it can be seen that the test, the DN, is favoured in comparison with the CS and comparable to SN, although presenting a very slight difference, however not significant (Fig. 11).

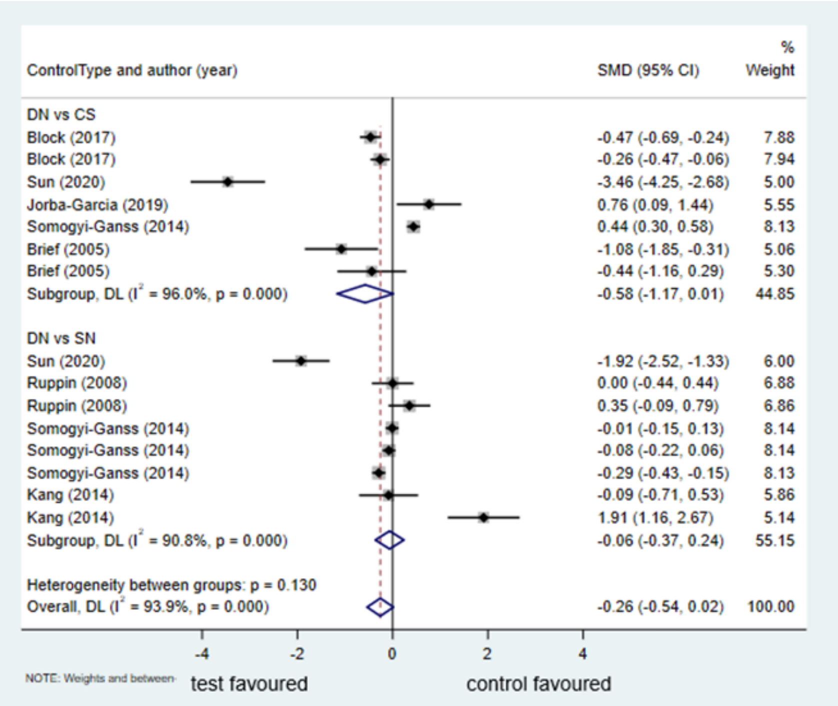

Fig. 11. *Apical Depth Deviation, Forest Plot.*

Summary of Meta-analysis results

In almost all the meta-analyses, heterogeneity was found between the studies, partly reflecting the variability of the surgical experiences.

Concerning primary outcomes, using a Dynamic Navigation method allows for significantly better accuracy than conventional surgery; compared to static navigation; however, two slight differences are not statistically significant, and a moderate difference that is statistically significant, all in favor of dynamic navigation.

Regarding secondary outcomes, Dynamic Navigation is significantly more accurate than conventional surgery but less than Static Navigation, except for the Apical Depth Deviation in comparison with static navigation, which has minimal and no significant differences (Table XV).

Table XV. *Summary of Meta-analysis results, statistically significant differences are shown in bold.*

	DN vs SN		DN vs CS	
	SMD, 95%CI (p)	**I2 (p)**	**SMD, 95%CI (p)**	**I2 (p)**
PRIMARY OUTCOMES				
Total coronal deviation	-0.234, -1.055; 0.586 (p=0.576)	**92.5% (p= 0.000)**	**-1.650, -2.509; -0.791 (p=0.000)**	**96.5% (p= 0.000)**
Total apical deviation	**-0.556, -0.969; -0.143 (p= 0.008)**	**95.6% (p=0.000)**	**-1.919, -2.482; -1.355 (p= 0.000)**	**95.5% (p=0.000)**
Axis angular deviation	-0.199, -0.529; 0.132 (p= 0.239)	**93.6% (p=0.000)**	**-2.269, -2.850; -1.688 (p=0.000)**	**96.0% (p=0.000)**
SECONDARY OUTCOMES				
Linear coronal deviation	**0.449, 0.129; 0.768 (p=0.006)**	**91.5% (p=0.000)**	**-0.867 -1.358; -0.376 (p=0.001)**	**93.6% (p=0.000)**
Coronal depth deviation	**0.721, 0.268; 1.174 (p=0.002)**	0.0% (p=0.963)	**-0.408, -0.620; -0.195 (p=0.000)**	48.6% (p= 0.163)
Linear apical deviation	**0.289, 0.003; 0.576 (p=0.048)**	**89.1% (p=0.000)**	**-1.216, -1.603; -0.829 (p=0.000)**	**88.2% (p=0.000)**
Apical depth deviation	-0.065, -0.366; 0.236 (p=0.673)	**90.8% (p=0.000)**	**-0.577, -1.167; 0.013 (p=0.055)**	**96.0% (p=0.000)**

DISCUSSION

From the results obtained from this meta-analysis, it can be stated that the Dynamic Navigation mode allows for better accuracy than conventional surgery, the most used type of surgery, and is comparable to Static Navigation, the gold standard for accuracy.

Dynamic Navigation vs Conventional Surgery

Compared with conventional surgery, Surgery in Dynamic Navigation presents notable and significant differences in all the parameters taken into consideration.

In more detail, slight differences are found in the results obtained from conventional surgery (control surgery) in the two different clinical and model study settings, which appears to be slightly more accurate in model studies than at a clinical level. This difference can be traced back and explained by the fact that in the experimental setting, mainly due to the absence of saliva, blood, and soft tissue encumbrance, the notch on the drill used as a reference during the osteotomy is more easily identifiable.

Dynamic Navigation vs Static Navigation

When considering the primary outcomes from the comparison with Static Navigation, the data show that Dynamic Navigation has better accuracy. The Total Apical Deviation shows a moderate difference in favor of Dynamic Navigation and reaches statistical significance, while the Total Coronal Deviation and the Axis Angular Deviation show slight differences in favor of Dynamic Navigation, but neither of them reaches statistical significance.

Regarding the different types of studies (clinical, anatomical preparation, and model studies), in all three primary outcomes, there is some agreement in the results of the different types of studies, with some exceptions (14, 17, 21).

Kang et al., in regards to the Axes Angular Deviation, clearly differs from the other studies with a clear difference in favor of Static Navigation (values comparable to the other studies for Static Navigation, the worst among all studies included for Dynamic Navigation). However, the discrepancy between the study by Kang 21 and the other studies included manifesting itself in the test (DN) and being negligible as regards the control (SN) may be partly justified by the systematics used for Dynamic Navigation, which is not among those available on the market and therefore presumably still in the experimentation phase. In some studies, the discrepancy could be attributed to the systematics used (14, 17).

In secondary outcomes, compared with Static navigation, the data show that Static Navigation has better accuracy. The Coronal Lateral Deviation presents a moderate difference in favor of the Static Navigation and reaches statistical significance, the Coronal Depth deviation presents a high difference in favor of the Static Navigation and reaches statistical significance, the apical lateral deviation presents a slight difference in favor of Static Navigation and reaches statistical significance. In contrast, the apical depth deviation presents a slight difference in favor of Dynamic navigation but does not reach statistical significance.

Since the primary outcomes favour Dynamic navigation while the secondary outcomes favour Static Navigation, it can be concluded that overall Dynamic Navigation and Static Navigation have comparable accuracy.

Furthermore, the fact that secondary outcomes show better accuracy for static navigation must be analysed, taking into consideration that the data derive mainly from anatomical preparation studies and in vitro studies and little from clinical studies since secondary outcomes were considered in only one clinical study, and detail only the apical depth. The almost total absence of the clinical component in the analysis of secondary outcomes may explain the reason for the difference found with the primary ones.

The accuracy of Static Navigation strictly depends on the stability of the surgical guide, which in turn depends on the type of edentulousness from the supporting tissue, the movements of the muscle compartment, and the thickness and resilience of the supporting tissues (24, 25). All conditions in model studies, no matter how much you try to recreate and reproduce them, do not negatively affect the performance of this navigation mode, thus resulting in better accuracy than in anatomical preparation studies and clinical studies (26). However, exactly the opposite happens for Dynamic Navigation; considering Dynamic Navigation, this trend not only does not manifest itself but also presents an opposite trend; by comparing the weighted averages obtained on the model and in the clinical setting, a better accuracy emerges in favor of clinical studies in all the parameters considered except for the Total Coronal Deviation (Table XVI).

Table XVI. *Comparison of Dynamic Navigation results divided by study type.*

	Total coronal deviation, mm	Total apical deviation, mm	Axis angular deviation, °	Lateral coronal deviation, mm	Coronal depth deviation, mm	Lateral apical deviation, mm	Apical depth deviation, mm
CLINICAL	1.23 (0.59)	1.45 (0.65)	3.41 (2)	0.78 (0.47)	0.84 (0.68)	0.97 (0.61)	0.85 (0.66)
ANATOMICAL PREPARATION	-	-	8.1 (4.75)	1.1 (0.55)	-	-	0.7 (0.5)
VITRO	0.86 (0.46)	1.50 (0.56)	3.6 (1.85)	1.21 (0.62)	0.95 (1.05)	1.30 (0.62)	1.05 (0.7)
OVERALL	1.17 (0.57)	1.47 (0.61)	3.75 (2.1)	0.98 (0.54)	0.85 (0.70)	1.12 (0.61)	0.92 (0.67)

Comparison of Dynamic Navigation results divided by study type

The fact that in Dynamic Navigation, the clinical data are better than the model studies can be partly explained by the fact that the clinical studies are recent and therefore report the data of systematic DNs updated and tested over time than those used in experimental settings on a model, which may still be in the process of being perfected or even prototypes. It should also be considered that using these DN systematics in the clinical setting is reserved for operators who have usually completed extra-clinical training before using them on the patient. This condition is not necessary for experimental settings based on the model and in which it can therefore be assumed that the inexperience in the use of these systematic DNs adversely affects the performance detected, in fact, the existence of a learning curve in the use of Dynamic Navigation has been demonstrated, with statistically significant differences between the measurements obtained in the first and subsequent surgical interventions (12, 27) (Table XVI).

CONCLUSIONS

Although this meta-analysis has limitations due to the small number of articles in the literature regarding this recent surgical technique and also due to the high heterogeneity obtained by including anatomical preparation studies and model studies, we can conclude that further clinical studies, possibly RCTs, are needed in order to make a comparison characterised by greater statistical power and better homogeneity (28-30).

Despite these limitations, based on the foregoing sections, it can be stated that the introduction and use of a Dynamic Navigation system in implantology represents a predictable and reliable surgical technique. (31-33) (Table XVI).

Compared to conventional surgery, which is still the most widespread implant placement modality, Dynamic Navigation allows for greater accuracy, which potentially translates into a lower number of intra-operative complications and more optimal prosthetic management, simplifying its steps and reducing the need to use complex and unexpected solutions that would lead to an increase in costs and times. (34-37).

When using Dynamic Navigation, a safety distance of at least 2 mm from the surrounding anatomical structures must be established and considered in the design phase, as for Static Navigation (38, 39); this is because Dynamic Navigation while allowing a high reduction of the discrepancy detected between virtual planning and real positioning, has a residual margin of error (40-42).

Compared with Static Navigation, currently the gold standard in terms of accuracy, Dynamic Navigation allows you to obtain overlapping results whose possible differences, found mainly in the secondary outcomes, remain slight and insignificant. (43, 44)

This minimal difference in favor of Static Navigation is, however, entirely compensated by the many advantages introduced by Dynamic Navigation; first of all, the enormous flexibility of use which, not being constrained by a rigid template (typical instead of Static Navigation), allows the surgeon the possibility to modify the rehabilitation project in the intra-operative phase and to manage the peri-implant tissues in the most suitable way for the patient's clinical situation. (45, 46)

In conclusion, although further studies are necessary to validate the cost-benefit ratio, the possible extension of operating times must also be carried out for the reasons just expressed, Dynamic Navigation is proposed, when available, as the system of the first choice in implantology, combining in a single instrument the indispensable versatility offered by conventional surgery with the accuracy typical of Static Navigation. (47, 48)

Conflicts of Interest

All the Authors confirm no conflict of interest or financial support.

REFERENCES

1. Moraschini V, Poubel LAC, Ferreira VF, Barboza ESP. Evaluation of survival and success rates of dental implants reported in longitudinal studies with a follow-up period of at least 10 years: A systematic review. Int J of Oral and Maxillofac Surg 2015; 44(3):377–88.
2. Pjetursson BE, Thoma D, Jung R, Zwahlen M, Zembic A. A systematic review of the survival and complication rates of implant-supported fixed dental prostheses (FDPs) after a mean observation period of at least 5 years. Clin Oral Implants Res 2012; 23(suppl 6):22–38.
3. Hämmerle CHF, Tarnow D. The etiology of hard- and soft-tissue deficiencies at dental implants: A narrative review. J Clin Periodontol 2018; 45(Suppl 20):S267–S277.
4. Mediavilla Guzmán A, Riad Deglow E, Zubizarreta-Macho Á, Agustín-Panadero R, Hernández Montero S. Accuracy of Computer-Aided Dynamic Navigation Compared to Computer-Aided Static Navigation for Dental Implant Placement: An In Vitro Study. J Clin Med 2019; 8(12):2123.
5. Herklotz I, Beuer F, Kunz A, Hildebrand D, Happe A. Navigation in implantology. Int J Comput Dent 2017; 20(1): 9–19.
6. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. PLoS Med 2009; 6(7):e1000097.
7. Milner KA, Cosme S. The PICO Game: An Innovative Strategy for Teaching Step 1 in Evidence-Based Practice. Worldviews Evid Based Nurs 2017; 14(6):514–516.
8. Higgins JPT, Thompson SG. Quantifying heterogeneity in a meta-analysis. Stat Med 2002; 21(11):1539–58.
9. DerSimonian R, Laird N. Meta-analysis in clinical trials. Control Clin Trials 1986; 7(3):177–88.
10. Egger M, Smith GD, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ 1997; 315(7109):629–34.
11. Kaewsiri D, Panmekiate S, Subbalekha K, Mattheos N, Pimkhaokham A. The accuracy of static vs. dynamic computer-assisted implant surgery in single tooth space: A randomised controlled trial. Clin Oral Implants Res 2019; 30(6):505–514.
12. Block MS, Emery RW, Cullum DR, Sheikh A. Implant Placement Is More Accurate Using Dynamic Navigation. J Oral and Maxillofac Surg 2017; 75(7):1377–1386.
13. Yimarj P, Subbalekha K, Dhanesuan K, Siriwatana K, Mattheos N, Pimkhaokham A. Comparison of the accuracy of implant position for two-implants supported fixed dental prosthesis using static and dynamic computer-assisted implant surgery: A randomised controlled clinical trial. Clin Implant Denti Relat Res 2020; 22(6):672–678.
14. Sun TM, Lee HE, Lan TH. Comparing accuracy of implant installation with a navigation system (NS), a laboratory guide (LG), NS with LG, and free-hand drilling. Int J Environ Res Public Health 2020; 17(6):2107.

15. Aydemir CA, Arısan V. Accuracy of dental implant placement via dynamic navigation or the free-hand method: A split-mouth randomised controlled clinical trial. Clin Oral Implants Res 2020; 31(3):255–263.
16. Ruppin J, Popovic A, Strauss M, Spüntrup E, Steiner A, Stoll C. Evaluation of the accuracy of three different computer-aided surgery systems in dental implantology: Optical tracking vs. stereolithographic splint systems. Clin Oral Implants Res 2008; 19(7):709–16.
17. Zhou M, Zhou H, Li SY, Zhu YB, Geng YM. Comparison of the accuracy of dental implant placement using static and dynamic computer-assisted systems: an in vitro study. J Stomatol Oral Maxillofac Surg 2021; 122(4):343-348.
18. Jorba-García A, Figueiredo R, González-Barnadas A, Camps-Font O, Valmaseda-Castellón E. Accuracy and the role of experience in dynamic computer guided dental implant surgery: An in-vitro study. Med Oral Patol Oral Cir Bucal 2019; 24(1):e76–e83.
19. Chen CK, Yuh DY, Huang RY, Fu E, Tsai CF, Chiang CY. Accuracy of Implant Placement with a Navigation System, a Laboratory Guide, and Freehand Drilling. Int J Oral Maxillofac Implants 2018; 33(6):1213–1218.
20. Somogyi-Ganss E, Holmes HI, Jokstad A. Accuracy of a novel prototype dynamic computer-assisted surgery system. Clin Oral Implants Res 2015; 26(8):882–890.
21. Kang SH, Lee JW, Lim SH, Kim YH, Kim MK. Verification of the usability of a navigation method in dental implant surgery: In vitro comparison with the stereolithographic surgical guide template method. J Cranio-Maxillofac Surg 2014; 42(7):1530–5.
22. Hoffmann J, Westendorff C, Gomez-Roman G, Reinert S. Accuracy of navigation- guided socket drilling before implant installation compared to the conventional free-hand method in a synthetic edentulous lower jaw model. Clin Oral Implants Res 2005; 16(5):609–14.
23. Brief J, Edinger D, Hassfeld S, Eggers G. Accuracy of image-guided implantology. Clin Oral Implants Res 2005; 16(4), 495–501.
24. Tahmaseb A, Wu V, Wismeijer D, Coucke W, Evans C. The accuracy of static computer-aided implant surgery: A systematic review and meta-analysis. Clin Oral Implants Res 2018; 29(Suppl 16):416–435.
25. Tahmaseb A, Wismeijer D, Coucke W, Derksen W. Computer Technology Applications in Surgical Implant Dentistry: A Systematic Review. Int J Oral Maxillofac Implants 2014; 29(Suppl):25–42.
26. Bover-Ramos F, Viña-Almunia J, Cervera-Ballester J, Peñarrocha-Diago M, García-Mira B. Accuracy of Implant Placement with Computer-Guided Surgery: A Systematic Review and Meta-Analysis Comparing Cadaver, Clinical, and In Vitro Studies. Int J Oral Maxillofac Implants 2018; 33(1):101–115.
27. Stefanelli L, DeGroot B, Lipton D, Mandelaris G. Accuracy of a Dynamic Dental Implant Navigation System in a Private Practice. Int J Oral Maxillofac Implants 2019; 34(1):205–213.
28. Barone A, Toti P, Bertossi D, Marconcini S, De Santis D, Nocini PF, Iurlaro A, Alfonsi F, Covani U. Gene Expression of Human Mesenchymal Stem Cells Cultured on Titanium Dental Implant Surfaces. J Craniofac Surg 2016; 27(3):712-7.
29. Bertossi D, Fiorino P, Corega C, Sbricoli L, De Santis D, Donadello D, Ricciardi G, Luciano U, Bressan E, Pardo A, Albanese, M, Zangani A. Cone-beam volumetric imaging in craniofacial medicine. Minerva Stomatol 2019; 68 (4):200-212.
30. Corega C, Vaida L, Festila DG, Rigoni G, Albanese M, D'Agostino A, Nocini PF, Bertossi D, Pardo A, Marconcini S, Gelpi F. Blood levels of interleukins in patients with ameloblastoma. Minerva Stomatol 2013; 62:23-26.
31. Bertossi D, Nocini R, Luciano U, et al. Piezoelectric surgery inserts vs conventional burst: a clinical investigation. J Biol Regul Homeost Agents 2018; 32(2 Suppl 2):15-19.
32. Corega C, Vaida L, Festila DG, et al. The benefits of Quercitin for dentistry and maxillofacial surgery: a systematic review [published online ahead of print, 2014 Jan 14]. Minerva Stomatol 2014.
33. De Santis D, Graziani P, Castellani R, et al. A New Radiologic Protocol and a New Occlusal Radiographic Index for Computer-Guided Implant Surgery. J Craniofac Surg 2016; 27(5):e506-10.
34. Genovesi AM, Lorenzi C, Lyle DM, et al. Periodontal maintenance following scaling and root planing. A randomised single-center study comparing minocycline treatment and daily oral irrigation with water [published online ahead of print, 2014 Jan 14]. Minerva Stomatol 2014.

35. Lombardo G, Pardo A, Signoretto C, Signoriello A, Simeoni E, Rovera A, Nocini PF. Hyperbaric oxygen therapy for the treatment of moderate to severe periodontitis: a clinical pilot study. Undersea Hyperb Med 2020; 47 (4):571-580.
36. Corega C, Vaida L, Festila DG, et al. Dental white spots associated with bulimia nervosa in orthodontic patients [published online ahead of print, 2014 Jan 14]. Minerva Stomatol 2014.
37. De Santis D, Sinigaglia S, Pancera P, et al. An overview of guided bone regeneration. J Biol Regul Homeost Agents 2019; 33(1 Suppl. 1):49-53.
38. Gelpi F, Romoli L, D'Arienzo D, et al. Lateral periodontal cyst (LPC) mimicking periodontal socket in a young patient: Report of a case and review of the literature [published online ahead of print, 2014 Jan 14]. Minerva Stomatol 2014.
39. Lombardo G, Signoretto C, Corrocher G, et al. A topical desiccant agent in association with ultrasonic debridement in the initial treatment of chronic periodontitis: A clinical and microbiological study. New Microbiol 2015; 38(3):393-407.
40. De Santis D, Sinigaglia S, Pancera P, et al. An overview of socket preservation. J Biol Regul Homeost Agents 2019; 33(1 Suppl. 1):55-59.
41. Lombardo G, Signoriello A, Corrocher G, Signoretto C, Burlacchini G, Pardo A, Nocini PF. A topical desiccant agent in association with manual debridement in the initial treatment of peri-implant mucositis: A clinical and microbiological pilot study. Antibiotics (Basel) 2019; 8(2):82.
42. Marconcini S, Barone A, Perrini N, et al. Conservative treatment of unicystic odontogenic keratocyst by piezosurgery approach. A case report [published online ahead of print, 2014 Jan 14]. Minerva Stomatol 2014.
43. Nocini PF. De Santis D, Ferrari F, Bertele GP. A Customised Distraction Device for Alveolar Ridge Augmentation and Alignment of Ankylosed Teeth.Int J Oral and Maxillofa Implants 2004; 19(1):133-44.
44. Pardo A, Signoriello A, Signoretto C, et al. Detection of periodontal pathogens in oral samples and cardiac specimens in patients undergoing aortic valve replacement: A pilot study. J Clin Med 2021; 10(17):3874
45. Marconcini S, Genovesi AM, Marchisio O, et al. In vivo study of titanium healing screws surface modifications after different debridment procedure [published online ahead of print, 2014 Jan 14]. Minerva Stomatol 2014.
46. Pedullà E, Plotino G, Scibilia M, et al. Cyclic fatigue comparison among endodontic instruments with similar cross section and different surface coating. Minerva Stomatol 2019; 68(2):67-73.
47. Pellegrino G, Taraschi V, Zacchino A, Ferri A, Marchetti C. Dynamic navigation: a prospective clinical trial to evaluate the accuracy of implant placement. Int J Comput Dent 2019; 22(2):139–147.
48. Ricci M, Marchisio O, Genovesi AM, et al. Comparison between oscillating-twisting rotating of brush head vs a characteristic sweeping bristles motion on reducing oral inflammation [published online ahead of print, 2014 Jan 14]. Minerva Stomatol 2014.

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Review

Could digital workflow replace the conventional? A narrative review

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ABSTRACT

In the last ten years, digital technologies have conditioned our lives in many ways. Also, in dentistry, new inventions changed our working routine, accompanying the clinician from the analogic epoch to the digital. A fully digital workflow seems to be very promising in terms of less discomfort for the patients and less time needed to make an impression than the traditional method. However, many aspects still need to be investigated, such as the procedure's complexity, the optical impression's reliability, the precision of the CAD-CAM-made crown, the costs, and the time needed to deliver a final crown. This review aims to understand, analyzing some RCT studies, whether a digital workflow is reliable compared to the analogic.

INTRODUCTION

In the last years, digital Technologies have become part of our lives to the point of conditioning the timing and how we communicate with each other. Nowadays, it would be unthinkable to work without any electronic device, whether a computer, a smartphone, or a tablet, since such devices allow us to store and share a significant amount of fundamental data for our activities.

In dentistry, digital progress has been principally developed in CAD/CAM systems and imaging systems. Computer-aided design (CAD) systems and computer-aided manufacturing systems were initially developed in 1950 by the American Air Force to design automotive and aeroplane components. After three decades, this technology was also applied to dentistry when Francois Duret developed the first CAD/CAM dentistry device, which was substantially made by an optical device for the impression and a numerically controlled milling machine (1).

Werner Mormann developed the CEREC System, the first commercially available chairside CAD/CAM system for dentistry, and it allowed delivery of a fixed final crown in a few hours (2). The first chairside treatment made with CEREC was executed in 1985 at the Zurich Dental School and the fact that this system allowed the clinician to deliver a fixed final ceramic crown the same day as the impression was revolutionary (3-7).

Nowadays, the CEREC system is largely used worldwide, and with the progress of technology, it has become a predictable and accessible workflow system. The evolution of dentistry digital imaging started with the invention of CBCT (8) and culminated 10 years ago with the invention of optical scanners.

The intraoral optical scanners allow the clinician to take a direct impression by projecting a light source onto the teeth and soft tissues of the mouth (9, 10). The image is captured by high-resolution cameras and processed by powerful software that produces a 3D digital model (11, 12). It allows the clinician to avoid the traditional plaster models and to have, in a few minutes, a digital model that replicates dentogingival tissues (13, 14).

There are many different types of optical impressions systems; the most common ones on the market are Trios 3, 4, 5(3Shape), iTERO Element 2, iTERO 5d Element (Align Technology), CS3800 (Carestream), Panda P2 (Pengtum technologies), Medit i700 (Medit Corporation), Planmeca Emerald S (Planmeca), Cerec Omnicam (Dentsply Sirona).

Each scanner has specific characteristics; comparative studies comparing different scanners have been performed, such as the one performed by Pokpong Amornvit, Dinesh Rokaya and Sasiwimol Sanohkan: "Comparison of Accuracy of Current Ten Intraoral Scanners" (15). In this study, a maxilla model was scanned with different scanners and measurements were taken on the respective STL files in the X, Y, Z and XY axes.

According to the study, the greater the distance the scanner travels, the lower the accuracy and the greater the error. The precision in this study appears similar for all the scanners analyzed, while the trueness value varies, showing that Trios 3 and 4 from 3Shape reported better results than the others in both categories.

Other studies comparing the various optical impression systems include, for example, Miran Kwon and Coll's "Full-arch accuracy of five intraoral scanners: In vivo analysis of trueness and precision" (16) from which, comparing trueness and precision values, concludes that in the two categories the one that seems to perform better still turns out to be Trios 3.

The analysis conducted by Walter Renne, "Evaluation of the accuracy of 7 digital scanners: An *in vitro* analysis based on 3-dimensional comparisons" (17), shows that regarding trueness values for the full-arch, the best performance was recorded by D800 (3Shape), followed by iTero (Align Technology), TRIOS 3 (3Shape), followed by the others.

Regarding Precision values in full-arch scanning, the best scanner was CS3500 (Carestream), then iTero (Align Technology), then TRIOS3 (3Shape) and then all others. On the other hand, the most accurate and truthful scanner for posterior sextant scanning was the CS3500 (Carestream), while for full-arch scan, TRIOS3 (3Shape) offers the best compromise between scanning speed and accuracy.

The traditional impression technique could sometimes be very uncomfortable for patients, especially those with strong gag reflexes (18-20). On the contrary, the optical impression is well tolerated by the patients, and sometimes it could also be easier for the clinician (18, 21, 22). Once the 3D model is obtained, it can be used by the technician to project and model a prosthesis, a provisional and final crown or bridge, a Toronto bridge, a bite, a surgical or radiological guide and so on.

One of the most widely used software is Exocad's Dental Cad software, which allows for most designs, from custom abutments, screw-retained bridges, simple and complex bars, monolithic zirconia crowns, metal copings, esthetic veneers and more (23). When the technician completes the projecting phases, the STL file can be sent to a CAM milling machine or a 3D printer to obtain the final physical product.

A fully digital workflow seems advantageous for patients and clinicians, but it is a relatively new way of working, and we are still trying to understand the limits of this technique. Therefore, this review aims to investigate those aspects that could be critics in making a prosthetic rehabilitation using a fully digital workflow compared to the traditional, analyzing data from four specific articles in which these protocols had been examined.

The secondary aim is to provide unbiased information about a new digital way of working, analyzing features such as operative times, prosthetic success rate, costs, patient satisfaction and more.

An overview of the advantages and disadvantages of both traditional and digital workflow will be provided, helping the reader understand the clinical situations in which a digital workflow can be used successfully. This article wants to analyze the available data about these technologies impartially, obtaining some clear indications about their use in clinical practice.

Design of the review

The digital workflow is a current argument in research, one of the first articles about digital workflow making CAD-CAM references was written by Dennis J Fasbinder in 2010 (24). In the last twelve years, reviews have been written to clarify this new workflow's positive and negative aspects, sometimes showing discordant outcomes.

This paper aims to indagate the argument by analyzing data of RCT studies and trying to track a common line to shed light on the present and future of restorative and prosthodontic dentistry.

For this review, PubMed research has been conducted using the keywords "digital" AND "crown" and selecting RCT as an option. The research produced 100 articles which were reduced to 20 after selecting "full-text". Articles published before 2015 were excluded from this review to obtain updated data about the topic.

Only articles with a good level of evidence were selected. Four articles were chosen from the twenty after reading the abstract, following homogeneity criteria. The selected articles strictly dealt with the topic and provided valuable data in accordance with the aims of this study.

We opted to do a narrative review, analyzing aspects that could be more critical for clinicians and patients. The most important findings of the articles selected for the present study were analyzed and reported in the review. The focus of this review is to answer simple questions that clinicians could ask before approaching these new techniques:

- Is the digital workflow equally efficient compared to the analogic one?
- Does the digital workflow have fewer working and crafting prothesis times than the analogic workflow?
- How do the patients perceive the optical impression compared to the traditional one?
- What kind of technique do the clinicians and technicians prefer?
- Is the quality of the prosthesis comparable?
- Does the cost of the prosthesis decrease for the clinician using a digital workflow?
- Are there more complications using a digital workflow compared to the analogic workflow?

RESULTS

First article

To answer these questions, we analyzed four articles: the first one was written in 2018 by Francesco Mangano: "Digital versus Analog Procedures for the Prosthetic Restoration of Single Implants: A Randomized Controlled Trial with 1 Year of Follow-Up" (25).

This RCT study compares a digital workflow to an analogic workflow in single implant restoration. The population was made of 50 patients, 22 male and 28 female, with an average age of 52, divided with randomization into two groups of 25, the test and control groups. Both groups were treated with single-implant prosthetic crowns. The test group was treated with a monolithic zirconia crown following a digital workflow; the control group was treated with a single ceramic-steel crown following the analogic workflow instead.

After a one-year follow-up, no patient dropped out of the study, and the success rate was 92% for both groups. The test group recorded a percentage of biological and prosthetic complications of 4%, while the control group had 8% of biological complications but no prosthetic complications. Both groups showed a prosthetic success rate of 92% without any statistically significant difference between them. Also, in the case of marginal bone loss, no differences between the groups were recorded, with a total value of 0.47 ± 0.31 mm.

Patient satisfaction was evaluated with a VAS scale, and during the impression procedure, patients considered the optical impression more comfortable than the traditional one, with fewer gagging and nausea episodes. However, no differences were observed in comfort during the restoration phase.

The digital workflow received a higher rating in treatment times (average difference in VAS:+16,$p < 0.0001$) and costs (+9.2, $p = 0.01$). For the esthetic results, there were no differences between the two groups. However, the VAS total score showed a statistically significant difference in favour of digital workflow (+ 9.9, $p < 0.0001$).

To take an optical impression requires less time than the analogic one made with the double impression technique, which requires more than double the time (20 ± 5min versus 50 ± 7min; $p < 0.0001$). When calculating the active working time for the dental technician, the workflow in the test group was more efficient than that of the control group for both the provisional (70 ± 15 min versus 340 ± 37 min; $p < 0.0001$) and the final crown (29 ± 9 min versus 260 ± 26 min; $p < 0.0001$). There were no differences in the delivery times.

The realization cost of a final zirconia crown with a digital workflow was Euro 277.3, whereas a ceramic-steel final crown made with a traditional analogic workflow was Euro 392.2.

In analyzing this article, a digital workflow seems to be more advantageous in terms of comfort for the patient, working times and costs. Regarding impression times, such a big difference between the two groups could be due to the double impression technique used for the control group. This data contrasts with other works, and using a different technique, such as a polyether mono-impression, could significantly reduce the traditional impression times.

Second article

The title of the second article analyzed was "Randomized controlled clinical trial of digital and conventional workflows for the fabrication of zirconia-ceramic fixed partial dentures.

Part I: Time efficiency of complete-arch digital scans versus conventional impressions": it included a small population of 10 patients needing a posterior tooth-supported 3-unit FPD (26). The clinical treatments were performed by 3 calibrated clinicians (I.S., G.B., S.M.) experienced with digital scanners and ceramic CAD-CAM prostheses. For each patient, the clinicians used three digital scanners (iTero, Cerec and Lava) and one conventional impression.

The results showed that the full-arch conventional impression took less time than the intraoral scanner. The difference was statistically significant for two of the three scanners, iTero and Cerec; moreover, using Cerec took more time than the other two systems. The scanning had to be repeated three times with the Lava scanner and seven times with iTero, while the conventional impression was only made once.

When the VAS value was assessed, the patients and the clinician evaluated the digital scanner less comfortably than the conventional impression; in particular, they found scanners that required powder during the procedure more complex than the others. However, the patients generally did not express any preference between the different impression methods.

The clinician preferred traditional impressions to digital ones and impressions without using powder to the ones with powder. In this study, data regarding the timing of the procedures are opposite to the results of the first study.

Third article

The third article examined is an RCT (27) which analyzes the prosthetic implant restoration of single implant tissue level Straumann RN, comparing the optical impression to the analogical one, using polyether. Again, 32 patients underwent rehabilitation, and a total of 32 implants were used: 23 for the test group and 22 for the control group.

Twenty-one patients received a single crown, 9 patients two crowns and 2 patients 3 crowns. In 9 of the 23 patients in the test group (39.1%) and 2 of the 22 patients in the control group (18.2%), fitting was adequate and did not require modifications. Fourteen crowns in the test group and 18 in the control group required modifications before being placed in the mouth. The time used by the clinician to modify the crown went from 3 to 11 minutes (mean = 3.35 min) in the test group and from 2 to 18 minutes (mean = 6,09 min) in the control group.

During the first year of loading, two complications occurred to the same implant in the control group. In the test group, one biological complication developed after three months of loading, leading to implant mobility with no signs of inflammation.

The results of this study show that a try-in of a CAD-CAM solitary screw-retained monolithic zirconia implant restoration needs shorter adjustment times than the conventional for the same restoration type and exhibit low complication rates and higher survival rate on the short-term (one-year follow-up).

Fourth article

The fourth study reviewed is an RCT titled “Digital vs conventional workflow for one-abutment one-time immediate restoration in the esthetic zone: a randomized controlled trial” (28). The article analyzes the short-term outcomes of single implants in esthetic areas in 18 patients, using the technique “one abutment, one time” and comparing a conventional workflow (analogical) to a fully digital workflow.

In the study, the impressions were made using alginate and 3Shape (TRIOS®, Denmark) for each patient; then the patients got CBCT scan, and the STL files from the digital impression were imported and merged in DicoDiagnostiX® software. The implant positioning was planned using this software.

The test group used the CARES software to do a digital tooth setup. The setup was combined with the initial planning, modifying the position of the implant to have a prosthetic-favourable final position. A fully guided drill guide was ordered at the end of the planning phase. The technician, guided by the previous planning, created a custom-made zirconia abutment and a provisional prosthesis in PMMA CAD-CAM, which were then used on the day of the surgery. Moreover, the technician built a silicon verification key on the surgical guide’s buccal side so it was possible to verify the implant position during its placement.

In the control group, orthocryl free-hand surgical guides based on a conventional wax-up were performed, and the technicians created an individual impression tray. During surgery, the consecutive drills of the implantation procedure were carried through the free-hand guide to position the implant according to the prosthodontic planning. A precision impression was then taken using the individual impression tray immediately after the implant insertion. Using the impression taken after the surgery, the technician planned a final zirconia abutment using the diagnostic wax-up. Following this phase, a PMMA-stratified provisional crown was produced.

Surgical results

In the control group, the insertion of the conventional guide was possible for every patient with no modifications; in the test group, the surgical guide needed modifications in order to be fitted. The higher deviation in the entrance site was 1.13 mm in the test group’s surgical guide, which was modified later. In one case, the clinician had to change the height of the implant due to a standard deviation of 2mm in the vertical dimension.

The global apical deviation (GAD) was significantly higher in the control group compared to the test group ($p = 0.014$). In addition, significant differences were observed for the Angular deviation ($p = 0.014$) and the Apical vestibular deviation ($p = 0.038$) in favor of the fully guided surgery.

No significant differences were registered regarding the Coronal global deviation, Coronal distal deviation, Coronal vestibular deviation, Coronal apical deviation, Apical distal deviation, and Apical deviation.

All the implants obtained primary stability, a 15Nm torque was used for all the custom-made zirconia abutments, and all the provisional prostheses were inserted right after the surgery in the test group and after 10 days in the control group. There were no statistically significant differences between the two groups concerning occlusion and interproximal contacts; the two groups both required occlusal modifications in almost half of the patients.

The White Esthetic Score (WES) showed no significant difference between the two groups, even though the scoring was not higher in the group with the conventional stratified provisional crown. However, the PES score tended to be higher in the test group. In terms of soft tissue colour and texture, the values of “2” were recorded for all patients in the test group, while the proportion of score “2” was 44.4% in the control group ($p = 0.029$, respectively).

The satisfaction scores were similar between the groups, except for the comfort during the polyether impression (control group) vs digital impression (test group); the digital impression was found to be significantly more comfortable compared to the conventional one ($p = 0.014$). No statistical differences were registered in the esthetic VAS in the two groups. Both methods showed the authors registered satisfactory results and no statistically significant differences in the outcome regarding esthetics. The patients preferred the optical impression to the conventional polyether one, as the previous one caused less discomfort.

DISCUSSION

In the past two decades, dentistry has made great strides in evolution in both techniques and materials (29-48), nowadays increasing number of clinicians use the optical impression in their office, choosing the digital workflow for many reasons. From these studies, we deduce that in terms of aesthetics and reliability of the final crown, there are no differences between digital and analogic workflow, which also concerns the need for occlusal and interproximal modification in the delivery appointment.

There were no differences between the two groups in the post-delivery prosthetic complications. For what concerns the times needed for the impression, there is a certain discrepancy of data and, in our opinion, it depends a lot on the conventional impression technique used for the comparison; however, it seems to be easier to take the impression using a scanner without the necessity of the powder.

A fully digital workflow seems to be more efficient for the realization of the final crown, showing shorter times in the crafting process. The costs of a final crown made using a fully digital workflow seem less expensive for the clinician compared to the analogic.

The patient, except for the second article, appears to prefer the optical impression compared to the traditional one, mainly because of a less gagging and nausea episodes, whereas there are still contrasting opinions among the clinicians, and it might depend on the dexterity in using the new technique.

These data agreed with recently published systematic reviews such as “3D Digital Impression Systems Compared with Traditional Techniques in Dentistry: A Recent Data Systematic Review” by Marco Cicciù et al. (49), in which, in addition to what has already been said, there is evidence of greater ease of use of the optical impression for students than for established professionals, this may be due to the unwillingness of those professionals, who have been used to working in a certain way for so long, to change.

Limitations

Since digital workflow was introduced in dentistry not years ago, only a few data about these new technologies are available in the literature. Moreover, the high cost of the equipment makes it even more challenging to design clinical studies that provide data with a high level of evidence.

Extended research that includes a larger number of reliable studies should be conducted in the future when more knowledge about these technologies will be acquired, and the use of the equipment will be extended in clinical practice.

This paper has not considered all the techniques that could be used for digital workflow; however, interesting recent reviews, such as that of Lavorgna et al. (50), does compare the values obtained with different optical impression systems and the photo-detection system on which Digital Smile Design is based.

CONCLUSIONS

The use of the optical impression undoubtedly required a learning curve to optimize times and avoid making the same impression many times. However, even with some critical points, such as powder use, the optical impression seems reliable and precise, especially for single or small implant-supported bridges.

From the analysis of these papers, we can conclude that, for what concerns fixed implant-supported prosthesis, a digital workflow showed promising results. However, the limits of these methods are the powder's use and the time needed to take an impression.

A digital workflow is a viable alternative to the traditional workflow; it seems to work better for some treatments than others. However, there is still a conflicting opinion in the literature and among clinicians about its applicability and benefits in daily clinical practice.

It will undoubtedly be interesting to carry out new research in the future, also trying to create large databases to enter all the various digital data collection systems and compare them with each other in order to highlight the strengths and weaknesses of each.

REFERENCES

1. Duret F, Blouin JL, Duret B. CAD-CAM in dentistry. J Am Dent Assoc 1988; 117(6):715-720.
2. Mormann WH, Brandestini MLF. The Cerec system: computer-assisted preparation of direct ceramic inlays in 1 setting. Quintessenza 1987; 38:457–70.
3. Mörmann WH. The evolution of the CEREC system. J Am Dent Assoc 2006; 137 Suppl(9 SUPPL.).
4. Miyazaki T, Hotta Y, Kunii J, Kuriyama S, Tamaki Y. A review of dental CAD/CAM: current status and future perspectives from 20 years of experience. Dent Mater J 2009; 28(1):44-56.
5. Miyazaki T, Hotta Y. CAD/CAM systems available for the fabrication of crown and bridge restorations. Aust Dent J 2011; 56 Suppl 1(SUPPL. 1):97-106.
6. Van Noort R. The future of dental devices is digital. Dent Mater 2012; 28(1):3-12.
7. Davidowitz G, Kotick PG. The use of CAD/CAM in dentistry. Dent Clin North Am 2011; 55(3):559-570.
8. Bertossi D, Fiorino P, Corega C, et al. Cone-beam volumetric imaging in craniofacial medicine. Minerva Stomatol 2019; 68(4):200-212.
9. Zimmermann M, Mehl A, Mörmann WH, Reich S. Intraoral scanning systems - a current overview. Int J Comput Dent 2015; 18(2):101-129.
10. Martin CB, Chalmers E V., McIntyre GT, Cochrane H, Mossey PA. Orthodontic scanners: what's available? J Orthod 2015; 42(2):136-143.
11. Ting-shu S, Jian S. Intraoral Digital Impression Technique: A Review. J Prosthodont 2015; 24(4):313-321.
12. Logozzo S, Zanetti EM, Franceschini G, Kilpelä A, Mäkynen A. Recent advances in dental optics – Part I: 3D intraoral scanners for restorative dentistry. Opt Lasers Eng 2014; 54:203-221.
13. Imburgia M, Logozzo S, Hauschild U, Veronesi G, Mangano C, Mangano FG. Accuracy of four intraoral scanners in oral implantology: a comparative in vitro study. BMC Oral Health 2017; 17(1).
14. Aragón MLC, Pontes LF, Bichara LM, Flores-Mir C, Normando D. Validity and reliability of intraoral scanners compared to conventional gypsum models measurements: a systematic review. Eur J Orthod 2016; 38(4):429-434.
15. Amornvit P, Rokaya D, Sanohkan S. Comparison of Accuracy of Current Ten Intraoral Scanners. Biomed Res Int 2021; 2021:2673040
16. Kwon M, Cho Y, Kim DW, Kim M, Kim YJ, Chang M. Full-arch accuracy of five intraoral scanners: In vivo analysis of trueness and precision. Korean J Orthod 2021; 51(2):95-104.
17. Renne W, Ludlow M, Fryml J, et al. Evaluation of the accuracy of 7 digital scanners: An in vitro analysis based on 3-dimensional comparisons. J Prosthet Dent 2017; 118(1):36-42.
18. Yuzbasioglu E, Kurt H, Turunc R, Bilir H. Comparison of digital and conventional impression techniques:

evaluation of patients' perception, treatment comfort, effectiveness and clinical outcomes. BMC Oral Health 2014; 14(1).

19. Wismeijer D, Mans R, van Genuchten M, Reijers HA. Patients' preferences when comparing analogue implant impressions using a polyether impression material versus digital impressions (Intraoral Scan) of dental implants. Clin Oral Implants Res 2014; 25(10):1113-1118.
20. Means CR, Flenniken IE. Gagging--a problem in prosthetic dentistry. J Prosthet Dent 1970; 23(6):614-620.
21. Park HR, Park JM, Chun YS, Lee KN, Kim M. Changes in views on digital intraoral scanners among dental hygienists after training in digital impression taking. BMC Oral Health 2015; 15(1).
22. Joda T, Brägger U. Time-Efficiency Analysis Comparing Digital and Conventional Workflows for Implant Crowns: A Prospective Clinical Crossover Trial. Int J Oral Maxillofac Implants 2015; 30(5):1047-1053.
23. EXOCAD. No Title. https://exocad.com/our-products/exocad-dentalcad. Accessed November 7, 2022.
24. Fasbinder DJ. Digital dentistry: innovation for restorative treatment. Compend Contin Educ Dent 2010; 31 Spec No 4:2-11.
25. Mangano F, Veronesi G. Digital versus Analog Procedures for the Prosthetic Restoration of Single Implants: A Randomized Controlled Trial with 1 Year of Follow-Up. Biomed Res Int 2018; 2018:5325032.
26. Sailer I, Mühlemann S, Fehmer V, Hämmerle CHF, Benic GI. Randomized controlled clinical trial of digital and conventional workflows for the fabrication of zirconia-ceramic fixed partial dentures. Part I: Time efficiency of complete-arch digital scans versus conventional impressions. J Prosthet Dent 2019; 121(1):69-75.
27. Derksen W, Tahmaseb A, Wismeijer D. Randomized Clinical Trial comparing clinical adjustment times of CAD/CAM screw-retained posterior crowns on ti-base abutments created with digital or conventional impressions. One-year follow-up. Clin Oral Implants Res 2021; 32(8):962-970.
28. Hanozin B, Li Manni L, Lecloux G, Bacevic M, Lambert F. Digital vs. conventional workflow for one-abutment one-time immediate restoration in the esthetic zone: a randomized controlled trial. Int J Implant Dent 2022; 8(1).
29. Lombardo G, Signoriello A, Corrocher G, Signoretto C, Burlacchini G, Pardo A, Nocini PF. A Topical Desiccant Agent in Association with Manual Debridement in the Initial Treatment of Peri-Implant Mucositis: A Clinical and Microbiological Pilot Study. Antibiotics (Basel) 2019; 8(2):82.
30. Pedullà E, Plotino G, Scibilia M, et al. Cyclic fatigue comparison among endodontic instruments with similar cross section and different surface coating. Minerva Stomatol 2019; 68(2):67-73.
31. Lombardo G, Signoretto C, Corrocher G, et al. A topical desiccant agent in association with ultrasonic debridement in the initial treatment of chronic periodontitis: a clinical and microbiological study. New Microbiol 2015; 38(3):393-407.
32. Corega C, Vaida L, Festila DG, et al. The benefits of Quercitin for dentistry and maxillofacial surgery: a systematic review. Minerva Stomatol 2014.
33. Pardo A, Signoriello A, Signoretto C, et al. Detection of Periodontal Pathogens in Oral Samples and Cardiac Specimens in Patients Undergoing Aortic Valve Replacement: A Pilot Study. J Clin Med 2021; 10(17):3874.
34. Corega C, Vaida L, Festila DG, et al. Dental white spots associated with bulimia nervosa in orthodontic patients. Minerva Stomatol 2014; ahead of print.
35. Marconcini S, Barone A, Perrini N, et al. Conservative treatment of unicystic odontogenic keratocyst by piezosurgery approach. A case report. Minerva Stomatol 2014; ahead of print.
36. Ricci M, Marchisio O, Genovesi AM, et al. comparison between oscillating-twisting rotating of brush head vs a characteristic sweeping bristles motion on reducing oral inflammation. Minerva Stomatol 2014; ahead of print.
37. Lombardo G, Pardo A, Signoretto C, Signoriello A, Simeoni E, Rovera A, Nocini PF. Hyperbaric oxygen therapy for the treatment of moderate to severe periodontitis: a clinical pilot study. Undersea Hyperb Med 2020 Fourth-Quarter; 47(4):571-580.
38. Bertossi D, Fiorino P, Corega C, et al. Cone-beam volumetric imaging in craniofacial medicine. Minerva Stomatol 2019; 68(4):200-212.
39. Gelpi F, Romoli L, D'Arienzo D, et al. Lateral periodontal cyst (LPC) mimicking periodontal socket in a young patient: report of a case and review of the literature. Minerva Stomatol 2014; ahead of print.
40. Genovesi AM, Lorenzi C, Lyle DM, et al. Periodontal maintenance following scaling and root planing. A

randomized single-center study comparing minocycline treatment and daily oral irrigation with water. Minerva Stomatol 2014; ahead of print.

41. Marconcini S, Genovesi AM, Marchisio O, et al. In vivo study of titanium healing screws surface modifications after different debridment procedure. Minerva Stomatol 2014; ahead of print.
42. Corega C, Vaida L, Festila DG, et al. Blood levels of interleukins in patients with ameloblastoma. Minerva Stomatol 2014; ahead of print.
43. Nocini PF, De Santis D, Ferrari F, Bertele GP. A customized distraction device for alveolar ridge augmentation and alignment of ankylosed teeth. Int J Oral Maxillofac Implants 2004; 19(1):133-44.
44. De Santis D, Graziani P, Castellani R, et al. A New Radiologic Protocol and a New Occlusal Radiographic Index for Computer-Guided Implant Surgery. J Craniofac Surg 2016; 27(5):e506-10.
45. Bertossi D, Nocini R, Luciano U, et al. Piezoelectric surgery inserts vs conventional burst: a clinical investigation. J Biol Regul Homeost Agents 2018; 32(2 Suppl. 2):15-19.
46. Barone A, Toti P, Bertossi D, et al. Gene Expression of Human Mesenchymal Stem Cells Cultured on Titanium Dental Implant Surfaces. J Craniofac Surg 2016; 27(3):712-7.
47. De Santis D, Sinigaglia S, Pancera P, et al. An overview of socket preservation. J Biol Regul Homeost Agents 2019; 33(1 Suppl. 1):55-59.
48. De Santis D, Sinigaglia S, Pancera P, et al. An overview of guided bone regeneration. J Biol Regul Homeost Agents 2019; 33(1 Suppl. 1):49-53.
49. Cicciù M, Fiorillo L, D'Amico C, et al. 3D Digital Impression Systems Compared with Traditional Techniques in Dentistry: A Recent Data Systematic Review. Materials (Basel) 2020; 13(8):1982.
50. Lavorgna L, Cervino G, Fiorillo L, et al. Reliability of a Virtual Prosthodontic Project Realized through a 2D and 3D Photographic Acquisition: An Experimental Study on the Accuracy of Different Digital Systems. Int J Environ Res Public Health 2019; 16(24):5139.

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Review

Minimally invasive rehabilitation with total removable implants supported prosthesis with conometric connection

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ABSTRACT

Since its inception, modern dentistry has been a discipline in continuous evolution. Thanks to this progress, the prosthetic rehabilitation of the edentulous patient can now be effectively addressed by multiple therapeutic approaches rooted in the decision-making marriage between patient and clinician in both partial and total edentulous patients. From a historical perspective, the aesthetic-functional restoration of the completely edentulous maxillary arch has been subverted in the possibilities of intervention by the introduction of implantology, which has made it possible to overcome the otherwise mandatory use of removable devices with complete mucous support (1). The current study is intended to be an example of this evolution by describing one out of five clinical cases performed. Furthermore, it is intended to demonstrate how the newly proposed implant-prosthetic techniques, where a fixed implant rehabilitation is not possible due to age constraints, lack of bone support or unfavourable mechanical-aesthetics parameters, allow the rehabilitation of the upper total edentulous jaw with a removable device without a solidarizing intermediate bar to rely upon for the implants. The implants and the whole rehabilitation are, however, consolidated thanks to the stability provided by the presence of a telescopic connection, combining viable long-term survival (2) with optimal results for the patient in terms of cost (3), comfort, chewing capability (4), aesthetics and home hygiene.

INTRODUCTION

The therapeutic possibilities for the implant-prosthetic rehabilitation of the oral cavity afflicted by total edentulism can be primarily distinguished in relation to the possibility of removal, both by the patient and by the doctor, of the strictly prosthetic component constituting the rehabilitation.

According to reports by Misch (5) in 1990, there are five categories of implant-prosthetic rehabilitation for fully edentulous arches, three fixed and two removable; the distinction between the two removable options is mainly related to the fact that the support can either be based entirely on dental implants (RP-4) or be the combination of an implant-mucous one (RP-5).

According to the literature (6), the choice to carry out a removable implant-prosthetic rehabilitation may be justified by multiple reasons. Among these, the reduced cost offered by these treatment plans compared to the fixed counterparty, often resulting from a reduced implant demand, is very important for decision-making. Indeed, the implants are frequently placed in the anterior maxillary region, and the posterior region is supported by the combination of a cantilever element with mucous support, thus making it less pressing to perform higher bone additive procedures since the anterior bone resorption is, in general, less marked.

Other advantages attributable to a removable prosthesis on implants lie in the possibility of making up for soft tissue deficiency (7, 8), the best home hygiene that the patient can put in place, the possibility of removing the prosthesis at night to mitigate the effects of a possible parafunctional habit and the ease of repair, given the possibility of delivering the artefact to the dental laboratory.

While conducting a cost-benefit analysis of prosthetic rehabilitation, the clinician must assess the degree of atrophy and the patient's age (9). Regarding the degree of atrophy, one of the most appreciated classifications in the literature, that of Misch & Judy (10), published in 1987, notes the existence of a biomechanical relationship between the residual crestal bone amplitude and the maximum inclination of the dental implant with respect to the bone base, such that when the values of crestal amplitude are less than 5mm the inclination as mentioned above should not exceed 20 degrees. In these scenarios, the therapeutic will to guarantee, through a full-mouth fixed bridge, adequate home hygiene and satisfying aesthetic contrasts with the implant biomechanics and, therefore, the needle of the balance “cost-effectiveness” tends towards a removable implant-prosthetic rehabilitation.

When it comes to the removable implant-supported rehabilitation of the completely edentulous upper arch, it is common to find in the literature (6, 10-13) that a device with a “bar” retention system with solidarized implants is superior on both the mechanical and hygienic-prognostic planes compared to other types of connections on non-solidarized dental implants (14, 15). From a combined clinical and biomechanical perspective, the magnitude of the stabilization mentioned above derives, at least partly, from the type of connection chosen. The literature (16, 17) reports a greater ability to withstand functional loads for “locator” attachments and bar-supported solutions when compared to “ball” attachments.

The literature is not so rich regarding “telescopic” or “conometric” connections; however, it is sufficient for some considerations. It is reported that the connections guarantee greater stability and rigidity than others (18) and allow the distribution of masticatory forces comparable to that obtainable with a bar, albeit with some differences (19); furthermore, one must consider that the literature has not come to a clear conclusion when considering the marginal bone loss as the effect of the overload applied on fully osseointegrated implants (20). The mechanical advantage of these connections is attributed (21) to the intimate circumferential contact between the components, resulting in the reduction of rotational torque generated by applying any masticatory load.

Considering the statements mentioned above, this study aims to report the possibility of performing an implant-prosthetic rehabilitation of the maxillary district through a telescopic connection without a “bar” superstructure, granting hygienic and economic benefits without mechanical or prognostic sacrifice.

In order to give scientific support to the therapeutic option proposed in the current paper, a search has been conducted on the bibliographic search engines PubMed and Scopus to identify similar publications, which allowed a broader spectrum of considerations than the ones directly inherited by the individual sample reported by the authors and which could therefore support the scientific rationale of the therapeutic plan.

Case study

The case involves an adult male patient (74 years) with a medical history positive for hypertension, which is reported to be pharmacologically compensated at the time of treatment. The patient, who has a total edentulous upper arch, has requested a prosthetic rehabilitation of this sector through an implant-prosthetic treatment, not bearing the possibility of a completely mucous-supported prosthesis.

Following the case study, carried out through gipsographic models, radiographic examinations and objective evaluation of the oral cavity, the therapeutic possibilities individualized for the specific case were illustrated. Given the massive bone atrophy and unfavourable aesthetic-prosthetic parameters when a fixed implant-supported device was considered, a removable prosthesis with telescopic connection on implants placed in the 1.3, 1.2, 2.2 and 2.3 sites was theorized.

From the subsequent comparison with the patient, it was decided to proceed with the therapy, given the criteria set out in the previous section and the lowest cost of the whole treatment plan. Therefore, the treatment plan was carried out with the placement of the dental implants, of size and diameter commensurate with bone availability and biomechanical aspects (14, 22), in the planned sites and, after waiting an adequate time for osteointegration to happen, with the positioning of the relative implant connection abutments. Then, the removable prosthetic device, coupled through a telescopic connection, was manufactured on those supports.

MATERIALS AND METHODS

The preparation of the patient involved obtaining the preliminary analogue-digital documentation, consisting of initial photos (analysis of chewing - exposure of the smile - general aesthetics of the patient), study models and computed tomography to define bone availability. A radiological-surgical-prosthetic template was then commissioned to the dental laboratory, through which the position chosen for the dental implant was radiologically and prosthetically verified before the surgery (Fig. 1, 2).

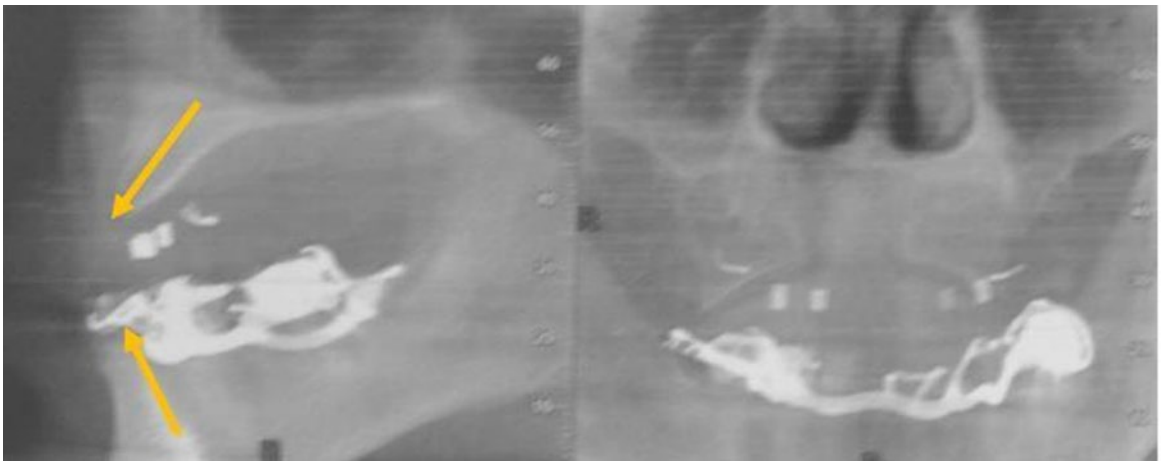

Fig. 1. *Implant-prosthetic project by cone beam computerized tomography.*

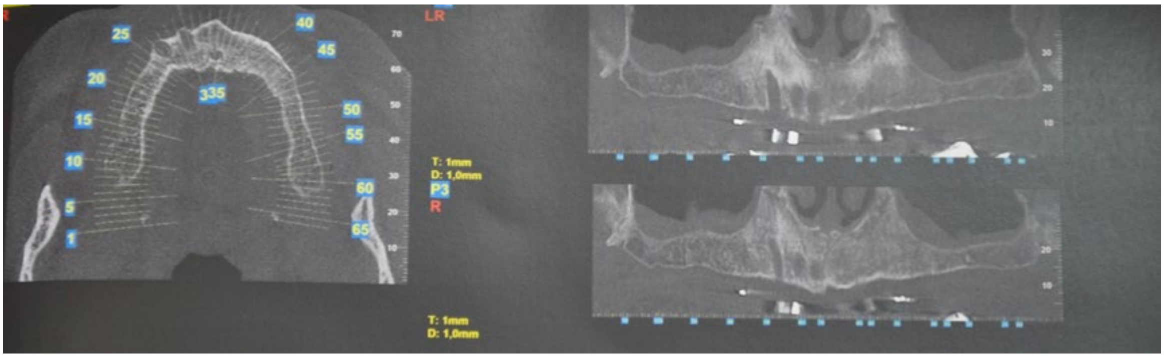

Fig. 2. *Pre-implant surgery orthopantomography.*

Then, we proceeded with the surgical phase. Firstly, perioral skin disinfection (Povidone Iodine 10%) was associated with Vaseline to moisten the tissues, and local anaesthesia followed. The gingival surface was then treated with a topical anaesthetic (Lidocaine + cetrimonium bromide 15 %), and plexal anaesthesia was inoculated both at the level of the upper vestibular fornix microcirculation and in the palate (Articaine 4% + adrenaline 1/200,000).

Secondly, an oblique incision of the tissues at the vestibular paracrestal level was made with full-thickness tissue cleavage palatally and narrowly at the vestibular level (scalpel 12C). The total bone exposure made it possible to trace the reference points determined by the positioning of the radiological-surgical-prosthetic template and the consequent execution of exploratory milling using “lanceolate” milling (1.9 mm) at 5mm in the predetermined sites 1.3-1.2-2.2-2.3.

After a clinical examination of bone density (D3 classification of Misch (5)) with an implant probe, the first milling (2.2mm) was performed at 5mm and then completed, radiologically verified the inclination, up to 13 mm in sites 1.2-2.2 and up to 11 mm in sites 1.3-2.3. A second milling for 5mm (diameter 2.8 mm) and a third milling (diameter 3.3 mm) was subsequently carried out for 3mm to prevent excessive bone pressure by the implant element during insertion, favoring the primary osteogenesis but also ensuring implant stability. Four implants (titanium 5 HRS surface) were inserted, with a diameter of 3,75 mm and a length of 12 mm in the 1.2 and 2.2 locations, and a diameter of 3,75 mm and a length of 10 mm in the 1.3 and 2.3 locations, up to 1 mm below the bone ridge, favoring prosthetic aesthetics (23).

Following the insertion of the cap screw on each implant, a check orthopantomography was performed to verify the operation's success. Next, the flap was carefully sutured using a closing flap through single intrapapillary stitches in positions 1.4-2.4 and a horizontal mattress crossed between the vestibular and palatal front portions.

This method, the wrapping of the suture in the vestibular paracrestal position obtained from the initial incision mode, has decreased the risk of infection of the implant stumps since the incision and the consequential suture are both laterally placed to the insertion site (glycolic acid absorbable suture).

The patient was discharged following pharmacological indications, antibiotic bactericidal and anti-inflammatory (amoxicillin with clavulanic acid 1gr every 8 hours for six days and paracetamol with codeine 500mg + 30mg when needed), associated with post-surgical indications, indications to hygiene and, for the first month, to a soft diet. The patient was finally given the temporary, pre-packaged, mobile prosthesis with light silicone relining, adapting the occlusion to the lower arch. Three weeks later, the sutures were removed, and a monthly radiographic check was carried out for a quarter. We proceed with the radiographic control three months after the surgery to assess osseointegration (Fig. 3).

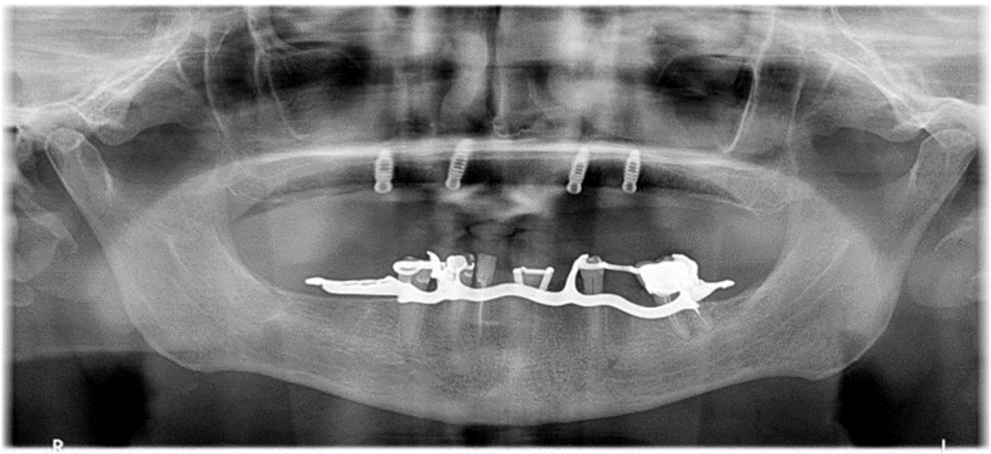

Fig. 3. *Post-implant surgery orthopantomography.*

The optimal results in the radiogram made it possible to proceed with the second surgical phase of implant uncovering to start the prosthetic rehabilitation. In this phase, about a quarter from the previous one, we proceeded with the same procedure of disinfection and anesthesiology, as reported above. We then drew a flap characterized by an oblique paracrestal palatal incision with partial thickness cleavage vestibular and full thickness palatally (scalpel 12C). This incision increased the volume of vestibular tissues, the simultaneous exposure of the smooth peri-implant collar and the subsequent placement of healing screws (Fig. 4).

Fig. 4. *Mucosa during implant activation.*

Once the necessary healing screws were placed, the suture (glycolic acid absorbable suture) and the readaptation of the temporary mobile prosthesis were performed. Finally, the photographic documentation was updated, and an alginate impression was taken to create an individual impression holder before the surgical phase mentioned above.

Once the time of the healing of the perimplant tissues had elapsed, the treatment plan was continued with the taking of a first analogic precision mucostatic impression (polysulfide) necessary for the realization of the removable prosthesis. In the same session, a second precision analogic impression was performed (polysilicon) using transfers to determine the correct position of the implant pillars. With this information, the intermediate supports necessary for the subsequent screwing of the primary telescopic abutment (standard length 4.3mm and standard angle 5 of the patient) were chosen, relying on the gum volume at the intraoral level and the parallelism between primary stumps at the extraoral level on dedicated models (Fig. 5).

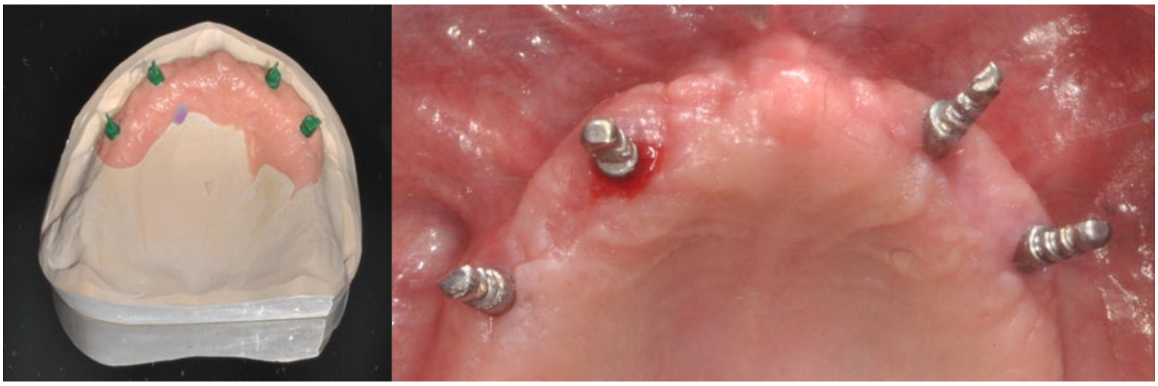

Fig. 5. *Implant position evaluation.*

Specifically, an intermediate support of length 1.5mm with an inclination of 25° was placed in position 1.3; in seat 1.2, the length was 5mm with an inclination of 15°; in site 2.2 length was 5mm with an inclination of 35° and in seat 2.3 length was 3mm with an inclination of 25° (Fig. 6, 7).

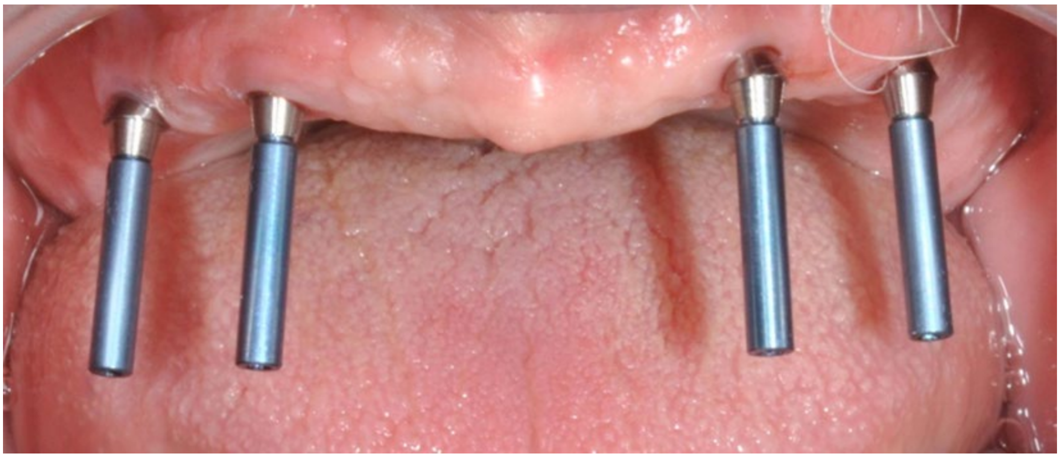

Fig. 6. *Intermediate supports for screwing the telescopic primary stumps.*

Fig. 7. *The telescopic primary stumps.*

In the following sessions, we realized the prosthesis through the test of the wax rims, placed on the provisional prosthetic flange, and thus detecting the vertical dimension, the correct model of occlusion, through precise mastication on dedicated auxiliary wax, and the interdental midline related to the tip of the nose and chin.

The tooth test was then performed, first in the front and then in the rear (Fig. 8, 9); the prosthesis was also subjected to a chewing control, in which we assured that while performing lateral excursions and protrusions, there were not too many tangential stresses (Fig. 10).

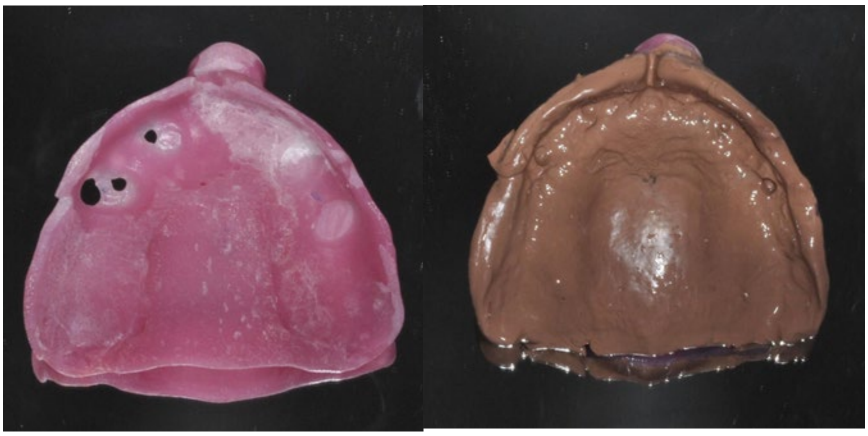

Fig. 8. *Accurate impression in order to produce a removable prothesis.*

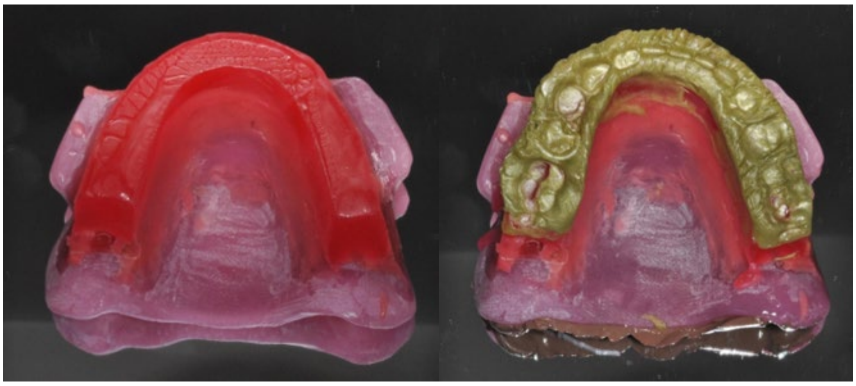

Fig. 9. *Structure test - vertical dimension evaluation - chewing test.*

Fig. 10. *Chewing test.*

In the same session, a phonetic test was also carried out, associated with a further aesthetic evaluation by a family member. As a final step, the palatal coverage was removed from the prosthesis, and an alloy reinforcement grid (chromium-cobalt) was incorporated at the dental laboratory.

Finally, at the time of delivery, four secondary telescopic crowns in peek (Standard length 4.3mm and standard angle 5,6 mm) have been inserted into the final removable prosthesis using a direct relining (polymethyl methacrylate). Those were calibrated for the primary telescopic abutments of the implant elements 1.3-1.2-2.2-2.3 and were necessary to determine the telescopic anchorage on the implant elements of the said prosthesis (Fig. 11-13).

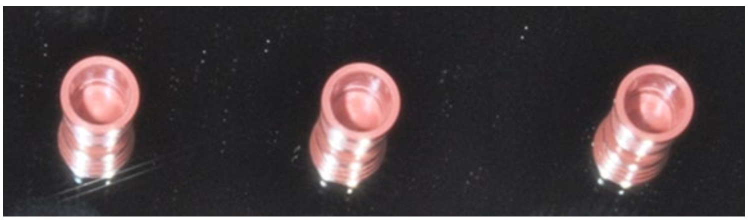

Fig. 11. *Peek® secondary telescopic crowns.*

Fig. 12. *Peek® secondary telescopic crowns insertion.*

Fig. 13. *Removable prothesis.*

After approximately one month, the patient was reviewed for the execution of an indirect relining through the support of the dental laboratory updating, in the same session, the photographic documentation and verifying the positive course of rehabilitation (Fig. 14).

Fig. 14. *Smile.*

In order to perform a comparison of the proposed rehabilitation protocol with other similar publications, a search has been carried out on the search engines PubMed and Scopus, using as a query the following string:' ("Telescopic" or "Conometric" or "Milled bar") AND ("Overdentures" or "implant-supported prosthesis" or "Dental Bridge" or "Removable prosthesis") AND "Dental Implants"'. The titles and abstracts of the 93 individual results were then analyzed to make a further selection of the comparative studies, and the three independent revisors involved selected a preliminary total of 4 publications.

Only one article (15) was found to be suitable for comparison since it included removable telescopic-coupled overdentures, among other types of connections, supported by more than 4 implants in treating patients with edentulous upper jaws.

RESULTS

At the end of the first trimester, the first clinical inspection checked the stability of the implants, the intermediate prosthetic components and the gum tissue structure and professional oral hygiene were performed. After delivery, the second clinical and radiographic check was carried out to analyze the stability of the implants, the intermediate prosthetic components and the gum-tissue structure.

In both measurements, the stability of the implants, prosthetic components, and gingival-tissue structure was optimal, accompanied, in the second examination, by the radiographic evidence of complete osseointegration. Therefore, professional oral hygiene was carried out every four months for the first year, ensuring gum health of the mucous channels and making the patient aware of the importance of such attention to achieve an optimal duration of the prosthetic rehabilitation.

DISCUSSION

Dentistry is a medical discipline that requires a certain amount of therapeutic flexibility on the part of the practitioner: no protocol allows all clinical cases to be successfully concluded, but all clinical cases can be fully satisfied by the correct choice of a treatment plan (24).

A further aspect of peculiarity, which constitutes the foundation of modern medicine, is the continuous evolution of therapeutic methods, where what was generally considered not optimal in the past can be, to date, thanks to technical progress, considered the best desirable treatment for a specific patient (25).

A clear example of the importance of adapting the prosthetic treatment plan to the patient's needs using new therapeutic algorithms has already been reported by Zanotti and colleagues in the minimally invasive telescopic prosthetic restorations (26). The concept is further evidenced by the reported clinical cases, in which the need to converge objectives on the appropriate levels of stability, aesthetics and durability of rehabilitation sought by the clinician with the patient's expectations, existing both clinically and economically, has imposed an innovative approach to the total removable prosthetic rehabilitation of the upper jaw, denying the poor predictability that is attributed in the literature to IODs (27, 28) (maxillary implant-supported overdentures).

The rehabilitation method adopted, assuming as a requirement the adequate availability of bone in the premaxilla, has allowed the placement of the implants in the optimal locations for the realization of a removable prosthesis with mixed implant-mucous support and thus allowed to reduce costs and discomfort for the patient compared to fixed alternatives, which would have required surgical bone augmentation procedures.

The contextual design of a telescopic device based on mixed support, as opposed (29, 30) to the ones solidarized by bars or other types of connections, has further contained costs without sacrificing stability and prognosis, in line with the assertions in the previous sections. Furthermore, an advantage obtained, thanks to the prosthetic-implant design proposed, further than those mentioned above, consists in the possibility to reduce the prosthetic flange on the vestibular side and eliminate the palatal component, thanks to the convergence of the coronal prosthetic component to the implant support resulting from the absence of a rigid superstructure.

Eliminating the palatine component improves patient comfort since many phonemes are produced by addressing the tip of the tongue to the premaxilla, and the presence of clutter is often referred to as an obstruction to the phonation (31). At the same time, the reduction of the vestibular flange made the rehabilitation more appealing aesthetically, in compliance with the perioral musculature.

There is no clear evidence that implant solidarization employing a bar is favourable for the survival of the rehabilitation, where the possible advantage of its use as a better compensation of the tangential forces in a phase of disengagement of the device in the case of non-aligned implants in patients with marked modification of the original arch shape, would not have been significative in the specific patient analyzed.

What emerges clearly from the literature (31, 32) is the strong influence that the "hygienic potential" conferred by the prosthetic design has on peri-implant disease. For example, Serino (31) reports that in 48% of the samples analyzed, peri-implantitis was associated with poor prosthesis hygiene and that this parameter had predictive power for the onset of the pathology for 82%. The authors, therefore, consider, in the light of the above literary data and based on their clinical experience, that they can summarize the advantages of the treatment solution adopted as follows.

The first aspect is the possibility of rehabilitating an elderly edentulous patient if the initial bone volume does not allow the realization of a fixed implant-supported prosthesis without performing regenerative surgery, with low costs compared to bars and comparable costs to alternative couplings. The second advantage is that compared to the aforementioned alternative couplings, namely 'Interlock' and "ball" attachments, the wear of the structural components seems to be lower, while the hygienic potential of the device is kept extremely high. The clinician should also note that telescopy is an approach that makes extreme precision its pivotal point and therefore requires meticulous accuracy in all its steps, which from a certain point of view, can be a disadvantage;

Secondly, telescopic systems tend to show a more significant number of mechanical complications during maintenance. However, it should be noted that in the literature, this data is discordant (33, 34), and, in the scenario of those happening, they are fully manageable on a regular ambulatorial recall.

CONCLUSIONS

In the reported scenarios, the chosen therapeutic plan made it possible to achieve optimal and stable clinical results, giving a hopeful demonstration of the importance of critically interpreting the consolidated prosthetic dictates resulting from empirical experience. The authors also consider it necessary to stress that, in addition to the obvious advantages in economic terms and invasiveness compared to fixed or bar-supported counterparts, the approach adopted, that is, the use of a removable device without a fixed superstructure has allowed for improved hygiene at home, which is by no means secondary to the incidence of peri-implant disease (32, 33, 34).

In order to document the difficulty of comparing the therapeutic approach described therein with statistical data available in the literature, a recent systematic review is considered, published by Kern et. Al (35). The work has shown that the factors influencing the clinical success of implant-prosthetic rehabilitation are many. In general, fixed rehabilitations have a greater survival rate than the removable alternatives; that is why the latter would be preferable under idealistic conditions. However, the same publication also reports the impossibility of making a direct comparison between the implant's survival rate obtainable with "ball" attachments and telescopic connections rather than between "bar" structures and telescopic connections since the number of studies available is very limited.

It is therefore considered, in agreement with the literature, plausible to conclude that, although within the limitations of the experiential sample considered, the total removable prosthesis with telescopic connections may constitute a therapeutically and prognostically comparable alternative (36), if not even superior in terms of peri-implant soft tissues health (37), to bar retained IODs in cases where, due to medical, clinical or economic reasons, fixed rehabilitation loses absolute value; while adopting this approach the clinician should, however, consider the possibility of encountering a slightly higher number of mechanical complications during maintenance visits: this statement is based on literary data (15), given the already mentioned timespan and sample limitations of this study.

REFERENCES

1. Buser D, Sennerby L, De Bruyn H. Modern implant dentistry based on osseointegration: 50 years of progress, current trends and open questions. Periodontol 2000; 73(1):7-21.
2. Ghiasi P, Ahlgren C, Larsson C, Chrcanovic BR. Implant and prosthesis failure rates with implant-supported maxillary overdentures: a systematic review. Int J Prosthodont 2021; 34(4):482-491.
3. Zhang Q, Jin X, Yu M, Ou G, Matsui H, Liang X, Sasaki K. Economic Evaluation of Implant-Supported Overdentures in Edentulous Patients: A Systematic Review. Int J Prosthodont 2017; 30(4):321-326.
4. Afrashtehfar KI, Schimmel M. Muscular activity may improve in edentulous patients after implant treatment. Evid Based Dent 2016; 17(4):119-120.
5. Misch C. Classifications and treatment options for the completely edentulous arch in implant dentistry. Dent Today 1990; 9(8):26, 28-30.
6. Mericske-Stern R. Treatment outcomes with implant-supported overdentures: clinical considerations. J Prosthet Dent 1998; 79(1):66-73.
7. Misch CE. Dental Implant Prosthetics. Second Edition. Mosby 2015.
8. Blum IR, McCord JF. A clinical investigation of the morphological changes in the posterior mandible when implant-retained overdentures are used. Clin Oral Implants Res 2004; 15(6):700-8.
9. Gil-Montoya JA, de Mello AL, Barrios R, Gonzalez-Moles MA, Bravo M. Oral health in the elderly patient and its impact on general well-being: a nonsystematic review. Clin Interv Aging 2015; 10:461-7.

10. Misch CE, Judy KW. Classification of partially edentulous arches for implant dentistry. Int J Oral Implantol 1987; 4(2):7-13.
11. Mañes Ferrer JF, Fernández-Estevan L, Selva-Otaolaurruchi E, Labaig-Rueda C, Solà-Ruiz MF, Augustin-Panadero R. Maxillary Implant-Supported Overdentures: Mechanical Behavior Comparing Individual Axial and Bar Retention Systems. A Cohort Study of Edentulous Patients. Medicina (Kaunas) 2020; 56(3):139.
12. Raghoebar GM, Meijer HJ, Slot W, Slater JJR, Vissink A. A systematic review of implant-supported overdentures in the edentulous maxilla, compared to the mandible: how many implants? Eur J Oral Implantol 2014; 7 (Suppl 2):S191-201.
13. Takahashi T, Gonda T, Maeda Y. Effects of Reinforcement on Denture Strain in Maxillary Implant Overdentures: An In Vitro Study Under Various Implant Configurations. Int J Oral Maxillofac Implants 2016; 31(6):e162-e167.
14. Kiener P, Oetterli M, Mericske E, Mericske-Stern R. Effectiveness of maxillary overdentures supported by implants: maintenance and prosthetic complications. Int J Prosthodont 2001; 14(2):133-40.
15. Zou D, Wu Y, Huang W, Wang F, Wang S, Zhang Z, Zhang Z. A 3-year prospective clinical study of telescopic crown, bar, and locator attachments for removable four implant-supported maxillary overdentures. Int J Prosthodont 2013; 26(6):566-73.
16. Sabouri, A, Barjini N, Tabatabaian F. Comparison of the effect of ball and bar attachment designs on retention and stability of mandibular implant-supported overdentures. Journal of Dental School, Shahid Beheshti University of Medical Sciences 2017; 35(1):21-25.
17. Ebiary M, Eldid L, Abdelhakim A. Comparative study of bar, positioner and ball attachment in solitary versus splinted implant assisted mandibular overdenture (in vitro study). Alexandria Dental Journal 2021; 46(3):110-116.
18. ELsyad MA, Soliman TA, Khalifa AK. Retention and Stability of Rigid Telescopic and Milled Bar Attachments for Implant-Supported Maxillary Overdentures: An In Vitro Study. Int J Oral Maxillofac Implants 2018; 33(5):e127–e133.
19. Heckman SM, Winter W, Meyer M, Weber HP, Wichmann MG. Overdenture attachment selection and the loading of implant and denture-bearing area. Part 2: A methodical study using five types of attachment. Clin Oral Implants Res 2001; 12(6):640-7.
20. Afrashtehfar KI, Afrashtehfar CD. Lack of association between overload and peri-implant tissue loss in healthy conditions. Evid Based Dent 2016; 17(3):92-93.
21. Alqutaibi AY, Kaddah AF. Attachments used with implant supported overdenture. International Dental & Medical Journal of Advanced Research. 2016; 1(2):1-5.
22. Di Francesco F, De Marco G, Gironi Carnevale UA, Lanza M, Lanza A. The number of implants required to support a maxillary overdenture: a systematic review and meta-analysis. J Prosthodont Res 2019; 63(1):15-24.
23. Zanotti G, Gelpi F, Sinigaglia S, et al. Agenesis: pilot case report by 2.9 mm implant. J Biol Regul Homeost Agents 2019; 33(Suppl 1):61-65.
24. Pjetursson BE, Lang NP. Prosthetic treatment planning on the basis of scientific evidence. J Oral Rehabil 2008; 35 Suppl 1:72-9.
25. Chipidza FE, Wallwork RS, Stern TA. Impact of the Doctor-Patient Relationship. Prim Care Companion CNS Disord 2015; 17(5):10.
26. Zanotti G, Luciano U, Montagna P, et al. Mini-invasive rehabilitation with removable total prosthesis with mixed conometric connection on 1.4-1.5-2.2 (2.9 mm) implant abutments and 1.6-2.3-2.4 dental abutments: a two-year follow-up. J Biol Regul Homeost Agents 2021; 35(Suppl1):23-32.
27. De Bruyn H, Raes S, Matthys C, Cosyn J. The current use of patient-centered reported outcomes in implant dentistry: a systematic review. Clin Oral Implants Res 2015; 26(Suppl) 11:45-56.
28. Trbakovic A, Toljanic JA, Kumar VV, Thor A. Eight to eleven-year follow-up of immediately loaded implants placed in edentulous maxillae with compromised bone volume and poor bone quality: a prospective cohort study. Clin Implant Dent Relat Res 2020; 22(1):69-76.

29. Mirchandani B, Zhou T, Heboyan A, Yodmongkol S, Buranawat B. Biomechanical Aspects of Various Attachments for Implant Overdentures: A Review. Polymers (Basel) 2021; 13(19):3248.
30. Hatakeyama W, Takafuji K, Kihara H, et al. A review of the recent literature on maxillary overdenture with dental implants. J Oral Sci 2021; 63(4):301-305.
31. Selim K, Ali S, Reda A. Implant Supported Fixed Restorations versus Implant Supported Removable Overdentures: A Systematic Review. Open Access Maced J Med Sci 2016; 4(4):726-732.
32. Serino G, Ström C. Peri-implantitis in partially edentulous patients: association with inadequate plaque control. Clin Oral Implants Res 2009; 20(2):169-74.
33. Krennmair G, Seemann R, Weinländer M, Piehslinger E. Comparison of ball and telescopic crown attachments in implant-retained mandibular overdentures: a 5-year prospective study. Int J Oral Maxillofac Implants 2011; 26(3):598-606.
34. Kern JS, Kern T, Wolfart S, Heussen N. A systematic review and meta-analysis of removable and fixed implant-supported prostheses in edentulous jaws: post-loading implant loss. Clin Oral Implants Res 2016; 27(2):174-95.
35. Heitz-Mayfield LJA, Heitz F, Lang NP. Implant Disease Risk Assessment IDRA-a tool for preventing peri-implant disease. Clin Oral Implants Res 2020; 31(4):397-403.
36. Cercadillo-Ibarguren I, Sánchez-Torres A, Figueiredo R, Schwarz F, Gay-Escoda C, Valmaseda-Castellon E. Immediately loaded implant-supported full-arches: Peri-implant status after 1-9 years in a private practice. J Dent 2017; 67:72-76.
37. Krennmair G, Sütö D, Seemann R, Piehslinger E. Removable four implant-supported mandibular overdentures rigidly retained with telescopic crowns or milled bars: a 3-year prospective study. Clin Oral Implants Res 2012; 23(4):481-8.
38. Elsyad M, Denewar BA, Elsaih EA. Clinical and Radiographic Evaluation of Bar, Telescopic, and Locator Attachments for Implant-Stabilized Overdentures in Patients with Mandibular Atrophied Ridges: A Randomized Controlled Clinical Trial. Int J Oral Maxillofac Implants 2018; 33(5):1103-1111.

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Review

The paranasal sinus localization of cholesteatoma: a systematic review

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DISCLOSURE: **ALL AUTHORS REPORT NO CONFLICTS OF INTEREST RELEVANT TO THIS ARTICLE.**

ABSTRACT

Paranasal sinus cholesteatoma is a rare occurrence for which only a few cases have been reported in the literature, particularly in the frontal and maxillary sinuses. The clinical features are non-specific, and thus a broad differential diagnosis should be considered. In most cases, diagnostic imaging is carried out through CT and/or MRI scans, and the treatment goal is complete eradication regardless of the approach. In our review, we followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines and Egger et al.'s approach for Systematic Reviews in Health Care. The papers included were in English or Italian, with an available and congruous full text. Out of the 140 selected articles, we included only 22 papers, ranging from 1958 to 2020 and accounting for 24 patients. Eleven had cholesteatoma in the frontal, 9 in the maxillary sinus, and 4 in other sites. Most patients underwent CT scans or combined CT and MRI, and an open approach was the most selected procedure. Only 2 patients showed postoperative complications, and 5 patients had a recurrence over an average follow-up period of 25 months. In this first systematic review on this subject, we provide an overview of the diagnostic procedures, the proper surgical approach and the postoperative follow-up found in the literature without precise and shared guidelines.

INTRODUCTION

While cholesteatoma involving the middle ear and the mastoid is well described in the literature, the paranasal sinuses are very rare. Therefore, only a few cases are described in the literature, and there are no standard guidelines for properly managing this condition.

Cholesteatoma is a benign lesion formed by keratin layers within a hyperkeratinized squamous epithelium that can progressively and independently grow to involve the underlying bone and tends to recur (1). This progressive growth leads to the erosion of the surrounding structures and requires surgical removal (2). Only a few cases reported of paranasal sinus cholesteatoma can be found in the literature. Of these few cases, the most common locations are the frontal and the maxillary sinus, followed by the sphenoidal and the ethmoidal sinus (3).

Although the pathogenesis of cholesteatoma in the paranasal sinuses is not completely clear, several hypotheses can explain it, among them congenital epithelial remnants, the implantation theory, the immigration theory, and the metaplasia theory (4, 5). In addition, some Authors claim that previous surgery and long-term recurrent sinusitis may play an essential role in forming paranasal sinus cholesteatoma (6).

The most used imaging tool to diagnose a cholesteatoma of the maxillary sinus is computed tomography (CT). Magnetic resonance imaging (MRI) can differentiate it from a malignant tumor. Normally CT shows an expansive lesion with bony erosion/destruction and sinus opacification. However, due to the limited number of CT findings reported in the literature and their extreme variability, they cannot be considered specific for cholesteatoma. Although MRI is helpful for diagnosis and decision-making because of its excellent soft tissue projection, there are fewer case reports than the ones in which CT was used. Cholesteatoma on MRI is usually seen as a low-intensity lesion on T1 and high-intensity T2 sequences (7, 8).

The differential diagnosis should include various diseases affecting the paranasal sinuses, such as non-neoplastic lesions, like mucocele, mucosal retention cyst, pseudocyst and pyocele, benign neoplastic lesions, and malignant neoplastic lesions (3, 9).

The clinical features of cholesteatoma include nasal obstruction, cheek pain, painless cheek swelling, a sensation of maxillary expansion, rhinorrhea, recurrent sinusitis, postnasal drip, intraoral swelling, and generalized headache, and even visual disturbances are non-specific, also occurring in other conditions (10, 11).

The final diagnosis of cholesteatoma can be confirmed through a histopathological examination characterized by stratified, keratinizing squamous epithelium with immunoreactivity for cytokeratin (12).

The state of the art of treatment for the cholesteatoma that is located in the middle ear and mastoid is the surgery to remove it all to avoid recurrence; for the paranasal sinus localization of cholesteatoma there are no current guidelines for treatment, but the general opinion is that it should be removed entirely to prevent further erosion of the surrounding structures and recurrence (13). The literature describes both open and endoscopic techniques for paranasal sinus cholesteatoma (14). In the past, open approaches were more common, especially the Caldwell-Luc one, but progress in endoscopic surgery may lead it to become the chosen technique in the future (5, 15). However, some authors believe that endoscopic surgery is inadequate for completely removing cholesteatoma in the paranasal sinus (6). Therefore, regardless of the technique, the main goal of the treatment is eradicating the disease and preventing recurrence.

Research method

This review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (16) and Egger et al.'s approach for Systematic Reviews in Health Care (17) (Table I).

The research was carried out using PubMed, Google Scholar, and Cochrane Library databases. The keywords were "paranasal sinus, cholesteatoma". We included all the articles we found using the abovementioned keywords without any time restriction. Our previous research was conducted in November 2021.

The inclusion criteria of the research were articles in English or Italian whose full text was available. We excluded papers without the stated criteria or having an incongruous topic.

Our group consisted of 7 otolaryngologists, 5 of whom are residents, with a common purpose. Each group member took part in formulating the review's question, which was the second step. Once we chose the review topic, which involved the investigation and description of rare paranasal sinus cholesteatoma, the third step was performed. First, each group member researched articles on PubMed, PMC, and Scopus using the study's keywords and inclusion criteria. Then they took part in abstract reading, and finally, two of them (RN and NB) carried out the full-text reading. In the last phase, we analyzed the data collected from the literature.

Table I. *Egger's approach for systematic reviews.*

STEP	GENERAL ACTIVITIES	SPECIFIC ACTIVITIES
I	Formation of a working group	Formation of a seven-member working group of Otorhinolaryngology, each member acting as a methodological reviewer
II	Formulation of the review question	Evaluation and analysis of literature about paranasal sinus cholesteatoma
III	Identification of relevant studies on PubMed, PMC, and Scopus	1. Identification of keywords: "paranasal sinus, cholesteatoma" 2. Inclusion criteria language English or Italian; full-text articles. Exclusion criteria: no full text available; other languages (neither English nor Italian); incongruous articles 3. Abstract reading 4. Full-text reading
IV	Analysis and presentation	Analysis of data from all included studies

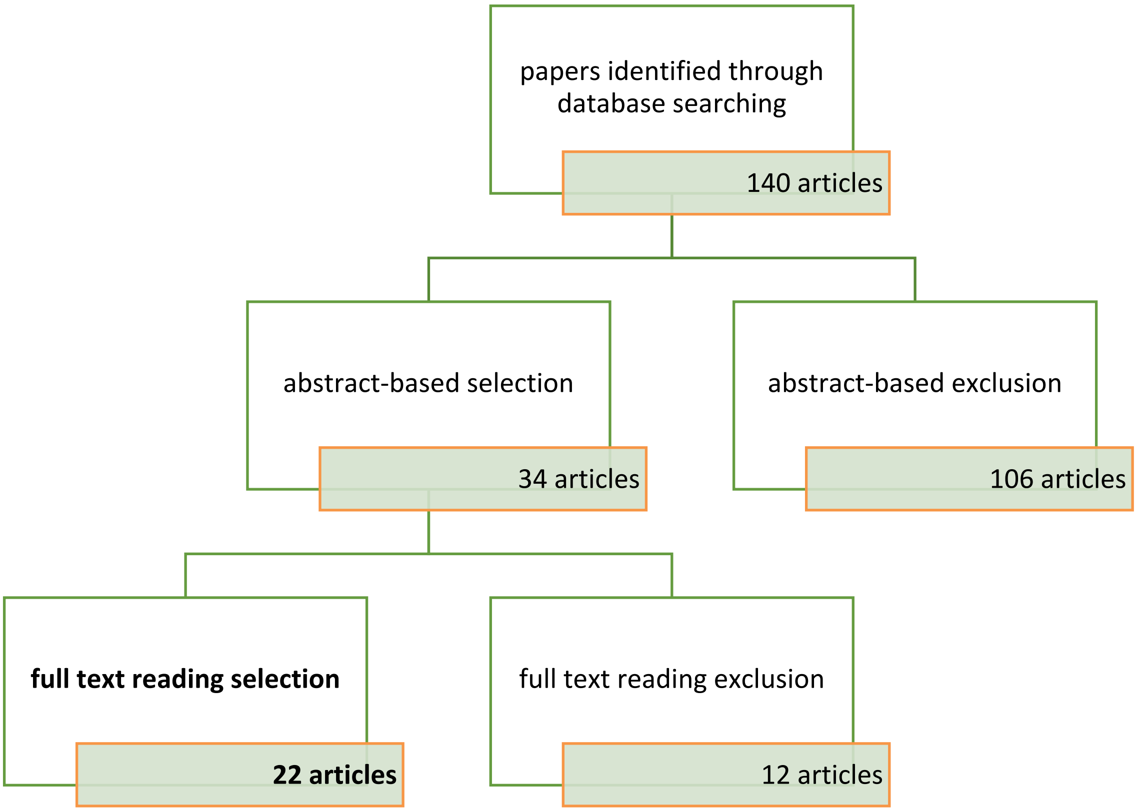

Fig. 1. *Paper selection process.*

RESULTS

One hundred forty articles were selected at the end of the research. Then the results were filtered, choosing articles in keeping with the inclusion criteria. First, we skimmed the articles based on the abstract reading procedure; eventually, 34 papers were left. After this, we excluded further articles reading the full-length text, with 22 remaining. In this phase, incongruous articles or studies with insufficient data were excluded. Finally, we analyzed all 22 articles, extracting data about authors, study design and year of publication, age and gender of the patients, localization, imaging and histologic reports of the paranasal sinus cholesteatoma, type of treatment and treatment results, complications and related treatment, eventual recurrence, and related treatment and follow up. The literature selection process following the PRISMA statement guidelines is reported in Figure 1, and the results are summarized in Table II.

Table II. *Results.*

Authors	Study design	Year	Gender	Age	Imaging	Localization	Treatment	Results	Histology	Complications	Recurrence	Follow up
Min HJ, Shin JH, Kim KS [6]	Case report + literature review	2016	F	34	CT	Left maxillary sinus	Open: Caldwell-Luc	Complete eradication	Cholesteatoma and keratinous debris	No	No	12 m
Tejani N, Kshirsagar R, Song B, Liang J [18]	Case report	2020	M	45	CT and MRI	Right frontal sinus	Endoscopic	Subtotal eradication	Cholesteatoma and keratinous debris	No	Residual disease	30 m
Kurien R, Thomas L, Varghese L, Nair BR [19]	Case report	2019	F	27	CT and MRI	Frontal sinus	Endoscopic	Complete eradication	Cholesteatoma	No	No	6 m
Sozansky J, Josephson JS [15]	Case report + literature review	2015	M	72	CT	Right maxillary sinus	Endoscopic	Complete eradication	Cholesteatoma and Keratinous debris	No	No	156 m
Hammami B, Mnejja M, Chakroun A, Achour I, Chakroun A, Charfeddine I, Ghorbel A [20]	Case report	2010	M	25	CT and MRI	Frontal sinus	Endoscopic and open	Complete eradication	Cholesteatoma	No	No	12 m
Kanjanawasee D, Chaowanapanja P, Keelawat S, Snidvongs K [21]	Case report + literature review	2019	F	82	CT	Left sphenoidal sinus	Endoscopic	Complete eradication	Cholesteatoma and Keratinous debris	YES open surgery	-	Patient died due to complications of ASB defect
Zoia C, Pusateri A, Carena P, Matti E, Galioto S, Benazzo M, Gaetani P, Pagella F [14]	Case report	2015	M	32	CT	Frontal sinus	Endoscopic	Complete eradication	Cholesteatoma	YES open surgery	YES frontal sinus, endoscopic 2nd look	18 m
Storper IS, Newman AN [9]	Case report	1992	M	12	CT	Left maxillary sinus	Open: Caldwell-Luc	Complete eradication	Cholesteatoma and keratinous debris	No	No	8 m
Hansen S, Sørensen CS, Stage J, Mouritzen A, Caye ́-Thomasen P [10]	Case report + literature review	2007	F	80	CT and MRI	Frontal sinus	Open	Complete eradication	Cholesteatoma and keratinous debris	No	No	6 m
Cingi E, Cingi C [22]	Case report	1991	F	16	CT	Ethmoidal sinus	Open	Complete eradication	Cholesteatoma	No	No	26 m
Cukurova I, Demirhan E, Arslan IB, Cumurcu S [23]	Case report	2010	M	81	CT	Concha bullosa	Endoscopic	Complete eradication	Cholesteatoma and keratinous debris	No	No	14 m
Sadoff RS, Puskin A [24]	Case report	1989	F	55	RX	Left maxillary sinus	Open	Complete eradication	Cholesteatoma and keratinous debris	No	No	8 m
Viswanatha B [25]	Case report	2011	M	10	CT	Maxillary and ethmoidal sinus	Endoscopic	Complete eradication	Cholesteatoma	No	No	6 m
Barnett FC, Barnett, JC Jr. [26]	Case report	1992	M	76	CT and MRI	Frontal and ethmoidal sinus	Open	Complete eradication	Keratinous debris with a small amount of stratified squamous epithelium	Nonea	-	-
Cole TB, McCoy G [27]	Case report	1967	M	18	RX	Sphenoidal sinus	Open	Partial eradication	-	No	Residual disease	24 m
Campanella RS, Caldarelli DD, Friedberg SA [11]	Case report	1979	M (3)	53	RX	Frontal sinus	Open	Complete eradication	Cholesteatoma	No	No	-
Holt GR, Holt JE, Davis WE [28]	Case report	1977	F	54	RX	Left frontal sinus	Open	Complete eradication	Cholesteatoma	No	YES frontal sinus, open surgery	24 m
Paaske PB [2]	Case report	1984	M	76	CT	Left maxillary sinus	Open: Caldwell-Luc	Partial eradication	Cholesteatoma	No	Residual disease	-
Mills CP, Sycamore EM [29]	Case report	1958	F	65	RX	Left maxillary sinus	Open	-	-	No	-	-

Pogorel BS, Budd EG [30]	Case report	1965	M	36	RX	Left maxillary sinus	Open: Caldwell-Luc	Complete eradication	Cholesteatoma	No	-	-
Baxter JSR [31]	Case report	1966	M	20	RX	Left maxillary sinus	Open: Caldwell-Luc	Complete eradication	Cholesteatoma	No	No	3 m
Kirchner FS, Toledo PS, Robinson JT [32]	Case report	1967	F	29	RX	Left frontal sinus	Open	Complete eradication	Cholesteatoma	No	No	48 m

All articles are case reports; four contain a literature review (Min HJ. et al. 14 works; Sozansky J. et al. 6 works; Kanjanawasee D. et al. 17 works; Hansen S. et al. 22 works). The oldest article was published in 1958 (Mills CP et al.), and the newest one in 2020 (Tejani N et al.).

The total number of patients described in the articles is 24; 15 (62.5%) patients are male, and 9 (37.5%) are female. The average age of the patients is 45,4 years (range 10-82 years).

All patients had pre-surgery imaging: 9 (37.5%) had only CT, 5 (20.8%) had both CT and MRI, and 10 (41.7%) of them had only X-Ray scans.

Nine (37.5%) patients showed cholesteatoma in the maxillary sinus (one of them had cholesteatoma in both the maxillary and the ethmoidal sinus); 11 (45.8%) patients had cholesteatoma in the frontal sinus (one of them had it in both the frontal and the ethmoidal sinus); 2 (8.3%) patients had the sphenoidal sinus involved. Finally, 1 (4.2%) patient had cholesteatoma in the ethmoidal sinus and 1 (4.2%) in the chonca bullosa.

The treatment approach was open surgery for 16 (66.7%) patients, endoscopic surgery for 7 patients (29.1%), and combined surgery for 1 (4.2%) patient. As a result, complete eradication of cholesteatoma was achieved for most patients (20; 83.3%) after surgery. Only in 3 (12.5%) cases was disease eradication incomplete.

For all patients, histology was diagnostic for “cholesteatoma” or “cholesteatoma and keratinous debris”. Nevertheless, for 2 (8.3%) patients, histological results were not available.

Only 2 patients, with sphenoidal and frontal sinus involvement, had complications after surgery, which were solved through the conversion from an endoscopic to an open approach.

Five (20.8%) patients had a recurrence of the disease, 4 (16.7%) showed no data about the recurrence, and the rest of the patients had no recurrence (15 patients; 62.5%).

Finally, the average follow-up was 25,1 months (ranging from 3 to 156 months) for 16 patients. 7 (29.2%) patients had no follow-up record, and one died during follow-up because of the disease.

DISCUSSION

The main goal for the surgery of paranasal sinus cholesteatoma, just like the one of the middle ear and the mastoid, is its complete eradication to avoid the risk of recurrence but while literature about the middle ear lesion is abundant, the one about paranasal sinus cholesteatoma is much less investigated.

We aim to clarify a field that in the last 60 years has not been systematically explored and to highlight the correct management of the patients with this uncommon pathology, starting from the proper diagnostic imaging to the postoperative follow-up in the first ever systematic review. However, we know the difficulty in comparing a small group of papers published over a considerable period.

First, our review demonstrates that imaging work has a crucial role. There has been a significant development through time in this field, as nowadays it is impossible to consider an X-Ray scan the only diagnostic means for proper radiological workup, as we found in 8 papers written between 1958 and 1989. More recent papers have availed themselves of CT imaging which, combined with MRI, is now considered the diagnostic gold standard (18-20).

A significant change has also occurred in the surgical approach. Whereas the first articles only showed the availability and use of an open approach as described by Baxter JSR with the Caldwell-Luc technique for the maxillary sinus (31-33), as time went by, the endoscopic surgery gained momentum, only to become the first treatment option in most instances, to date. However, it should be considered that for some localizations, such as the frontal sinus, an open coronal or bicoronal approach should be used with endoscopic technique or during second-look surgery in case of recurrences. For maxillary involvement, the endoscopic approach lets the surgeon control the whole sinus through angled optics.

Our systematic review also reveals a low incidence of complications; only 2 papers (9.1%) described complications treated through second-look surgery. The first paper described an endoscopically treated lesion of the left sphenoid sinus; two months after surgery, the patient developed an extensive skull base osteomyelitis which needed a debridement of the infected bone through an endoscopic revision approach and a subtemporal and suboccipital craniotomy. Unluckily the patient died after a short while (21). The second paper regarded an endoscopically treated cholesteatoma of the frontal sinus, which was initially only partially removed. The early post-surgery complication was a brain abscess of the left frontal lobe, successfully resolved through a frontal osteoplastic flap and the aspiration of the abscess to completely eradicate the cholesteatoma itself (14).

Only one lesion involving the frontal sinus yielded a recurrence thanks to the endoscopic approach. In such cases, both a second look endoscopic and an open approach could be carried out (34-36). Moreover, 5 papers (22.7%) included in our review did not provide a long-term follow-up, which is a major issue in the management of this disease given its risk of recurrence, as it is well known from the handling of middle ear cholesteatoma. Moreover, only 5 patients (20,8%) had a recurrence of the disease, a similar rate to the one described by Møller for the middle ear localization (37).

The main limitation of the present study concerns the nature of the literature under observation, as most of the papers included were case reports, and not all the data was always complete.

CONCLUSIONS

Paranasal sinus cholesteatoma is a rare pathology, and literature shows an absence of precise and shared guidelines concerning the diagnosis, the proper surgical approach, and the postoperative follow-up. However, we might suggest that combining CT and MRI is the gold standard for imaging workup before surgery.

Focusing on treatment, the endoscopic approach is the first choice, while the open approach could be considered a second choice or can be used in case of recurrence. As far as the postoperative follow-up is concerned, from our research, it appears necessary to manage the patients through nasal endoscopic examinations and CT scans (10, 15).

Second-look surgery is not required for this type of disease, unlike middle ear and mastoid cholesteatoma, which is needed in almost all cases. No consensus has been reached about the average follow-up time for paranasal sinus cholesteatoma, as it is for the middle ear, one that some suggest should be lifelong (38).

A shared protocol is still necessary to avoid a misdiagnosis and allow for a correct evaluation and treatment of the examined pathology.

REFERENCES

1. Abramson M, Gross J. Further studies on a collagenase in middle ear cholesteatoma. Ann Otol Rhinol Laryngol 1971; 80:177–85.
2. Paaske PB. Cholesteatoma of the maxillary sinus. J Laryngol Otol 1984; 98:539–541.
3. Viswanatha B, Nayah L, Karthik S. Cholesteatoma of the maxillary sinus. Ear Nose Throat 2007; 86:351–353.
4. Palacios E, Robertson H. Cholesteatoma of the maxillary sinus. Ear Nose Throat J 2005; 84:758.
5. Lee JM, Ryu NG, Choi IS. A case of maxillary sinus cholesteatoma originating from the retromaxillary sinus wall. Int J Otolaryngol Head Neck Surg 2015; 4:325–328.
6. Min HJ, Shin JH, Kim KS. Cholesteatoma of Maxillary Sinus: What Is the Best Surgical Approach? J Craniofac Surg 2016; 27(4):963-6.
7. Glasscock ME III, Shambaugh GE Jr. Pathology and clinical course of inflammatory diseases of the middle ear. In: Glasscock ME III, Shambaugh GE Jr, eds. Surgery of the Ear. 4th ed. Philadelphia, PA:WB Saunders; 1991:167–193.
8. Presutti L, Gioacchini FM, Alicandri-Ciufelli M, Villari D, Marchioni D. Results of endoscopic middle ear surgery for cholesteatoma treatment: a systematic review. Acta Otorhinolaryngol Ital 2014; 34(3):153-7.
9. Storper IS, Newman AN. Cholesteatoma of the maxillary sinus. Arch Otolaryngol Head Neck Surg 1992; 118:975–977.
10. Hansen S, Sørensen CS, Stage J, Mouritzen A, Caye-Thomasen P. Massive cholesteatoma of the frontal sinus: case report and review of the literature. Auris Nasus Larynx 2007; 34:387–92.
11. Campanella RS, Caldarelli DD, Friedberg SA. Cholesteatoma of the frontal and ethmoid areas. Ann Otol Rhinol Laryngol 1979; 88:518–23.
12. Buric N, Jovanovic G, Tijanic M. Usefulness of cone-beam CT for presurgical assessment of keratoma (cholesteatoma) of the maxillary sinus. Head Neck 2013; 35:E221–E225.
13. Hartman JM, Stankiewicz JA, Maywood II. Cholesteatoma of the paranasal sinuses: case report and review of the literature. Ear Nose Throat J 1991; 70:719–725.
14. Zoia C, Pusateri A, Carena P, et al. Frontal sinus cholesteatoma with intracranial complication. ANZ J Surg 2018; 88:110–2.
15. Sozansky J, Josephson JS. Cholesteatoma of the maxillary sinus: a case report and review of the literature. Am J Otolaryngol 2015; 36: 290–291.
16. Moher D, Shamseer L, Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst Rev 2015; 4(1):1.
17. Egger M, Smith GD, Altman DG. Systematic Reviews in Health Care: Meta-Analysis in Context; BMJ Publishing Group: London, UK, 2001.
18. Tejani N, Kshirsagar R, Song B, Liang J. Evolving Treatment of Frontal Sinus Cholesteatoma: A Case Report. Perm J 2020; 24:19.048.
19. Kurien R, Thomas L, Varghese L, Nair BR. Frontal sinus cholesteatoma: a masquerading diagnosis. BMJ Case Rep 2019; 12(11):e231495.
20. Hammami B, Mnejja M, Chakroun A, Achour I, Chakroun A, Charfeddine I, Ghorbel A. Cholesteatoma of the frontal sinus. Eur Ann Otorhinolaryngol Head Neck Dis 2010; 127(6):213-6.
21. Kanjanawasee D, Chaowanapanja P, Keelawat S, Snidvongs K. Sphenoid Sinus Cholesteatoma-Complications and Skull Base Osteomyelitis: Case Report and Review of Literature. Clin Med Insights Case Rep 2019; 12:1179547619835182.
22. Cingi E, Cingi C. Ethmoidal cholesteatoma. Ann Otol Rhinol Laryngol 1991; 100(5 Pt 1):424-6.
23. Cukurova I, Demirhan E, Arslan IB, Cumurcu S. Cholesteatoma of the concha bullosa: a case report. J Med Case Rep 2010; 4:407.
24. Sadoff RS, Puskin A. Cholesteatoma (keratoma) of the maxillary sinus: report of a case. J Oral Maxillofac Surg 1989; 47(8):873-6.

25. Viswanatha B. Cholesteatoma of the nose and maxillary and ethmoid sinuses: a rare complication of palatal surgery. Ear Nose Throat J 2011; 90(9):428-30.
26. Barnett FC, Barnett, JC Jr. Massive Bifrontal Epidermoid Tumor. Surg Neurol 1992; 38(6):437-40.
27. Cole TB, McCoy G. Congenital cholesteatoma of temporal bone and sphenoid sinus. report of a case. Arch Otolaryngol 1968; 87(6):576-9.
28. Holt GR, Holt JE, Davis WE. Late recurrence of a frontal sinus cholesteatoma. Ann Otol Rhinol Laryngol 1977; 86(6 Pt 1):852-5.
29. Mills CP, Sycamore EM. Cholesteatoma of the maxillary antrum. J Laryngol Otol 1958; 72(7):580-3.
30. Pogorel BS, Budd EG. Cholesteatoma of the maxillary sinus; a case report. Arch Otolaryngol 1965; 82(5):532-4.
31. Baxter JSR. Cholesteatoma of the maxillary antrum. J Laryngol Otol 1966; 80(10):1059-61.
32. Nocini R, Panozzo G, Trotolo A, Sacchetto L. Maxillary Sinusitis as a Complication of Zygomatic Implants Placement: A Narrative Review. Appl Sci 2022; 12:789.
33. D'Agostino A, Favero V, Nocini R, Venco J, Nocini PF, Trevisiol L. Does Middle Meatal Antrostomy Prevent the Onset of Maxillary Sinusitis After Zygomatic Implant Placement? J Oral Maxillofac Surg 2019; 77(12):2475-2482.
34. Kirchner FS, Toledo PS, Robinson JT. Modified osteoplastic approach to the frontal bone, sinuses, and-or the orbit. Trans Am Acad Ophthalmol Otolaryngol 1967; 71(6):951-5.
35. Girolami I, Pantanowitz L, Munari E, et al. Prevalence of PD-L1 expression in head and neck squamous precancerous lesions: a systematic review and meta-analysis. Head Neck 2020; 42(10):3018-3030.
36. Zhurakivska K, Maiorano E, Nocini R, et al. Necrotizing sialometaplasia can hide the presence of salivary gland tumors: A case series. Oral Dis 2019; 25(4):1084-1090.
37. Møller PR, Pedersen CN, Grosfjeld LR, Faber CE, Djurhuus BD. Recurrence of Cholesteatoma - A Retrospective Study Including 1,006 Patients for More than 33 Years. Int Arch Otorhinolaryngol 2020; 24(1):e18-e23.
38. Kuo CL, Shiao AS, Liao WH, Ho CY, Lien CF. How long is long enough to follow up children after cholesteatoma surgery? A 29-year study. Laryngoscope 2012; 122(11):2568-73.

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Comparative Study

Use of Cone Beam Computed Tomography for identification and evaluation of Medication-Related Osteonecrosis of the Jaws: a dosimetric and multimodal imaging comparison

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ABSTRACT

The aim of this study was to compare Orthopantomograms (OPT) and Computed Tomography (CT) with Cone Beam Computed Tomography (CBCT) in patients with Medication-Related OsteoNecrosis of the Jaws (MRONJ). The study included 25 patients (6 males and 19 females) with MRONJ who had a history of long-term bisphosphonate therapy or one of the recently re-entered MRONJ drugs and underwent OPT, CT and/or CBCT for determination of the extent of disease. We excluded patients with maxillary neoplasia. Considering the presence of early and late signs, OPT was diagnostic in 6 out of 17 cases (35%), while CT and CBCT were diagnostic in 25 out of 25 cases (100%). Analysing the different radiant doses delivered by the selected radiological methods on a phantom, it was found that a more significant effective dose was spread by CT (2.6 mSv) than CBCT (0.164 mSv) or OPT (0.02 mSv). CBCT, from our experience, is a candidate to replace OPT in the first diagnostic step in patients with suspected MRONJ, generating less effective doses and artefacts from metal components than CT.

INTRODUCTION

Medication-Related Osteonecrosis of the Jaws (MRONJ) is defined by the consensus of the American Association of Oral and Maxillofacial Surgeons (AAOMS) as exposed bone or bone that is palpable by probing an intra- or extra-oral fistula, which is persistent for more than 8 weeks in the maxillofacial region (1). This definition has been replacing the previous acronyms “BRONJ” (2-4) in order to emphasise the aetiology of this pathological condition that is ascribed not only to the administration of bisphosphonates but can also be induced by the intake of other drugs (4-6) like monoclonal antibody with anti-resorptive activity (Denosumab), anti-angiogenic drugs or anti-VEGF (Bevacizumab and Aflibercept), tyrosine-kinase inhibitor drugs (TKIs) (Sunitinib, Sorafenib and Cabozantinib), mammalian target of rapamycin (mTOR) inhibitor drugs (Everolimus and Temsirolimus).

The inclusion criteria for MRONJ are: previous or current therapy with bisphosphonates or other drugs falling into the MRONJ category and clinical and radiological diagnosis of progressive bone destruction and necrosis; the exclusion criteria are previous or current radiotherapy of the head and neck area.

Bisphosphonates are used to reduce pain, improve quality of life, and reduce bone complications such as fractures in patients with metastatic lytic lesions, malignant disease-related hypercalcemia, severe osteoporosis, multiple myeloma, Paget’s disease, and symptomatic fibrous dysplasia (4-6).

According to the literature, the incidence and prevalence of MRONJ are relatively low. Still, they can change with different types of patients (cancer patients or osteoporosis patients) and anti-resorptive drugs (sequential or single therapy) (2, 3).

The most common events associated with the disease are dental extraction, implantology, mandibular exostosis, periodontal pathology, and trauma (4, 5).

Before the advent of Cone Beam Computed Tomography (CBCT), the main radiological technique available for studying facial bones was multislice Computed Tomography (CT). Its well-established advantages are high sensitivity and specificity even on soft tissues with or without contrast medium, but it exposes the patient to a considerable quantity of ionising radiation (7, 8). Although the Orthopantomogram (OPT) is demonstrated to be exhaustive and complete in numerous circumstances, and it is considered the first step in the study of MRONJ, it often proves to be insufficient in the study of faces with complex conditions (9). Second-level methods like CT can, in most cases, detect early signs of a disease that are too small and nuanced to be identified by the first-level methods (9-12).

The aim of the study was to compare CBCT with CT and OPT and to suggest CBCT as an alternative in the case of MRONJ, even as a first-level examination; this is because CBCT can diagnose earlier than OPT, and it provides much more detailed information on the relationship between the lesion and the surrounding structures and on the presence of any complications. Moreover, it exposes the patient to a lower number of ionising radiations than CT, as already demonstrated in previous studies (13, 14). Only in evaluating the soft tissues adjacent to the lesion CBCT proves to be lacking, making it necessary to perform either a conventional CT or a Magnetic Resonance (MR) scan before and after administering the contrast medium.

MATERIALS AND METHODS

This study assesses all patients referred to the Department of Radiology G.B. Rossi Hospital between 2006 and December 2020 who were affected by MRONJ and presenting a long-term bisphosphonate therapy or one of the recently re-entered MRONJ drugs. We examined 25 patients (6 males and 19 females) from 48 to 92 years, excluding patients with maxillary neoplasia.

AAOMS inclusion criteria were applied (1): 1. Current or previous BP treatment; 2. Exposed necrotic bone in the maxillofacial region for more than 8 weeks; 3. No radiotherapy to the jaws.

Patients were affected respectively by breast cancer (8 pts), severe osteoporosis (6 pts), renal cancer (3 pts), rheumatoid arthritis (2 pts), multiple myeloma (2 pts), breast cancer associated with osteoporosis (2 pts), prostate cancer (1 pt) and severe osteoporosis associated with rheumatoid arthritis (1 pt). Among the population considered, 13 performed both CT and OPT, 6 only CT, 4 both CBCT, CT and OPT, 1 both CBCT and CT, and 1 only CBCT (Table I).

Table I. *Distribution of patients who underwent different types of radiological exams (CBCT, CT and/or OPT).*

n° patients/exams	CBCT	CT	OPT
13		x	x
6		x	
4	x	x	x
1	x	x	
1	x		

The ability of the radiological tests to make a diagnosis was assessed by considering respectively the 4 early signs (thickness of the alveolar ridge and hard lamina, non-healing post-extraction socket persistence, bone sequestrum, enlargement of the periodontal space) and the 5 late signs (pathological fracture, thickening of the canal of the inferior alveolar nerve, diffuse osteosclerosis, radiopacity of the maxillary sinus, periosteal reaction) that could be present on the OPT and then the 7 early signs (focal medullary osteosclerosis, cortical erosion, trabecular thickening, post-extraction socket persistence, bone sequestrum, periodontal space enlargement, thickening of the alveolar ridge and hard lamina) and the 8 late signs (diffuse osteosclerosis, oro-antral fistula, bucco-nasal fistula, mucocutaneous fistula, sinusitis, inferior alveolar nerve canal thickening, periosteal reaction, extended osteolysis to the maxillary sinus, osteosclerosis of cheekbone and /or hard palate) that could be present on CT or CBCT (9, 15).

The scanners used in the study were a CBCT Vgi (NewTom, Verona, Italy), a multislice Brilliance CT 64 (Philips, Eindhoven, The Netherlands) and an Orthopantomograph ProMax 2D (Planmeca, Helsinki, Finland). CBCT and CT used their respective protocols with FOVs to acquire the maxillo-facial district while the equipment pre-set mode was used in the OPT for acquiring both jaws.

The three devices were also subjected to dosimetric analysis using an adult male tissue-equivalent Rando Anthropomorphic Phantom (Alderson Research Laboratories, Stanford, CN, USA) (Fig. 1).

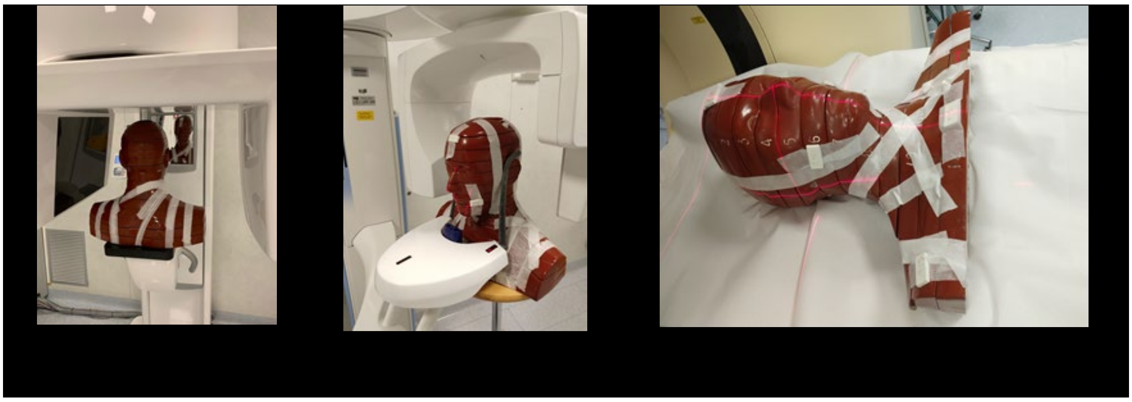

Fig. 1. *From left to right: phamtom under examination at CBCT, OPT and CT.*

Inside the phantom, sixty ThermoLuminescent Dosimeter chips (TLD-GR200A, Harshaw Chemical Co, Solon, USA) were inserted in areas of interest to measure the dose absorbed by specific organs and in other positions to be able to evaluate more generally the distribution of the dose. The examinations were performed using the manufacturer's protocols for the specific area, positioning the phantom similarly to the patient. The TLD readings were used to obtain the air kerma values. Tissue dose was obtained by multiplying the air kerma values by the ratio of air–muscle mass-energy absorption coefficients. The calculation was performed according to the latest International Commission on Radiological Protection (ICRP) guidelines (16). Equivalent doses delivered to different organs (Ht, measured in millisievert (mSv)) were calculated by multiplying the dose obtained with TLDs by the volume fraction of the irradiated organ (Dt, measured in mGy) and by the weight coefficient of ionising radiation (WR): the weight coefficient of radiation is considered equal to 1. The contribution of a single organ/tissue in determining overall patient risk during radiation exposure was obtained by multiplying the equivalent dose (Ht) by the tissue-weight coefficient (WT). The summation of the weighted products of single organs gives the value of effective dose (E, measured in mSv), which is the dose magnitude related to the stochastic, somatic and genetic risk ($E=Ht\times Wt$).

RESULTS

All patients were analysed by verifying the ability of OPT, CT and CBCT to diagnose MRONJ; in 8 cases (32%), the pathology was present only on the upper jaw, in 12 cases (48%) on the mandible alone, in 5 cases (20%) both on the maxilla and mandible.

The presence of early and late signs for OPT, CT, and CBCT was considered. OPT was diagnosed in 6 out of 17 cases (35%), and CT and CBCT were diagnostic in 25 out of 25 cases (100%).

In the 6 cases where OPT was diagnostic, the frequency of early and late signs presence is summarised in Table II.

Table II. *Early and late signs presence and percentage in OPT.*

OPT Early Signs	OPT Late Signs
• thickness of the alveolar ridge and hard lamina 2/6 (33%) • non-healing post-extraction socket persistence (33%) • bone sequestrum 2/6 (33%) • enlargement of the periodontal space 1/6 (16%)	• pathological fracture 0/6 (0%) • thickening of the canal of the inferior alveolar nerve 1/6 (16%) • diffuse osteosclerosis 5/6 (83%) • radiopacity of the maxillary sinus 0/6 (0%) • periosteal reaction 1/6 (16%)

In the 25 cases in which CT and CBCT were diagnostic, the frequency of early and late signs presence is summarised in Table III.

Table III. *Early and Late Signs were found in CBCT and CT.*

Early signs of CBCT and CT	Late signs of CBCT and CT
• focal medullary osteosclerosis 17/25 (68%) • cortical erosion 11/25 (44%) • trabecular thickening 11/25 (44%) • post-extraction socket persistence 9/25(36%) • bone sequestrum 9/25 (36%) • periodontal space enlargement 7/25 (28%) • thickening of the alveolar ridge and hard lamina 4/25 (16%)	• diffuse osteosclerosis 14/25 (56%) • oro-antral fistula, bucco-nasal fistula, mucocutaneous fistula 9/25 (36%) • sinusitis 9/25 (36%) • inferior alveolar nerve canal thickening 8/25 (32%) • periosteal reaction 7/25 (28%) • extended osteolysis to the maxillary sinus 5/25 (20%) • osteosclerosis of cheekbone and/or hard palate 5/25 (20%) • pathological fracture 2/25 (8%)

Our data analysis revealed that CBCT and CT could diagnose and provide comprehensive information on MRONJ in all cases (100%). Only 35% of the total cases were OPT diagnostic. Compared with OPT, it emerges that CBCT provides much more detailed information even in full-blown cases and when the upper jaw is involved (Fig. 2-4). CBCT is the only one capable of making an early diagnosis; however, it provides a higher quantity of ionising radiation to patients. Reconstructions with CBCT also include panoramic-like images similar to OPT, which is particularly useful for a preliminary global evaluation. In comparison with conventional CT, it emerges that the ability of CBCT to diagnose MRONJ is superimposable; the latter, however, thanks to the greater definition of the bone tissues and the lower susceptibility of the artefacts to hardening of the radiant beam, proves to be preferable to obtain even more precise images, it also exposes the patient to a lower quantity of ionising radiation. From the analysis on the phantom, all the equivalent doses delivered to different organs were obtained (Table IV). Finally, it was found that the effective dose in mSv is 0,164 for CBCT, 2,6 for CT and 0,02 for OPT, respectively (Fig. 5).

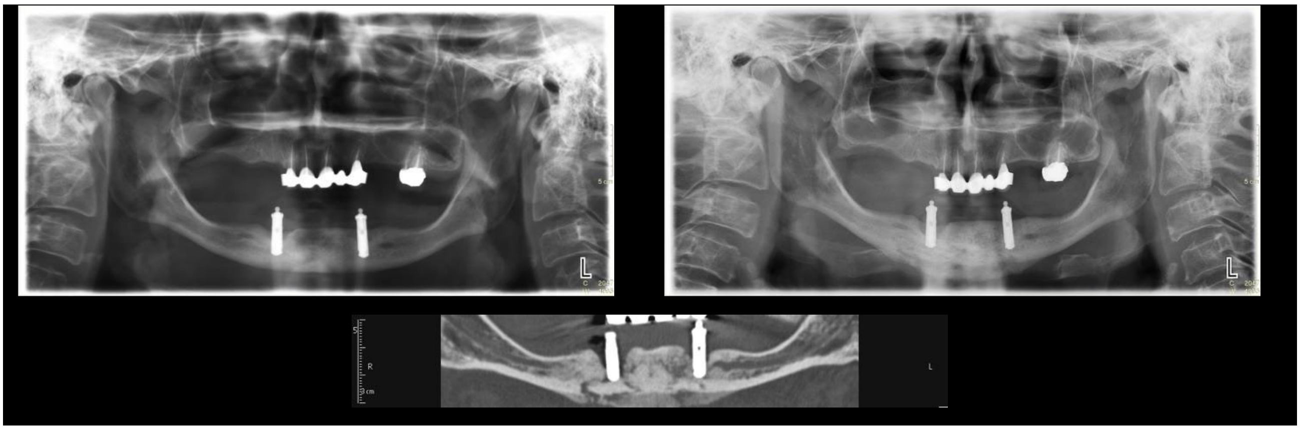

Fig. 2. *From top left clockwise: initial OPT shows no signs of MRONJ, only nonspecific signs of peri-implantitis and a very thin periosteal reaction area at the base of the mandible; OPT at the next check shows a clear picture of MRONJ; CT is the only method capable of providing important details of the lesion such as fistoulous routes.*

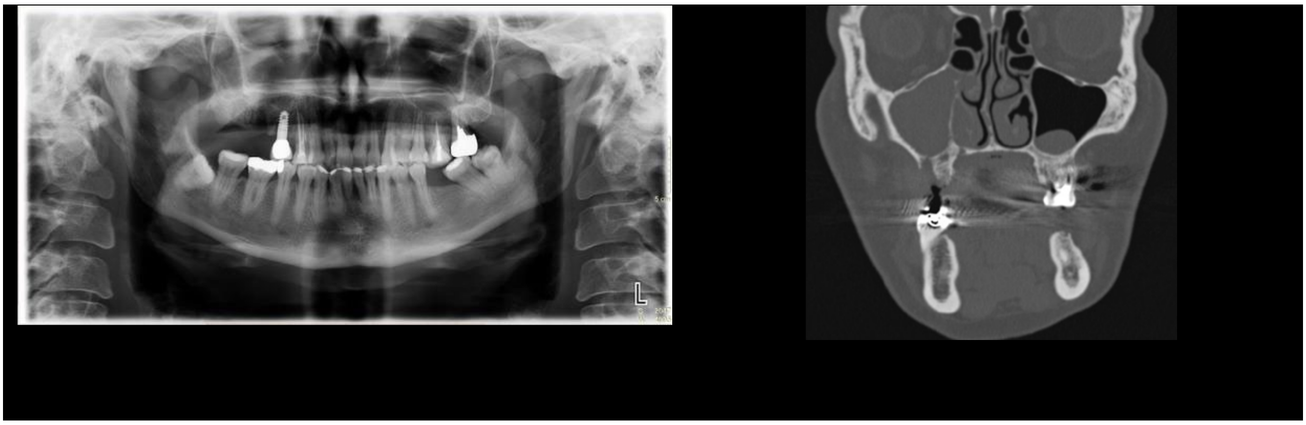

Fig. 3. *Left: OPT performed after an extraction procedure in the upper jaw shows no sign of MRONJ. Right: CT shows a clear imaging of MRONJ as well as the communication with the maxillary sinus fully occupied.*

Fig. 4. *Left: OPT in correspondence of the right mandible highlights only an osteo-thickening area. Right: on CT an area of bone detachment is highlighted.*

Table IV. *Example of dosimetric values of various organs/tissues evaluated on the phantom with an equivalent weighted dose expressed in μSv.*

	OPT	CBCT	CT
Organ/tissue	μSv	μSv	μSv
Bone marrow	4,856828	48,627417	749,648077
Esophagus	0,864072	2,049687	66,066957
Bone surface	0,404735	4,052284	62,470673
Brain	1,556679	22,964369	274,426440
Salivary glands	2,328707	7,341881	297,543381
Lung	0,522564	2,283972	6,491628
Bladder	0,174188	0,761324	2,163876
Bowel	0,522564	2,283972	6,491628
Gonads	0,348376	1,522648	4,327752
Thyroid	2,818524	14,569028	536,47098
Breast	0,522564	2,283972	6,491628
Liver	0,174188	0,761324	2,163876
Stomach	0,522564	2,283972	6,491628
Skin	0,131673	3,244105	41,512678
Remainder	2,131755	40,556470	412,938025

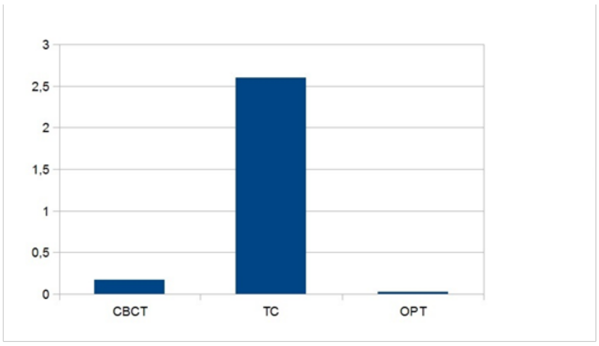

Fig. 5. *Summary graph of the effective dose according to the different radiographic systems.*

DISCUSSION

AAOMS defines the disease presentation and the stages of MRONJ (1), but the literature lacks quantitative studies and standardised imaging protocols to be followed (17).

A common clinical practice is still performing an OPT as a preliminary examination and then a conventional CT later to deepen the case study. In this way, patients are initially exposed to low ionising radiation. However, given the high number of false negatives, in the persistence of symptoms, it will be necessary to investigate further, exploiting another radiological examination with a greater amount of radiation administered. With the advent of new EURATOM guidelines (18), a clear understanding of the amount of radiation dose to which the patient is subjected has gained increasing importance in choosing the correct device an*d personam*. The ALARA principle ("As Low as Reasonably Achievable") is a starting point for physicians and radiologists to solve the diagnostic question. In our study, conventional CT can define the pathology in detail but exposes the patient to a greater quantity of ionising radiation than CBCT with the same diagnostic potential, also considering sometimes the necessity to perform follow-up examinations (8). Therefore, CBCT is found to be an extremely suitable method for defining the picture of osteonecrosis of the jaws, both for its ability to make an early diagnosis and for the definition of the disease (9). The ability to make an early diagnosis is crucial as it allows one to immediately proceed with a therapeutic approach that involves the suspension of the drug, the use of the antibiotic and targeted oral hygiene (4). In the most advanced cases, the therapy involves the surgical approach that can lead to mandibulectomy in the most serious cases. Osteonecrosis of the jaws, as seen from the name of the pathology itself, is a condition that mainly affects bone tissue, and CBCT is even more precise than CT in defining it. Furthermore, the mouth is often the site of non-removable metal components used in dental practice, which are responsible for the creation of artefacts, capable of decreasing the diagnostic capacity of the tissues adjacent to them. This type of artefact is less important in CBCT and OPT exams than in multislice CT.

CONCLUSIONS

In MRONJ advanced cases with clear clinical suspicion, OPT proves to be a sufficient method to diagnose osteonecrosis. However, it provides less information in terms of fine details and extent of the disease compared to CBCT; moreover, it appears to be strongly limited in the early stage of the disease and in those cases in which bone involvement is confined to the upper jaw. CBCT exposes the patient to a higher amount of ionising radiation than OPT but provides much more information about the size and stage of the disease.

OPT is still considered the first-level test in assessing oral status in asymptomatic patient candidates for medical therapy with bisphosphonates or other drugs at risk of MRONJ. Conversely, the use of OPT as a first-level exam in the early diagnosis of MRONJ in symptomatic or paucisymptomatic patients is deficient and can be burdened by false negative cases, resulting in a delay and greater invasiveness of the treatment. CBCT, thanks to its intrinsic characteristics (volumetric acquisition, high resolution at high contrast for the study of the bone, and low radiation exposure), is an optimal candidate to replace OPT in these cases with suspected MRONJ. The possibility of reconstructing the 2D "panoramic-like" images also facilitates the dentist or maxillofacial specialist's conventional evaluation of the two arches. In cases with an extra-osseous extension of the disease suspect and, therefore, soft tissue involvement, the first CBCT evaluation can be followed by a multislice CT scan after infusion of intravenous iodinated contrast medium or even better by an MR, also in the post-contrast phase.

REFERENCES

1. Ruggiero SL, Dodson TB, Fantasia J, et al. American Association of Oral and Maxillofacial Surgeons. American Association of Oral and Maxillofacial Surgeons position paper on medication-related osteonecrosis of the jaw--2014 update. J Oral Maxillofac Surg 2014; 72(10):1938-56.
2. Kawahara M, Kuroshima S, Sawase T. Clinical considerations for medication-related osteonecrosis of the jaw: a comprehensive literature review. Int J Implant Dent 2021; 7(1):47.
3. Srivastava, A, Nogueras Gonzalez, GM, Geng, Y, et al. Prevalence of medication related osteonecrosis of the jaw in patients treated with sequential antiresorptive drugs: systematic review and meta-analysis. Support Care Cancer 2021; 29(5):2305–2317.
4. Morag Y, Morag-Hezroni M, Jamadar DA, Ward BB, Jacobson JA, Zwetchkenbaum SR, Helman J. Bisphosphonate-related Osteonecrosis of the Jaw: A Pictorial Review. RadioGraphics 2009; 29(7):1971-1986.
5. Bertoldo F, Santini D, Lo Cascio V. Bisphosphonates and osteomyelitis of the jaw: a pathogenic puzzle. Nat Clin Pract Oncol 2007; 4(12):711-21.
6. Gonen ZB, Asan CY, Zararsiz G, Kiliç E, Alkan A. Osseous changes in patients with medication-related osteonecrosis of the jaws. Dentomaxillofac Radiol 2018; 47:20 170-172.
7. Bertossi D, Fiorino P, Corega C, et al. Cone-beam volumetric imaging in craniofacial medicine. Minerva Stomatol 2019; 68(4):200-212.
8. Berg BI, Mueller AA, Augello M, Berg S, Jaquiéry C. Imaging in Patients with Bisphosphonate-Associated Osteonecrosis of the Jaws. Dent J (Basel) 2016; Sep 2;4(3):29.
9. Olutayo J, Agbaje JO, Jacobs R, Verhaeghe V, Vande Velde F, Vinickier F. Bisphosphonate-Related Osteonecrosis of the Jaw Bone: radiological pattern and the potential role of CBCT in early diagnosis. J Oral Maxillofac Res 2010;1(2):e3.
10. Wilde F, Heufelder M, Lorenz K, et al. Prevalence of cone beam computed tomography imaging findings according to the clinical stage of bisphosphonate-related osteonecrosis of the jaw. Oral Surg Oral Med Oral Pathol Oral Radiol 2012; 114(6):804-811.
11. Bianchi SD, Scoletta M, Bozzalla Cassione F,Migliaretti G, Mozzati M. Computerised tomographic findings in bisphosphonate-associated osteonecrosis of the jaw in patients with cancer. Oral Surg Oral Med Oral Pathol Oral Radiol 2007; 104(2): 249-258.
12. Curè JK, Vattoth S, Shah R. Radiopaque Jaw Lesions: an approach to the differential diagnosis. Radiographics 2012; 32(7):1909-1925.
13. Faccioli N, Barillari M, Guariglia S, Zivelonghi E, Rizzotti A, Cerini R, Pozzi Mucelli R. Radiation dose saving through the use of cone-beam CT in hearing-impaired patients. Radiol Med 2009; 114(8):1308-18.

14. Faccioli N, Foti G, Barillari M, Atzei A, Pozzi Mucelli R. Finger fractures imaging: accuracy of cone-beam computed tomography and multislice computed tomography. Skeletal Radiol 2010; 39(11):1087-95.
15. Bisdas S, Chambron Pinho N, Smolarz A, Sader R, Vogl TJ, Mack MJ. Biphosphonate-induced osteonecrosis of the jaws: CT and MRI spectrum of findings in 32 patients. Clin Radiol 2008; 63(1):71-7.
16. International Commission on Radiological Protection (2007) The 2007 Recommendations of the International Commission on Radiological Protection. ICRP publication 103. Ann ICRP 37:1–332.
17. Leite AF, Ogata Fdos S, de Melo NS, Figueiredo PT. Imaging findings of Bisphosphonate-related osteonecrosis of the jaws: a critical review of the quantitative studies. Int J Dent 2014; 2014:784348.
18. https://eur-lex.europa.eu/eli/dir/2013/59/oj.

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Evaluation Study

An improvement of upper airway flow in patients treated with rapid maxillary expansion: a Cone Beam Computed Tomography study

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ABSTRACT

Rapid Maxillary Expansion (RME) is an orthopaedic treatment used to correct the transverse deficit of the maxilla. Most often, this defect is diagnosed in mouth-breathing patients. Rapid Palatal Expander (RPE) treatment increases the upper airways' volume and decreases resistance, promoting physiological nasal breathing. The aim of this study is to measure the volume of the upper airways by employing Cone-beam Computed Tomography (CBCT) to evaluate the anatomical space where the major effects of RME occurred. Twenty-four subjects (mean age, 10.17 ± 1.75 years) treated with McNamara-type rapid palatal expander were selected. Two CBCT scans were taken for each patient: the first at the beginning (T0) and the second at the end of the treatment (T1). For each CBCT scan, Total Volume (TV), Retropalatal Volume (RPV) and Retroglossal Volume (RGV) were measured with the software ITK-Snap. The statistical analysis was performed using the paired samples t-test, with a p-value of 0.05. RPV significantly increased (Δ T1-T0: 680.75 mm^3 ± 792.63 mm^3, $P<0.05$). No significant changes were found in TV (Δ T1-T0: 452.92 mm^3 ± 3091.7 mm^3, $P>0.05$) and in RGV (Δ T1-T0: 166.92 mm^3 ± 666.97 mm^3, $P>0.05$). In this study, patients showed a statistically significant increase in RPV after RPE treatment. The CBCT scans provide only quantitative volumetric data, so it would be appropriate to determine the clinical significance of the obtained results with a functional examination (for example, rhinomanometry). The radiological protocol should be standardised to overcome limitations such as tongue posture during scan recording, swallowing and breathing control. Further studies are needed to evaluate the long-term stability of these effects on the airways.

INTRODUCTION

Several studies in the literature have observed a correlation between respiratory functions and orthodontic treatment, and due to the introduction of three-dimensional radiographs, research on this topic still arouses keen interest among orthodontists (1).

Rapid Maxillary Expansion (RME) is an orthopaedic treatment whose main objective is the opening of the median palatal and circummaxillary sutures in patients with a maxillary transverse deficit (2).

A consequence of the treatment with Rapid Palatal Expander (RPE) is an increase in the volume of the upper airways and a decrease in their resistance to airflow. A consequence of this is an improvement in nasal breathing and a reduction in the incidence of nasal respiratory problems in patients with maxillary transverse deficiency and mouth breathing (3); this is why this treatment is recommended for patients with obstructive pathologies of the upper airway tract, sleep disorders, and conductive hearing loss (4).

Airway changes resulting from RPE treatment were studied using different methods, which have proved reliable for evaluating pathological respiratory conditions. These included functional tests, such as rhinomanometry and acoustic rhinometry, radiological tests, such as lateral or posteroanterior teleradiographs and Cone-beam Computed Tomography (CBCT) (5-10).

Currently, CBCT is the most used method for assessing the upper airway volume. However, it is difficult to compare data from the literature due to a lack of standardisation (11-17). Head and tongue posture, breathing phase (inspiration or exhalation), patient mobility, anatomical limits of the volume considered, and the software used for the reconstructions are all variables that can change the results (18).

The aim of this study was to evaluate the changes in airway volume after RPE treatment employing CBCT scans and to identify the anatomical space in which the most significant volume increases were obtained.

MATERIALS AND METHODS

Eligibility criteria

This study selected 24 subjects (12 males and 12 females). The inclusion criteria were: transverse skeletal deficit of the maxilla; monolateral or bilateral skeletal cross-bite; CS1 or CS2 cervical vertebral maturation stage, according to Baccetti et al. (19). The exclusion criteria were: genetic or endocrine diseases that could affect the treatment plan; previous orthopaedic and/or orthodontic treatment; skeletal abnormalities or significant facial asymmetry (20, 21).

Rapid maxillary expansion

At the beginning of the treatment (T0), a CBCT was performed for every patient, and patients were in mixed dentition.

The transverse discrepancy of each one was measured on the dental casts using a calliper with 0.01 mm accuracy to quantify the millimetres of expansion needed. Since all subjects had a mixed dentition, the transverse discrepancy was the result of the difference between the superior intermolar distance (distance between the central fossae of the upper first permanent molars) and the inferior intermolar distance (distance between the top of the distobuccal cusps of the inferior first permanent molars). In addition, the patients were treated with an acrylic-splint rapid palatal expander (i.e. McNamara-type rapid palatal expander) composed of a Hyrax-type screw embedded into a wire-and-acrylic framework; the acrylic splints were bonded to the deciduous molars and the permanent first molars (22).

The patients' parents were instructed to activate the expansion screw twice a day until the palatal cusps of the posterior maxillary teeth approximated the buccal cusps of the mandibular posterior teeth: every activation was a 0.25 mm expansion. Once reached the correct expansion, the screw was blocked, and the expander was kept in place for six months: this period was necessary to allow the reorganisation of the mid-palatal suture. At the end of this period (T1), the expander was removed, cleaned and given to the patient to wear as retention at night for a further 6 months. If the expander was not sufficiently retentive, the patient wore a Hawley retainer (23). Finally, a CBCT was taken for each subject. CBCTs were performed using NewTom VGi evo (QR s.r.l, Verona, Italy).

Immediately before scanning the image, patients were instructed to inhale and hold their breath after exhalation, not to swallow, and to keep the teeth in maximum intercuspation and the tip of the tongue against the palate. During the radiographic examination, patients stood with the Frankfurt plane parallel to the floor. Three volumes were measured for each CBCT using the ITK-Snap software (www.itksnap.org):

- Total Volume (TV), between a horizontal plane passing through the upper margin of the frontal sinus and a horizontal plane passing through the lower margin of C3;
- Retropalatal Volume (RPV), between a line that connects the basion to the posterior nasal spine and a horizontal plane passing through the most posteroinferior point of the soft palate (Fig. 1);
- Retroglossal Volume (RGV), between a horizontal plane passing through the most posteroinferior point of the soft palate and a horizontal line passing through the highest point of the epiglottis (Fig. 2).

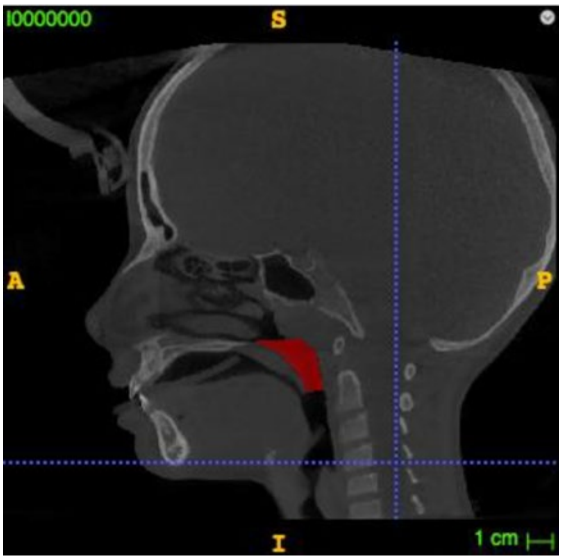

Fig. 1. *Retropalatal Volume (RPV).*

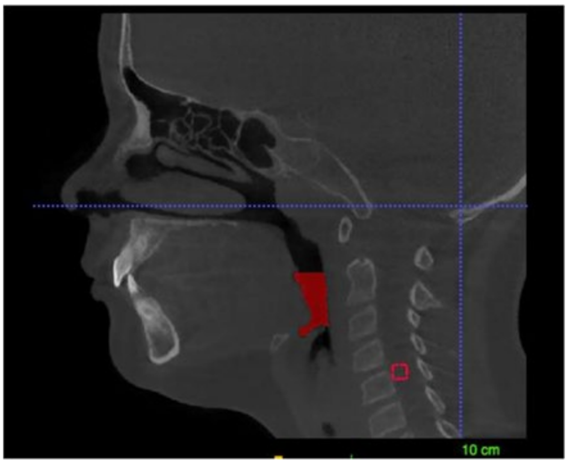

Fig. 2. *Retroglossal Volume (RGV).*

Statistical analysis

The statistical analysis was performed using STATA software (version 13; StataCorp LP, College Station, Texas, USA).

Mean ± standard deviation (SD) was calculated for all variables at T0 (pre-treatment) and T1 (after treatment). In addition, paired samples t-test was performed to evaluate the changes that occurred during treatment with RPE. The p-value was considered statistically significant if less than 0.05.

RESULTS

The mean age of the participants was 10.17±1.75 years. RPV significantly increased (Δ T1-T0: 680.75 mm^3 ± 792.63 mm^3, $P<0.05$). No significant changes were found in TV (Δ T1-T0: 452.92 mm^3 ± 3091.7 mm^3, $P>0.05$) and in RGV (Δ T1-T0: 166.92 mm^3 ± 666.97 mm^3, $P>0.05$) (Table I).

Table I. *Changes of the pre- (T0) and post-treatment (T1) variables.*

Variables	T0 (mm^3)	T1 (mm^3)	Δ T1-T0 (mm^3)	p-value
Total Volume (TV)	55910.58±11206.58	56363.5 ±11295.58	452.92 ± 3091.7	0.6218
Retropalatal Volume (RPV)	4676.83±1011.87	5357.58±1160.2	680.75 ± 792.63	0.0126*
Retroglossal Volume (RGV)	3598.58±1264.8	3765.5±1165.27	166.92 ± 666.97	0.4045

The values are expressed as mean ± standard deviation (SD) and their difference. It is also reported the p-value and the significance (*) obtained by the paired samples t test.

DISCUSSION

TV showed no statistically significant variation before and after treatment, probably because this volume had a wide range of variability, which was difficult to control. The high standard deviation value indicated this variability, determined by several factors, among which intraoral volume and the congestion of nasal and sinus mucosa.

More specifically, intraoral volume was considered by Iwasaki et al. as an index of the change in tongue posture following RPE treatment (15). As the appliance favours the transition from oral to nasal breathing, there is also a rise in the posture of the tongue and a reduction in the intraoral volume. Although a certain degree of congestion of the nasal and sinus mucosa could be identified, it was difficult to quantify the congestion of the nasal turbinates.

RPV showed a statistically significant increase (16% over the RPV at T0). This result is in agreement with many data reported in the literature: El and Palomo obtained an increase of 1719.9 ± 1510.7 mm^3 (P=0.046) of the retro-nasal volume, Iwasaki et al. reported an increase of 1413.9 mm^3 (P=0.02) in the nasal volume and Chang et al. showed a significant increase in the area of the airway section at the plane passing between the posterior nasal spine and the basion (P=0.0004) (12, 13, 15).

Also, Smith et al. identified a significant increase in the nasopharyngeal volume (P=0.00), with a mean increase of 522 ± 548 mm^3, corresponding to 16.1% of the initial volume (24). Zhao et al. performed a retrospective case-control study in which there was no increase in the nasopharyngeal volume despite increased intermolar distance after RPE treatment (11). A possible limitation of their study was the lack of standardisation of the tongue posture. Ribeiro et al. found an increase in the nasopharyngeal volume, but this was not statistically significant (P=0.11) (14).

Our results regarding RPV were lower than those reported in the literature. A possible explanation could be the age of the patients selected in our study (mean age = 10.17±1.75 years at T0), even if none were beyond the growth peak. As age increases, the skeletal effects of RPE decrease and therefore also those on the airways, as demonstrated by Baccetti et al., which identified a greater increase in the width of the nasal cavities in patients early treated compared to those treated at growth peak (25). Another possible factor that affects the increase in the RPV can be the number of activations performed. The greater the amount of the transversal defect and the number of activations necessary for its correction, the greater the volumetric gain, as the latter is related to the amount of skeletal expansion obtained.

According to a systematic review by Liu et al., the opening of the median palatal suture is directly related to that of the expander screw (26). Therefore, in patients with mild or moderate defects, the effects on airway volumes are more limited or absent. However, further studies are needed to correlate the amount of expansion

with the increase in the volume of the upper airways, perhaps dividing the sample into different subgroups based on the number of activations performed.
RGV did not show a statistically significant change. According to the literature, the effects of RPE on the oropharyngeal volume are somewhat controversial: Zhao et al., El and Palomo, Chang et al. and Iwasaki et al. did not find statistically significant variations of this volume (11-13, 15).

Ribeiro et al. identified a statistically significant variation in the oropharyngeal volume, but the latter was attributed to the lack of standardisation of the head and tongue posture, the breathing phase and the swallowing during the radiographic examination (14).

Zeng and Gao reported a slight statistically significant reduction in the oropharyngeal volume, with an extensive range of variability of this volume within the sample and a tendency of the section of the oropharynx to become oval: this could improve respiratory function, even if in a limited way (16). Smith et al. reported a non-statistically significant reduction in the oropharyngeal volume, probably linked to a palatal plane lowering following RPE treatment (24).

A possible case in which a particular increase in RGV can be identified is RME in patients with retruded mandible, in which the expansion of the maxilla releases the mandible forward, with a consequent increase in the retro-mandibular space, but studies are needed to test this hypothesis.

Moreover, several studies agree that RPE was effective in treating Obstructive Sleep Apnea Syndrome (OSAS) patients without other upper airway obstructions as a physiological nasal airflow was achieved (27-29). The improvements induced by RME in OSAS patients are mainly functional because the improvement in nasal airflow generates less sub-atmospheric inspiratory pressure, reducing the vulnerability to pharyngeal collapse (28). Since the increase in RGV was not statistically significant, it is impossible to affirm that the physiological nasal airflow was restored.

In order to complete this study, it would be necessary to combine the volumetric assessment of the upper airways with a functional assessment (i.e. rhinomanometry). Furthermore, a long-term evaluation of the stability of the obtained results would be useful. An adequate period of retention and the removal of the causal factors determining mouth breathing is indispensable for the stability of the treatment.

CONCLUSIONS

In this study, patients showed a statistically significant increase in RPV, equal to 16% of the initial volume, after treatment with RPE. No statistically significant changes were found in TV and RGV.

The volumetric increase obtained predisposes to a reduction in the resistance of the upper airways, promoting physiological nasal breathing and, therefore, a correction in craniofacial development. However, it would be necessary to complete the study with a functional examination (i.e. rhinomanometry) to evaluate the obtained results clinically.

The standardisation of the radiological protocol should be improved to overcome some limitations: tongue posture, swallowing, and respiratory phase is difficult to control in children.

It is appropriate to deepen the topic by looking for a possible correlation between variation in the volume of the airways and the amount of expansion. Finally, it would be useful to evaluate the long-term stability of the results obtained: an adequate period of retention and the removal of the causal factors for mouth breathing are indispensable for the stability of the treatment.

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REFERENCES

1. Lanteri V, Farronato M, Ugolini A, et al. Volumetric Changes in the Upper Airways after Rapid and Slow Maxillary Expansion in Growing Patients: A Case-Control Study. Materials (Basel) 2020; 13(10):2239.
2. Bucci R, D'Antò V, Rongo R, Valletta R, Martina R, Michelotti A. Dental and skeletal effects of palatal expansion techniques: a systematic review of the current evidence from systematic reviews and meta-analyses. J Oral Rehabil 2016; 43(7):543-64.
3. Kiliç N, Oktay H. Effects of rapid maxillary expansion on nasal breathing and some naso-respiratory and breathing problems in growing children: a literature review. Int J Pediatr Otorhinolaryngol 2008; 72(11):1595-601.
4. Abate A, Cavagnetto D, Fama A, Matarese M, Lucarelli D, Assandri F. Short term effects of rapid maxillary expansion on breathing function assessed with spirometry: A case-control study. Saudi Dent J 2021; 33(7):538-545.
5. Monini S, Malagola C, Villa MP, et al. Rapid maxillary expansion for the treatment of nasal obstruction in children younger than 12 years. Arch Otolaryngol Head Neck Surg 2009; 135(1):22–7.
6. Compadretti GC, Tasca I, Bonetti GA. Nasal airway measurements in children treated by rapid maxillary expansion. Am J Rhinol 2006; 20(4):385- 93.
7. De Felippe NLO, Da Silveira AC, Viana G, Kusnoto B, Smith B, Evans CA. Relationship between rapid maxillary expansion and nasal cavity size and airway resistance: short- and long-term effects. Am J Orthod Dentofacial Orthop 2008; 134(3):370-82.
8. Cameron CG, Franchi L, Baccetti T, McNamara JA Jr. Long-term effects of rapid maxillary expansion: a posteroanterior cephalometric evaluation. Am J Orthod Dentofacial Orthop 2002; 121(2):129-93.
9. Tecco S, Caputi S, Festa F. Evaluation of cervical posture following palatal expansion: a 12-month follow-up controlled study. Eur J Orthod 2007; 29(1):45- 51.
10. McGuinness NJ, McDonald JP. Changes in natural head position observed immediately and one year after rapid maxillary expansion. Eur J Orthod 2006; 28(2):126-34.
11. Zhao Y, Nguyen M, Gohl E, Mah JK, Sameshima G, Enciso R. Oropharyngeal airway changes after rapid palatal expansion evaluated with cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2010; 137(4 Supp):S71-8.
12. El H, Palomo JM. Three-dimensional evaluation of upper airway following rapid maxillary expansion: A CBCT study. Angle Orthod 2014; 84(2):265-73;
13. Chang Y, Koenig LJ, Pruszynski JE, Bradley TG, Bosio JA, Liu D. Dimensional changes of upper airway after rapid maxillary expansion: a prospective cone-beam computed tomography study. Am J Orthod Dentofacial Orthop 2013; 143(4):462-70.
14. Ribeiro AN, de Paiva JB, Rino-Neto J, Illipronti-Filho E, Trivino T, Fantini SM. Upper airway expansion after rapid maxillary expansion evaluated with cone beam computed tomography. Angle Orthod 2012; 82(3):458-63.
15. Iwasaki T, Saitoh I, Takemoto Y, et al. Tongue posture improvement and pharyngeal airway enlargement as secondary effects of rapid maxillary expansion: a cone-beam computed tomography study. Am J Orthod Dentofacial Orthop 2013; 143(2):235-45.
16. Zeng J, Gao X. A prospective CBCT study of upper airway changes after rapid maxillary expansion. Int J Pediatr Otorhinolaryngol 2013; 77(11):1805-10.
17. Cordasco G, Nucera R, Fastuca R, et al. Effects of orthopedic maxillary expansion on nasal cavity size in growing subjects: a low dose computer tomography clinical trial. Int J Pediatr Otorhinolaryngol 2012; 76(11):1547-51.

18. Di Carlo G, Saccucci M, Ierardo G, et al. Rapid Maxillary Expansion and Upper Airway Morphology: A Systematic Review on the Role of Cone Beam Computed Tomography. Biomed Res Int 2017; 2017:5460429.
19. Baccetti T, Franchi L, McNamara JA Jr. The cervical vertebral maturation (CVM) method for the assessment of optimal treatment timing in dentofacial orthopedics. Semin Orthod 2005; 11(3):119-29.
20. De Santis D, Sinigaglia S, Faccioni P, et al. Syndromes associated with dental agenesis. Minerva Stomatol 2019; 68(1):42-56.
21. Faccioni P, De Santis D, Sinigaglia S, et al. Effects of the sander bite jumping appliance in patients with class ii malocclusion before growth peak. J Biol Regul Homeost Agents 2020; 34(6 Suppl. 2):1-7.
22. Schulz SO, McNamara JA Jr, Baccetti T, Franchi L. Treatment effects of bonded RME and vertical-pull chincup followed by fixed appliance in patients with increased vertical dimension. Am J Orthod Dentofacial Orthop 2005; 128(3):326-36.
23. De Santis D, Pancera P, Luciano U, et al. evaluation of bacterial flora composition on teeth and periodontal tissues in patients in treatment with rapid palatal expander. J Biol Regul Homeost Agents 2018; 32(2 Suppl. 2):31-6.
24. Smith T, Ghoneima A, Stewart K, Liu S, Eckert G, Halum S, Kula K. Three-dimensional computed tomography analysis of airway volume changes after rapid maxillary expansion. Am J Orthod Dentofacial Orthop 2012; 141(5):618-26.
25. Baccetti T, Franchi L, Cameron CG, McNamara JA Jr. Treatment timing for rapid maxillary expansion. Angle Orthod 2001; 71(5):343-50.
26. Liu S, Xu T, Zou W. Effects of rapid maxillary expansion on the midpalatal suture: a systematic review. Eur J Orthod 2015; 37(6):651-5.
27. Pirelli P, Saponara M, Guilleminault C. Rapid maxillary expansion in children with obstructive sleep apnea syndrome. Sleep 2004; 27(4):761-6.
28. Cistulli PA, Palmisano RG, Poole MD. Treatment of obstructive sleep apnea syndrome by rapid maxillary expansion. Sleep 1998; 21(8):831-5.
29. Guilleminault C, Monteyrol PJ, Huynh NT, Pirelli P, Quo S, Li K. Adeno-tonsillectomy and rapid maxillary distraction in pre-pubertal children, a pilot study. Sleep Breath 2011; 15(2):173-7.