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Contents

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Observational Study

Prevention dental hygiene program in oncology patients

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ABSTRACT

This study aimed to assess the impact of on oral health in oncological patients. A Prevention Dental Hygiene Project was conducted in the Day-Hospital Oncology Unit. Fourteen patients who satisfied the inclusion criteria at their first visit were enrolled voluntarily. Their oral health conditions were evaluated using the Bleeding on probing (BoP), Visible Plaque Index (VPI) at the initial stage (T0), one month (T1), and two months after (T2) The results showed an improvement in inflammatory and plaque indices in patients who attended all visits and followed the instructions provided. In conclusion, the dental project implemented on frail patients highlights the significance of preventive measures and the value of multidisciplinary collaboration in the field of medicine.

INTRODUCTION

Increasing attention is being paid to the correlation between systemic disease and oral health (1). The cancer patient represents an example of such a correlation, where problems due to the disease are reflected in the oral cavity, especially in terms of oral manifestations due to the treatments these patients undergo (2). The correlation with the oral cavity is not only represented by such manifestations but also by its influence on periodontal disease.

Periodontal issues continuously grow worldwide and affect approximately 60% of the population. Periodontitis is a progressive inflammatory disease of the tooth-supporting tissues (gingiva, periodontal ligament, alveolar bone, and cementum). It has a multifactorial etiology and originates in response to periodontopathogenic agents within the dental plaque biofilm on tooth surfaces near the gingiva (3, 4).

Periodontal disease can be prevented and efficiently treated in its early stages; however, it can progress to chronic and irreversible states with significant destruction of the supporting tissues (5). The incidence of malignancies in Italy and the rest of the world is also steadily increasing, with approximately 400,000 new cases in 2012, representing the second leading cause of death after cardiovascular disease and 30% of all deaths.

Oral complications of oncological treatment are different, and they can have a relevant negative impact on the quality of the affected patient's life, the outcome of therapies during the treatment phase, and, therefore, the prognosis of the neoplastic pathology (6, 7).

All oncological therapies have undesirable side effects, affecting the oral cavity. Therefore, the patient's treatment plan includes, in addition to the therapeutic course, the prevention and treatment of therapy-induced side effects and, if necessary, the planning of prosthetic rehabilitation (8-10). The dental hygienist must be a guarantor of the oncological patient's health, intercepting and preventing adverse oral conditions and assisting the patient in maintaining good oral health at home (11). In addition, dental hygienists must be part of the oncology treatment team, together with dentists and other specialists, so that oral health promotion and treatment of oral lesions associated with systemic diseases and/or their therapies are possible (6, 12-14). The following observational study illustrates the effectiveness of this multidisciplinary collaboration in taking care of patients with cancer from a dental perspective.

MATERIALS AND METHODS

Study design and inclusion criteria

This observational epidemiological study was based on the "Prevention and Treatment of Oral Problems". The Project was conducted at the Dentistry and Maxillo-facial Surgery Unit (University of Verona) in collaboration with the Day-Hospital Oncology Unit of the Integrated University Hospital of Verona in 2023.

The prevention initiative was promoted to patients through dépliants and the communication of the project in the therapy rooms of the Oncology Day-Hospital Unit. Interested patients can schedule an appointment for the first visit, where the inclusion criteria are assessed. The inclusion criteria were as follows.

- signature for informed consent;
- positive diagnosis of oncological pathology;
- oncological chemotherapy treatment;
- the patient is not in a public or private dental recall program.

The nature and goals of this study and the anonymity in the scientific use of data were clearly presented in the consent form. The Declaration of Helsinki and the good clinical practice guidelines for human research were followed during this study's execution. This observational study received approval from the University Institutional Review Board (Prog. 3921CESC).

Study Protocol

After the project's communication, the Study Protocol provides the first visit, which is held in the Day-Hospital Oncology Unit. In addition to assessing the inclusion criteria at the first visit, an intra- and extra-oral examination of the mucosa, hard and soft tissues, the presence of plaque and/or tartar deposits, and periodontal pockets was performed.

If the clinical picture matched, the patient was asked to voluntarily join the project, thus initiating the project protocol (Table I).

Table I. *Flow chart of the study.*

Timing	Procedures
T0	• First visit with oral examination performed at the Day-Hospital Oncology Unit
T1	• Assessment of periodontal chart for patients who had periodontal pockets at T0 • Assessment of Plaque Index (PI) of Bleeding on Probing (Bop) • Professional Oral Hygiene with plaque detector • Home Oral Hygiene indication/instruction
T2	➢ Approximately 1 week from T1 • Follow-up visit to assess patient compliance and level of Home Oral Hygiene • Assessment of Plaque Index (PI) and Bleeding on Probing (Bop)
T3	➢ 2 months after T2 • Assessment of Plaque Index (PI) and Bleeding on Probing (Bop) • Performing Professional Oral Hygiene with plaque detector

Soft tissue assessment

A periodontal probe (Florida Probe, Florida Probes Company, Gainesville, FL, USA) was used to measure the soft tissues of the periodontium. The parameters considered were Clinical Attachment Loss (CAL),

Probing Pocket Depth (PPD), the Plaque Index (PI), Bleeding on Probing (BOP), and the Gingival Index (GI) (15, 16). The PI and BOP were calculated immediately after probing for PPD. The severity of periodontal disease (17) was measured as moderate (PPD 4 -5 mm) or severe (PPD > 5 mm).

All sites were detected four times: preoperatively (T0), at the first visit according to hospital availability (T1), after 1 week (T2), and after 2 months (T3). In addition, a complete clinical evaluation was performed at T0 to document any general periodontal condition and re-evaluate these conditions at subsequent times.

Statistical Analysis

The statistical results, analyzed using Microsoft Excel, were home oral hygiene habits and devices, Plaque Index (PI), Bleeding on Probing (BOP) at different times, and periodontal health condition (not affected by periodontitis and periodontitis). The "p-value," denoted as "$p < 0.05$," was used to detect statistical differences between the collected and compared data.

RESULTS

Demographic results

A total of 14 (5 men and 9 women) were included in the observational epidemiologic study. The demographic characteristics are reported in Table II.

Table II. *Representation of the sample.*

Variable	*n*	%
Sex		
Male	5	36%
Female	9	64%
Age		
Mean male	60	
Mean female	56	

Oral devices used

The investigation of oral devices used, carried out at T0, showed that 100% of the sample used a toothbrush and toothpaste for daily oral hygiene, 64% used interdental devices such as floss and/or brush, 14% used mouthwashes containing active agents, 21% used generic mouthwashes, and 78% used bicarbonate and water solution as a rinse to be performed several times throughout the day.

Periodontal disease

The T1 survey on periodontal disease showed that 50% of the sample had periodontitis. Of this group, 14% had a moderate form (PPD 4-5 mm), and 86% had a severe form (PPD >5 mm) (13) (Table III).

Table III. *Distribution of Periodontal disease in the sample.*

Periodontal disease	*n*	%
Sample		
Male	7	50%
Female	7	50%
Severity		
Moderate	2	14%
Severe	12	86%

Indices analyzed

Regarding PI and BOP, the evolution of the indices was analyzed in the total sample at T1, T2, and T3 (Table IV).

Table IV. *PI and BOP Index at T1, T2, e T3 in the total sample.*

	T1	T2	T3	p-value
PI (Plaque Index)	55%	45%	33%	*Δ(T1-T3): p=0,001*
BOP (Bleeding on Probing)	24%	19%	16%	*Δ(T1-T3): p=0,001*

Both indices improved, although, for BOP, patients were not bleeding much to begin with. Next, PI and BOP were analyzed again at T1, T2, and T3, dividing the sample into periodontal and non-periodontal and comparing the two indices in the two groups. For PI, there was an improvement in both groups of patients and also for BOP, noting how the bleeding from the beginning was low (Table V).

Table V. *PI and BOP Indexes at T1, T2 e T3 in the two groups (periodontal and non-periodontal).*

	PI	BOP
T1 perio	55%	22%
T1 no perio	55%	25%
T2 perio	42%	14%
T2 no perio	47%	24%
T3 perio	26%	10%
T3 no perio	39%	21%

DISCUSSION

Only a few studies have examined the correlation between cancer treatment and oral manifestations. Such manifestations increase with chemotherapy. Although improvements have been made in such therapies over the years, oral complications remain (18, 19).

The oral mucosa was the most affected site of the oral cavity. The toxicity of chemotherapy profoundly affects the mucosa, leading to the manifestation of oral mucositis (OM) (20, 21). OM is the most reported side

effect in 40-50% of patients undergoing chemotherapy, caused by thinning of the mucosa itself, which atrophies.

Therefore, it is important that these patients also receive dental care, with oral health as the first goal. Oral health is a complex concept because, according to the FDI/World Dental Federation, it comprises the ability to speak, smell, taste, touch, chew, swallow, and convey a range of emotions through facial expressions with confidence and without pain, discomfort, and disease of the craniofacial complex (head, face, and oral cavity) (22).

Dental visits during and after cancer treatment aim to prevent and/or minimize the severity of the side effects caused by the treatments themselves (23). That meta-analysis establishes a protocol for treating complications at all stages of therapy and in the home setting, thus beginning to provide clear guidelines for the care of oncology patients.

In addition, the literature provides several approaches to treat and manage periodontal tissue inflammation, such as hyperbolic, photodynamic, and air-polishing therapies (24, 25). The same thing is being done by the Ministry of Health (26), which draws up Recommendations for the Promotion of Oral Health, Prevention of Oral Disease, and Dental Therapy in Adult Patients with Neoplastic Disease. In that document, all the characteristics necessary to frame a cancer patient from a dental perspective are expressed, and great attention has been paid to chemotherapy-induced side effects.

Oral hygiene is an important preventive tool for these patients. Poor oral hygiene can also become a risk factor for serious diseases, such as osteonecrosis. Therefore, it is important that oncological and frail patients are included in a dental protocol that goes hand-in-hand with specialist medical examinations and oral hygiene education (27-31).

Thus, working on oral health contributes to a better quality of life for these patients and their longevity. Quality of life is essential, and very often, after a cancer diagnosis, it is lacking because patients are let go. Psychological aspects must be taken into consideration (32, 33).

In addition, regarding the oral cavity, letting go of these patients may induce less attention to home oral hygiene measures, potentially leading to poor oral hygiene influenced by the family and social environment (34). This study focuses heavily on this aspect, analyzing inflammatory and plaque indices changes in cancer patients and motivating them to maintain proper oral hygiene. The aforementioned side effects were also investigated without objective parameters, providing guidance and advice to mitigate them.

CONCLUSIONS

This study shows the importance of an oral prevention protocol for patients with debilitating systemic diseases, such as oncology. Little attention has been paid to the side effects of many systemic diseases manifesting in the oral cavity. The project was intended to focus on this particular aspect and to bring oncological patients closer to preventive dentistry, which is often neglected because of the disease itself.

Cases subjected to radiotherapy or antiresorptive and antiangiogenic drugs would deserve a more in-depth discussion that goes beyond this article, where oral prevention can avoid dramatic situations requiring extensive demolitions and complex reconstructions (35). The aim is not to eliminate oral manifestations induced by oncology therapies but to alleviate the discomfort they can cause through their knowledge and administering appropriate products. The secondary purpose is to instill more knowledge regarding these correlations, not only to patients but also to professionals.

As highlighted in other districts, the sharing of the skills of different specialists guarantees a complete evaluation of patients, with an improvement not only in treatment but also in quality of life (36). From the preliminary data of this study, there is an improvement in the oral health conditions of oncological patients. However, it is emphasized that the sample consisted of only a few subjects and the data collected, so further investigations will be needed to corroborate the results obtained.

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Evaluation Study

An evaluation of occlusal changes during orthodontic retention

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ABSTRACT

The problem of orthodontic relapse is of fundamental importance for clinicians. In the literature there are few studies concerning the change in position of the teeth after orthodontic treatment. This study analyzes the occlusal changes during the first six months of orthodontic retention and the effectiveness of the Hawley retainer at the upper arch and the canine-to-canine multi-stranded fixed retainer at the lower arch in maintaining the anterior tooth alignment. 48 patients were recruited. PAR index, ABO DI, ABO CRE, Irregularity Index, intercanine, interpremolar and intermolar widths were measured for each patient before (T0) and at the end (T1) of the fixed orthodontic treatment and after 1 (T2), 3 (T3) and 6 (T4) months of retention. Statistics used were paired samples t-test and Wilcoxon matched-pairs signed-ranks test. The p-value was considered statistically significant for $P<0.05$. During 6 months in retention there was a worsening of PAR index (mean: 1.13±1.08; $P<0.001$), dental alignment (median: 2.5; $P=0.0001$) and occlusal relationships (median: 2; $P=0.0101$); a statistically significant improvement of posterior occlusal contacts (median: 2.54; $P=0.0004$), marginal ridges (median: 0.5; $P=0.0250$) and interproximal contacts (median: 0.46; $P=0.0305$). The stability of the orthodontic results has proved to be similar for the two dental arches, as well as the effectiveness of the two retainers in maintaining the alignment of the anterior teeth. During 6 months in retention the occlusal changes were minimal and didn't affect the stability of the orthodontic treatment in a clinically significant manner. The effectiveness of the upper Hawley retainer and the lower multi-stranded fixed retainer in maintaining the alignment of the anterior teeth was similar.

INTRODUCTION

The stability of the orthodontic treatment is a problem that has always afflicted orthodontists. The focus of the problem had already been understood by Charles A. Hawley, who stated: "If anyone would take my cases when they are finished, retain them and be responsible for them afterward, I would gladly give them half the fee" (1). Numerous researches have been carried out on the stability and relapse of orthodontic treatment and many procedures and appliances have been introduced to improve orthodontic retention; however, despite the knowledge and techniques in this area have evolved, a definitive solution to the problem has not been found yet (2-4). Most of the studies in the literature that address this topic focus on the long-term occlusal changes that occur once the retention phase is over (5-8). Short-term teeth movements after fixed orthodontic treatment have been little studied, if not studied at all (9, 10). Precisely for this reason we decided to analyze the dental occlusion during the first six months of retention. The aim of this work was indeed to evaluate on study models and on radiographs: 1) Occlusal changes during the first six months of orthodontic retention by means of upper Hawley retainer and lower multi-stranded fixed retainer. 2) The differences in stability of the results obtained with the fixed orthodontic treatment between the upper and lower arch during the period of retention. 3) The differences in effectiveness between the Hawley retainer and the multi-stranded fixed retainer in maintaining the dental alignment respectively at the level of the upper and lower anterior sextant. The occlusal changes occurred between the beginning and the end of the orthodontic treatment were also analyzed to evaluate these three elements in an accurate and complete way and to understand if orthodontic relapse had occurred or not.

MATERIALS AND METHODS

Forty-eight subjects (24 males and 24 females; mean age at the beginning of the treatment: 16.64 ± 3.15 years; mean age at the end of the treatment: 18.94 ± 2.74 years) were enrolled in this study, that was approved by the Clinical Investigation Ethics Committee of Verona and Rovigo, Italy (protocol number 70252, 30 October 2018). The inclusion criteria were: two-arch multibracket fixed orthodontic treatment carried out by the same orthodontist; complete clinical documentation (clinical records, dental casts, radiographs, and intra-oral and extra-oral photographs); patient compliance to wear retention appliances; absence of periodontal problems. At the end of orthodontic treatment (T1) the following procedures were performed on each patient:

1) Debonding of the fixed orthodontic appliance and professional oral hygiene (11).

2) Application of the lower multi-stranded fixed retainer (TRI-FLEX ™ Twisted Wire 0175 inches, Rocky Mountain® Orthodontics, Denver, CO, USA) to the lower anterior sextant.

3) Taking alginate impressions (Kromopan®, LASCOD Spa, Sesto Fiorentino (FI), Italy) of the two arches and taking the bite registration wax (Small platewax for orthodontics, Zeta®, Industry Zingardi srl, Novi Ligure (AL), Italy) for the construction of the dental casts and of the superior Hawley retainer (12-14). After one week from debonding, each patient received Hawley retainer: it must be worn at night for at least one year. After 1 month from the debonding (T2), dental occlusion and the integrity of the retention appliances were evaluated, and alginate impressions and a bite registration wax were taken for the construction of the dental casts. The same procedure was performed at 3 (T3) and 6 months (T4) after the end of the orthodontic treatment. Subsequently, the initial (T0), final (T1) and post-treatment dental casts at 1 (T2), 3 (T3) and 6 months (T4), the T0 lateral teleradiographs and the orthopantomograms at T1 and T4 were analyzed. The analyses were performed using the Peer Assessment Rating index (PAR index) (15), the American Board of Orthodontics Discrepancy Index (ABO DI) (16), the American Board of Orthodontics Cast-Radiograph Evaluation (ABO CRE or ABO OGS) (17) and the Little Irregularity Index (II) (18). Intercanine, interpremolar and intermolar widths were also measured (19).

The PAR index, the ABO DI and the ABO CRE were analogously measured with the PAR ruler and the ABO Measuring Gauge respectively; the measurements of the II and of the dental arch widths were performed with the 3Shape OrthoViewer software (3Shape, Copenhagen, Denmark) after having transformed the dental models in plaster in digital format (.stl) with a dental scanner (Dental Smart scanner, Open Technologies, Rezzato, Brescia, Italy). The ANB, SN-MP and lower- incisors MP of ABO DI were calculated on the cephalometric traces of the initial lateral teleradiographs with the software Dolphin Imaging 11.7 (Dolphin, Imaging & Management Solutions, Chatsworth, CA, USA). Finally, the root angulation for the ABO CRE index was evaluated on orthopantomograms.

The statistical analysis was performed using STATA (version 13; StataCorp LP, College Station, Texas, USA). The median, maximum, minimum, 10th, 25th, 75th, and 90th percentile were calculated for all parameters; moreover, mean and standard deviation (SD) were reported for the normally distributed variables. Paired samples t-test and Wilcoxon matched-pairs signed-ranks test were performed for the evaluation of the occlusal changes that occurred during treatment and during the first six months of orthodontic retention. The same tests were used to compare the differences in stability of the results obtained with the orthodontic treatment between the two arches and the differences in effectiveness in maintaining the alignment of the anterior teeth between the upper Hawley retainer and the lower multi-stranded fixed retainer. The p-value was considered statistically significant when it was less than 0.05.

RESULTS

Regarding the occlusal changes that occurred between the beginning and the end of the orthodontic treatment, a statistically significant improvement was recorded in the PAR index and its variables (Table I).

Table I. *PAR Index and its variables at the beginning (T0) and the end (T1) of the treatment.*

	Median		Maxi-mum		Minimum		Mean ± SD		10th percentile		25th percentile		75th percentile		90th percentile		p-value
	T0	T1	T0	T1	T0	T1	T0	T1	T0	T1	T0	T1	T0	T1	T0	T1	
PAR Index	18	9	39	15	11	3			11	5	13.5	7	23	10.5	29	13	P<0.001
Upper right segment	2	1	4	3	1	0	2.13 ± 0.9	1.25 ± 0.79	1	0	1.5	1	3	2	3	2	P=0.0002
Upper anterior segment	3	1	12	2	2	0			2	1	2.5	1	4	2	4	2	P<0.001
Upper left segment	2	1	5	2	0	0	1.92 ± 1.14	1.04 ± 0.75	1	0	1	0.5	2	2	3	2	P=0.0006
Lower right segment	2	1	3	2	0	0	1.67 ± 0.7	1.13 ± 0.61	1	0	1	1	2	1.5	2	2	P=0.0005
Lower anterior segment	3	1	4	2	1	1			2	1	2	1	3	1	4	2	P<0.001
Lower left segment	2	1	3	3	1	0	1.96 ± 0.75	1.33 ± 0.7	1	1	1	1	2.5	2	3	2	P=0.0030
Right buccal occlusion	1.5	0	5	1	0	0			0	0	0	0	2	1	4	1	P=0.0004
Overjet	1	0	4	1	0	0			0	0	1	0	1.5	1	3	1	P=0.0002
Overbite	1	0	2	1	0	0	0.83 ± 0.7	0.25 ± 0.44	0	0	0	0	1	0.5	2	1	P=0.0012
Centreline	0	0	2	1	0	0			0	0	0	0	1	0	1	1	P=0.0255
Left buccal occlusion	1	0	5	2	0	0	1.54 ± 1.67	0.46 ± 0.66	0	0	0	0	2	1	5	1	P=0.0036

Moreover, the alignment of the anterior sextants has improved with the orthodontic therapy: the maxillary II changed from 7.07 ± 4.22 mm to 1.98 ± 0.75 mm (P<0.001); also the mandibular II has been statistically improved (from 5.59 mm at T0 to 1.67 mm at T1, P<0.001). The orthodontic treatment then determined the expansion of both dental arches (Table II). Concerning the dental occlusion evaluated according to the ABO indices, it was not possible to compare the ABO DI at T0 with the ABO CRE at T1 because the two indices are based on different variables (Table III). Regarding the occlusal changes during the first 6 months of orthodontic retention (Table IV), a statistically significant worsening of the occlusion according to the PAR

index was recorded: the score increased from 8.75 ± 2.98 at T1 to 9.88 ± 3.04 at T4 (P<0.001). In particular, for the aforementioned index, the worsening of the upper anterior segment, the lower left segment and the left buccal occlusion was statistically significant.

Table II. *Dental arch widths at beginning (T0) and the end (T1) of the treatment.*

	Median		Maximum		Minimum		Mean ± SD		10th percentile		25th percentile		75th percentile		90th percentile		p-value
	T0	T1	T0	T1	T0	T1	T0	T1	T0	T1	T0	T1	T0	T1	T0	T1	
Maxillary intercani-ne width	34.17	34.84	36.74	37.43	27.12	29.91	33.29 ± 2.61	34.42 ± 1.85	29.6	32.12	32.28	33.35	35.04	35.63	36.14	36.94	P=0.027
Maxillary interpre-molar width	39.84	42.49	44.35	50.05	29.15	38.33	39.55 ± 3.4	42.61 ± 2.66	35.87	39.27	37.62	40.85	41.97	44.27	43.02	45.66	P=0.0004
Maxillary intermo-lar width	49.61	50.58	54.84	58.04	41.12	45.66	48.94 ± 3.36	51.22 ± 3.34	44.32	46.71	46.94	48.39	51.33	53.5	53.05	55.39	P=0.0019
Mandibu-lar interca-nine width	25.81	25.82	28.72	29.3	19.42	23.24	25.36 ± 2.29	25.89 ± 1.5	21.48	23.9	24.35	24.97	26.76	26.58	28.21	28.16	P=0.2962
Mandibu-lar interpre-molar width	33.23	34.68	36.37	38.82	25.92	30.41			29.9	32.72	31.54	33.33	34.71	35.65	35.88	36.94	P=0.0152
Mandi-bular inter-molar width	43.87	44.11	52.8	50.33	38.43	39.21	44.26 ± 3.51	44.46 ± 3.09	39.89	40.56	41.34	42.51	46.63	46.92	49.27	49.37	P=0.6770

Table III. *ABO DI and its variables at the beginning of the treatment (T0) and ABO CRE and its variables at the end of treatment (T1).*

	Median	Maximum	Minimum	Mean ± SD	10th percentile	25th percentile	75th percentile	90th percentile
ABO DI (T0)	21.5	47	7	23.29 ± 10.71	13	15	27.5	38
Overjet (T0)	2	11	0		0	1	3	5
Overbite (T0)	0	5	0		0	0	2	2
Anterior open bite (T0)	0	10	0		0	0	1	3
Lateral open bite (T0)	0	12	0		0	0	0	2
Crowding (T0)	7	7	4		7	7	7	7
Occlusal relationship (T0)	4	6	0	2.92 ± 1.95	0	2	4	6
Lingual posterior crossbite (T0)	0	6	0		0	0	1	4
Buccal posterior crossbite (T0)	0	0	0	0	0	0	0	0
Cephalometrics (T0)	4	20	0	5.58 ± 6.02	0	0	10	14
Other (T0)	0	8	0	1.83 ± 2.5	0	0	4	5
ABO CRE (T1)	50.5	78	21	51.38 ± 13.03	38	44	57.5	69
Alignment / rotations (T1)	14	26	5	15.63 ± 6.44	8	10	22.5	25
Marginal ridges (T1)	5.5	9	1	4.92 ± 2.19	1	4	6	7
Buccolingual inclination (T1)	7	17	1	7.5 ± 4.14	2	5	10.5	12
Overjet (T1)	7	16	1	7.17 ± 3.51	4	4.5	10	12
Occlusal contacts (T1)	9	17	2	9.17 ± 3.64	4	7	11.5	14
Occlusal relationship (T1)	4	15	0		2	2.5	7	10
Interproximal contacts (T1)	0	4	0		0	0	1.5	4
Root angulation (T1)	1	3	0	0.92 ± 0.97	0	0	1.5	2

Table IV. *PAR Index and its variables at the end of the treatment (T1), after 1 (T2), 3 (T3) and 6 (T4) months of orthodontic retention.*

		Median	Maximum	Minimum	Mean ± SD	10th percentile	25th percentile	75th percentile	90th percentile	p-value
PAR Index	T1	9	15	3	8.75 ± 2.98	5	7	10.5	13	
	T2	9	15	4	9.13 ± 2.89	6	7	11.5	13	P=0.0166
	T3	9.5	15	4	9.33 ± 3.07	6	7	12	13	P=0.0036
	T4	9.5	16	5	9.88 ± 3.04	6	7.5	13	14	P<0.001
Upper right segment	T1	1	3	0	1.25 ± 0.79	0	1	2	2	
	T2	1	3	0	1.38 ± 0.71	1	1	2	2	P=0.0830
	T3	1	3	0	1.33 ± 0.76	0	1	2	2	P=0.3277
	T4	1	3	0	1.33 ± 0.76	0	1	2	2	P=0.3277
Upper anterior segment	T1	1	2	0	1.33 ± 0.56	1	1	2	2	
	T2	1	2	0	1.38 ± 0.58	1	1	2	2	P=0.3277
	T3	1.5	2	0	1.46 ± 0.59	1	1	2	2	P=0.0830
	T4	2	3	1	1.67 ± 0.56	1	1	2	2	P=0.0025
Upper left segment	T1	1	2	0	1.04 ± 0.75	0	0.5	2	2	
	T2	1	2	0	1.04 ± 0.75	0	0.5	2	2	
	T3	1	2	0	1.08 ± 0.78	0	0.5	2	2	P=0.3277
	T4	1	2	0	1.08 ± 0.78	0	0.5	2	2	P=0.3277
Lower right segment	T1	1	2	0	1.13 ± 0.61	0	1	1.5	2	
	T2	1	2	0	1.25 ± 0.68	0	1	2	2	P=0.0830
	T3	1	2	0	1.21 ± 0.72	0	1	2	2	P=0.3277
	T4	1	2	0	1.25 ± 0.74	0	1	2	2	P=0.1853
Lower anterior segment	T1	1	2	1		1	1	1	2	
	T2	1	2	1		1	1	1.5	2	P=0.3173
	T3	1	2	1		1	1	1.5	2	P=0.3173
	T4	1	2	1		1	1	2	2	P=0.0833
Lower left segment	T1	1	3	0	1.33 ± 0.7	1	1	2	2	
	T2	1	3	0	1.42 ± 0.72	1	1	2	2	P=0.3277
	T3	1	3	0	1.5 ± 0.78	1	1	2	3	P=0.1035
	T4	1	3	0	1.58 ± 0.83	1	1	2	3	P=0.0109
Right buccal occlusion	T1	0	1	0		0	0	1	1	
	T2	0	1	0		0	0	1	1	
	T3	0	1	0		0	0	1	1	
	T4	0	1	0		0	0	1	1	P=0.6547
Overjet	T1	0	1	0		0	0	1	1	
	T2	0	1	0		0	0	0.5	1	P=0.1573
	T3	0	1	0		0	0	0	1	P=0.0833
	T4	0	1	0		0	0	0.5	1	P=0.3173
Overbite	T1	0	1	0		0	0	0.5	1	
	T2	0	1	0		0	0	0.5	1	
	T3	0	1	0		0	0	0.5	1	
	T4	0	1	0		0	0	1	1	P=0.3173
Centreline	T1	0	1	0		0	0	0	1	
	T2	0	1	0		0	0	0	1	
	T3	0	1	0		0	0	0	1	
	T4	0	1	0		0	0	0	1	
Left buccal occlusion	T1	0	2	0	0.46 ± 0.66	0	0	1	1	
	T2	0	2	0	0.5 ± 0.66	0	0	1	1	P=0.3277
	T3	1	2	0	0.63 ± 0.65	0	0	1	1	P=0.0428
	T4	1	2	0	0.63 ± 0.65	0	0	1	1	P=0.0428

The upper anterior and lower left segments remained stable in the first 3 months of retention: their worsening reached statistical significance at the sixth month of follow-up when the difference in the score between T1 and T4 became respectively 0.33 ± 0.48 points (P=0.0025) and 0.25 ± 0.44 points (P = 0.0109). The worsening of the left buccal occlusion was not statistically significant at T2 (P = 0.3277): in fact, the score increased from 0.46 ± 0.66 points at T1 to 0.5 ± 0.66 at T2. At T3, the difference between the scores was 0.17 ± 0.38, reaching statistical significance (P=0.0428); at T4, the same values were obtained. Some variables of the ABO CRE have changed during the follow-up (Table V).

Table V. *ABO CRE and its variables at the end of the treatment (T1), after 1 (T2), 3 (T3) and 6 (T4) months of orthodontic retention.*

		Median	Maximum	Minimum	Mean ± SD	10th percentile	25th percentile	75th percentile	90th percentile	p-value
ABO CRE	T1	50.5	78	21	51.38 ± 13.03	38	44	57.5	69	
	T2	48.5	76	26	49.79 ± 12.49	36	41	57	68	P=0.0805
	T3	47.5	75	33	50.71 ± 11.9	38	42	58.5	72	P=0.5578
	T4	49.5	78	28	51.54 ± 13.27	35	41	60.5	71	P=0.9139
Alignment / rotations	T1	14	26	5		8	10	22.5	25	
	T2	14	27	6		8	11	24	26	P=0.0195
	T3	14.5	30	7		9	11	24.5	28	P=0.0024
	T4	16.5	31	7		9	12	25	29	P=0.0001
Marginal ridges	T1	5.5	9	1	4.92 ± 2.19	1	4	6	7	
	T2	5	9	1	4.83 ± 2.14	2	3	6.5	7	P=0.5748
	T3	5	8	1	4.75 ± 2.21	2	3	6	8	P=0.4445
	T4	5	8	1	4.42 ± 2.32	1	2	6	7	P=0.0250
Buccolingual inclination	T1	7	17	1	7.5 ± 4.14	2	5	10.5	12	
	T2	7	17	2	7.63 ± 4.13	2	5	10.5	12	P=0.2656
	T3	6.5	17	2	7.42 ± 3.65	4	5	10	12	P=0.7233
	T4	6.5	17	2	7.33 ± 3.64	4	5	10	12	P=0.4770
Overjet	T1	7	16	1	7.17 ± 3.51	4	4.5	10	12	
	T2	6	13	1	6.75 ± 2.91	4	5	8.5	11	P=0.1703
	T3	7	13	2	7.13 ± 3.19	4	4.5	9.5	12	P=0.9326
	T4	6.5	13	1	7.25 ± 3.19	4	5	10	11	P=0.8984
Occlusal contacts	T1	9	17	2	9.17 ± 3.64	4	7	11.5	14	
	T2	7.5	13	2	7.71 ± 3.3	4	5	10.5	12	P=0.0042
	T3	7.5	12	3	7.04 ± 2.91	3	4.5	9	11	P=0.0002
	T4	6	13	2	6.63 ± 3.24	3	4	9	12	P=0.0004
Occlusal relationship	T1	4	15	0		2	2.5	7	10	
	T2	5	15	0		2	3	7.5	8	P=0.2514
	T3	6	15	2		2	3	8	9	P=0.0143
	T4	6	14	2		2	3	8	12	P=0.0101
Interproximal contacts	T1	0	4	0		0	0	1.5	4	
	T2	0	4	0		0	0	1	2	P=0.0256
	T3	0	4	0		0	0	1	1	P=0.0171
	T4	0	4	0		0	0	0.5	1	P=0.0305
Root angulation	T1	1	3	0	0.92 ± 0.97	0	0	1.5	2	
	T2	1	3	0	0.92 ± 0.97	0	0	1.5	2	
	T3	1	3	0	0.92 ± 0.97	0	0	1.5	2	
	T4	1	3	0	0.92 ± 0.97	0	0	1.5	2	

Among these, the "Alignment/rotations" showed a statistically significant difference between T1 and T2: the maximum and the minimum increased by 1 point (P=0.0195). At T3, the score increased to 14.5 points (P=0.0024), while at T4 it reached 16.5 points (P=0.0001). The "Marginal ridges" variable has improved instead. It started from a score of 4.92 ± 2.19 at T1 and reached 4.42 ± 2.32 points at T4: the difference between the scores proved to be statistically significant (P=0.0250). In addition to the marginal ridges, there was a reduction in the score of the "Occlusal contacts" variable: already one month from the end of the orthodontic treatment, the score decreased from 9.17 ± 3.64 to 7.71 ± 3.3 reaching statistical significance (P=0.0042). The score further decreased at T3 (7.04 ± 2.91; P=0.0002) and at T4 (6.63 ± 3.24; P=0.0004). On the other hand, the "Occlusal Relationship" variable has already worsened at T2 from 4 to 5 points (P=0.2514). Still, the statistical significance was reached at T3 (P=0.0143) when the variable was measured at 6 points. This score was maintained at T4, although the statistical significance increased (P=0.0101).

Interproximal contacts improved in the first six months of orthodontic retention. Already at T1 the 75th percentile changed from a value of 1.5 to a value of 1; this variation was statistically significant (P=0.0256). A further improvement occurred at T3: the 90th percentile went from 2 at T2 to 1 at T3 (P=0.3173 between T2 and T3). At T4, the scores were similar to those of the previous phase, although the 75th percentile changed

from a value of 1 (T3) to a value of 0.5 (T4; P=0.9760 between T3 and T4). The maxillary and mandibular II suffered a statistically significant worsening during the first six months of orthodontic retention (Table VI), while the dental arch widths did not change (Table VII). As regards the stability of the results obtained in the two arches, it is possible to state that no statistically significant differences were found at 6 months from the end of the orthodontic treatment (Table VIII).

Table VI. *Maxillary and mandibular Irregularity Index (II) at the end of the treatment (T1), after 1 (T2), 3 (T3) and 6 (T4) months of orthodontic retention.*

		Median	Maximum	Minimum	Mean ± SD	10th percentile	25th percentile	75th percentile	90th percentile	p-value
Maxillary II	T1	1.86	3.55	0.95	1.98 ± 0.75	1.12	1.42	2.29	3.34	
	T2	1.94	3.81	0.98	2.07 ± 0.81	1.14	1.33	2.7	3.26	P=0.2500
	T3	2.06	3.87	1	2.19 ± 0.82	1.21	1.42	2.9	3.08	P=0.0258
	T4	2.2	4.13	1.15	2.43 ± 0.91	1.24	1.68	3.14	3.77	P=0.0005
Mandibular II	T1	1.67	3.28	1.11		1.16	1.34	1.94	2.72	
	T2	1.78	3.32	1.16		1.18	1.32	2.15	3.11	P=0.0053
	T3	1.8	3.54	1.16		1.22	1.41	2.15	3.17	P=0.0001
	T4	1.85	3.6	1.22		1.26	1.43	2.25	3.28	P<0.001

Table VII. *Dental arch widths at the end of the treatment (T1), after 1 (T2), 3 (T3) and 6 (T4) months of orthodontic retention.*

		Median	Maximum	Minimum	Mean ± SD	10th percentile	25th percentile	75th percentile	90th percentile	p-value
Maxillary intercanine width	T1	34.84	37.43	29.91	34.42 ± 1.85	32.12	33.35	35.63	36.94	
	T2	34.44	37.5	29.62	34.45 ± 1.8	31.91	33.56	35.55	36.86	P=0.7683
	T3	34.32	37.69	28.86	34.37 ± 1.92	31.92	33.55	35.46	36.96	P=0.7216
	T4	34.17	37.9	28.55	34.27 ± 2.05	31.8	33.52	35.47	37.06	P=0.3639
Maxillary interpremolar width	T1	42.49	50.05	38.33	42.61 ± 2.66	39.27	40.85	44.27	45.66	
	T2	42	49.16	38.26	42.4 ± 2.55	38.97	40.86	43.6	45.77	P=0.1293
	T3	41.93	48.52	38.09	42.36 ± 2.48	38.8	41.13	43.5	45.82	P=0.16699
	T4	41.88	48.14	37.2	42.24 ± 2.47	38.96	41.2	43.36	45.08	P=0.0910
Maxillary intermolar width	T1	50.58	58.04	45.66	51.22 ± 3.34	46.71	48.39	53.5	55.39	
	T2	50.76	57.68	45.71	51.07 ± 3.29	47.41	47.92	53.26	55.61	P=0.0738
	T3	50.79	57.62	45.24	51.09 ± 3.37	47.07	48.09	53.44	55.76	P=0.2775
	T4	50.65	57.66	45.32	50.97 ± 3.34	46.83	48.05	53.38	55.92	P=0.0682
Mandibular intercanine width	T1	25.82	29.3	23.24	25.89 ± 1.5	23.9	24.97	26.58	28.16	
	T2	25.75	29.37	23.22	25.84 ± 1.51	24.16	24.65	26.29	28.29	P=0.4203
	T3	25.97	29.4	23.16	25.89 ± 1.54	24.41	24.62	26.27	28.66	P=0.9953
	T4	25.93	29.6	23.14	25.89 ± 1.55	24.41	24.63	26.27	28.66	P=1.000
Mandibular interpremolar width	T1	34.68	38.82	30.41	34.55 ± 1.81	32.72	33.33	35.65	36.94	
	T2	34.37	37.22	30.34	34.45 ± 1.59	32.9	33.25	35.55	36.21	P=0.4784
	T3	34.6	37.35	30.32	34.51 ± 1.67	32.86	33.13	35.62	36.66	P=0.8005
	T4	34.6	37.38	30.21	34.51 ± 1.66	32.82	33.33	35.66	36.63	P=0.8328
Mandibular intermolar width	T1	44.11	50.33	39.21	44.46 ± 3.09	40.56	42.51	46.92	49.37	
	T2	44.17	50.59	39.87	44.32 ± 2.86	40.36	42.23	46.28	48.47	P=0.2608
	T3	44.17	51.04	39.86	44.36 ± 2.91	40.64	42.33	46.28	48.3	P=0.5839
	T4	44.02	51.34	39.94	44.31 ± 3.06	40.19	41.93	46.25	48.56	P=0.4011

Table VIII. *Difference of the maxillary and mandibular Irregularity Index, the upper and lower segments (anterior, right and left) and the maxillary and mandibular dental arch widths (intercanine, interpremolar and intermolar) between the end of the treatment (T1) and the first six months of orthodontic retention (T4).*

	Median	Maximum	Minimum	Mean ± SD	10th percentile	25th percentile	75th percentile	90th percentile	p-value
Difference of the maxillary Irregularity Index between T1 and T4	0.47	1.67	- 0.49		-0.26	0.1	0.73	1.39	P=0.0613
Difference of the mandibular Irregularity Index between T1 and T4	0.16	0.84	0.02		0.04	0.07	0.37	0.46	
Difference of the upper anterior segment between T1 and T4	0	1	0		0	0	1	1	P=0.1317
Difference of the lower anterior segment between T1 and T4	0	1	0		0	0	0	1	
Difference of the upper right segment between T1 and T4	0	1	-1		0	0	0	1	P=0.9451
Difference of the lower right segment between T1 and T4	0	1	-1		0	0	0	1	
Difference of the upper left segment between T1 and T4	0	1	0		0	0	0	0	P=0.0588
Difference of the lower left segment between T1 and T4	0	1	0		0	0	0.5	1	
Difference of the maxillary intercanine width between T1 and T4	-0.11	1.23	-1.79	-0.15 ± 0.78	-1.26	-0.73	0.43	0.96	P=0.4151
Difference of the mandibular intercanine width between T1 and T4	-0.02	0.69	-0.67	0.00 ± 0.37	-0.57	-0.26	0.28	0.5	
Difference of the maxillary interpremolar width between T1 and T4	-0.32	1.55	-3.59		-1.17	-0.79	0.18	0.59	P=0.2713
Difference of the mandibular interpremolar width between T1 and T4	-0.12	1.41	-2.38		-0.7	-0.39	0.46	1.11	
Difference of the maxillary intermolar width between T1 and T4	-0.3	0.97	-1.62	-0.25 ± 0.64	-1.11	-0.7	0.27	0.53	P=0.6263
Difference of the mandibular intermolar width between T1 and T4	-0.3	1.85	-2	-0.16 ± 0.89	-1.07	-0.74	0.52	0.91	

Comparing the differences between the maxillary and mandibular II, the anterior superior and inferior segments, the superior and inferior right segments, the upper and lower left segments, and the maxillary and mandibular dental arch widths (intercanine, inter-premolar, intermolar) between T1 and T4, no statistically significant difference was found. Finally, regarding the efficacy between the Hawley retainer and the lower multi-stranded fixed retainer in maintaining the anterior teeth alignment, by comparing the differences of the

II, the anterior segments, and the maxillary and mandibular intercanine widths between T1 and T4, it can be stated that, although there were more variations in the upper arch, there was no statistically significant difference between the two orthodontic retainers.

DISCUSSION

The orthodontic treatment determined an overall improvement in the occlusion. Comparing our results (PAR index: from 18 points at T0 to 9 points at T1) with those of Onyeaso and Begole (PAR index: from 18.55 ± 9.34 points at T0 to 0.96 ± 1.80 points at T1) (20), they obtained an improvement in the occlusion greater than ours. The difference of the obtained values can be due to the following reasons: Onyeaso and Begole could have considered only the patients with the best orthodontic results; moreover, their measurements made with the caliper could be less accurate than ours, which were made through a dedicated software. Orthodontic treatment has led to an improvement in the alignment of the anterior sextants. The maxillary II, in fact, decreased from 5.49 mm (T0) to 1.86 mm (T1), while the mandibular from 5.59 mm (T0) to 1.67 mm (T1).

The two final scores are similar to those of Bjering et al. (21), who obtained a maxillary II of 2.0 ± 1.1 mm and a mandibular II of 1.5 ± 0.8 mm at the end of the treatment. The orthodontic treatment determined the expansion of the dental arches: the upper arch was expanded more than the inferior one. These results agree with what was reported by other Authors (22-24), who have shown that during the phase of dental alignment a certain degree of dentoalveolar expansion often occurs, necessary to correct the crowding and the occlusal relationship. Regarding the occlusal changes during the first 6 months of orthodontic retention, a statistically significant worsening of the occlusion was recorded according to the PAR index: from T1 to T4 the score rose from 8.75 ± 2.98 points to 9.88 ± 3.04 points. This difference was found to be greater than that obtained by Al Yami et al. (8) after a year of orthodontic retention (0.56 ± 6.4): however, it is difficult to compare these data with each other because the retention appliances that were used were not specified in that study.

In our work, the PAR index parameters that statistically significantly worsened were the anterior superior segment, the left inferior segment and the left buccal occlusion, while in the study of Al Yami et al. the worsening concerned all the parameters of the PAR index except the lateral occlusion, the anterior crossbite and the open bite. Regarding the trend of the ABO CRE, it did not present statistically significant changes during the follow-up. The parameters of the ABO CRE that were statistically improved during the period under review were: marginal ridges, occlusal contacts and interproximal contacts. These results are in agreement with what was reported by Hoybjerg et al. (9): the reduction of the score of the parameter "Occlusal Contacts" underlines how the posterior teeth seek stable contact with each other (settling) after the orthodontic treatment and how the upper Hawley retainer is an appliance that favors this phenomenon (10, 25). The improvement of the three aforementioned parameters also occurred in a study by Lyotard et al. (26) on occlusal changes after one month from the debonding in patients not subjected to orthodontic retentions. The parameters of the ABO CRE that have worsened in our work were "Alignment-rotations" and "Occlusal relation".

The worsening of the dental alignment, also present in the studies of Hoybjerg (9) and Lyotard (26), is mainly due to the instability of the upper anterior sextant: in fact, the maxillary II during the first six months of orthodontic retention increased from 1.98 ± 0.75 mm at T1 to 2.43 ± 0.91 mm at T4. Destang and Kerr (27) have shown that relapse may already occur during the retention period in a study that compared two protocols for the use of the upper Hawley retainer: the mean difference of the maxillary II over time reported by us (0.45 ± 0.55 mm) was found to be better than those reported by those two Authors (0.99 mm in the group who wore Hawley retainer for 6 months; 0.71 mm in the group that wore it for 1 year). On the other hand, the mandibular

II, although worsened, showed a more limited variation: its value at T1 was 1.67 mm, while at T4 it was 1.85 mm. From the comparison between the two variations of the II at T1 and T4 (0.47 mm for the maxilla and 0.16 mm for the mandible) a difference was found at the limits of the statistical significance (P=0.0613). However, it is possible to hypothesize that the major change in the upper anterior sextant depends on the type of retention appliance: in fact, the effectiveness of the Hawley retainer, being a removable appliance, depends on the patient's compliance; moreover, its application time is certainly lower than that of a fixed retainer.

At the level of the mandibular arch, on the other hand, the bonded retainer has led to a smaller variation in the alignment of the anterior teeth. However, even these teeth were not exempt from small movements. This is in line with what reported by other studies: in fact, Dahl and Zachrisson (28) described space reopening at the level of the inferior anterior sextant despite the presence of the fixed retainer in situ, while Katsaros et al. (29) reported cases of changes in torque and rotations of these teeth: these events did not occur in our work. The slight displacements of the teeth involved in the fixed retention were most likely caused by the deformation of the wire and the lack of passivity of the retainer as reported by Wolf et al. (30) and by Atack et al. (31). This latter, although her study was aimed at investigating the effectiveness of the fixed and of the Hawley retainer at the inferior arch, has reached conclusions similar to ours, that is, at one year of follow-up there are no statistically significant differences between the variations of the II in the two groups; however, this parameter changes more in the dental arch that is retained through the use of removable appliances.

From our investigations the increase in the score of the ABO CRE "Occlusal relationship" (4 points at T1 vs 6 points at T4), also occurred in the study of Hoybjerg (9), reflects the slight worsening of the occlusal relationship and alignment of the left emiarches: in fact, the median of the left vestibular occlusion of the PAR index passed from 0 to 1 and a difference in the average score of the lower left segment was recorded (0.25 ± 0.44 points between T1 and T4). This difference between the left and right sides of the mouth could be justified because the sample showed a greater number of variations in the interproximal contacts (diastema closure or reopening) at the level of the left emiarches. Overall, the upper and lower dental arch widths dunderwent nostatistically significant change. These results are in agreement with what was reported by Destang and Kerr (27) for the upper arch and by O'Rourke et al. (32) for the lower arch. In our work, the maxillary widths narrowed more than the mandibular ones: this is due to the greater expansion of the upper arch compared to the inferior one during the orthodontic treatment and therefore to its greater tendency to relapse (5). The intercanine mandibular width has proved to be more stable than the interpremolar and the intermolar ones: the reason lies in the fact that, since the multi-stranded fixed retainer extended up to the canines, the stability of the posterior mandibular teeth depends only on their settling with the antagonists (32).

CONCLUSIONS

A slight worsening of the dental occlusion was found according to the PAR index but not according to the ABO CRE index during the first six months of orthodontic retention, using the upper Hawley retainer and the lower multi-stranded fixed retainer. In particular, the dental alignment and the occlusal relationship worsened. However, there was also an improvement in posterior occlusal contacts, marginal ridges, and interproximal contacts. The worsening of the alignment of the anterior sextants was statistically significant for both arches. Although the maxillary II worsened slightly more than the mandibular one, the variation was similar. Upper and lower dental arch widths did not undergo any statistically significant changes during the follow-up; however, the maxillary widths narrowed more than the mandibular ones, most likely as a consequence of the greater expansion occurred during the orthodontic treatment.

In the coming years, better algorithms and new, fully automated methods of 3D comparison will probably be developed, making comparison even more precise and dependable (33). At the same time, less compliance will be required during retention and orthodontic treatment (34).

The stability of the results obtained with orthodontic therapy at the two arches was substantially similar, as was the effectiveness of the upper Hawley retainer and the lower multi-stranded fixed retainer in maintaining the alignment of the anterior teeth in the first six months of orthodontic retention. Overall, occlusal changes during the follow-up were minimal and the stability of the orthodontic treatment was not clinically compromised.

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Retrospective Study

Postoperative pain evaluation and pain management in implantology: retrospective study and literature review

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ABSTRACT

To evaluate post-operative pain in a sample of patients undergoing implant prosthetic rehabilitation. To accomplish a literature review about pain perception and pain management in implantology; to assess patient satisfaction according to current studies. A sample of 23 consecutively treated patients was enrolled in the study. To fulfill the research inquiries, a questionnaire about postoperative pain was administered to all patients every day for the first 7 days following implantology. Data were collected, and statistical analysis was performed. A literature review was conducted to compare our results to those of other similar studies. Post-operative pain is a fairly common problem in patients undergoing implant-prosthetic rehabilitation, and it varies in intensity and duration.

INTRODUCTION

Post-operative pain management after implant surgery is a rather important issue to consider in dental care (1-4). Post-operative pain is mainly due to the surgical insult to the tissue: the inflammatory process that develops in the surgical site releases prostaglandins and simultaneously sensitizes peripheral nerve endings, resulting in electrophysiological changes and pain sensation (5, 6). Moreover, an emotional reaction to surgery has been demonstrated (7). Tingting et al. investigated the degree of pain after implantation. They noted that most patients and surgeons consider postoperative pain as a natural phenomenon that can only be endured (7). Still, despite this belief, pain should be managed and kept under control. Pain management is closely related to patient satisfaction in implantology.

In 1986, Albrektsson et al. first described principles for successful implantology: health of the surgical site, surgical technique, prosthetic elements, the biocompatibility of materials, implant macroscopic structure, and surface. None of these features should be considered second to the others to achieve optimal results (8). Since the 80s, implant technologies have dramatically improved with the introduction of short implants, the design of new implant-abutment interfaces, and new implant surfaces (9).

Today, implant surfaces are classified as smooth, minimally rough, moderately rough, or rough. Smooth and minimally rough surfaces have reduced bone integration in comparison to other surfaces. Conversely, some research indicated that moderately rough surfaces may elicit a more favorable bone response than excessively rough surfaces. Some authors have proposed that moderately rough surfaces (with a roughness between 1 and 2 μm) offer the optimal balance between adhesion and promotion of osseointegration(10-20). In addition, there are now numerous implant surface lavage techniques that increase the roughness of the implant and promote its osseointegration process, such as acid treatment of titanium implant surfaces, which promotes the adhesion and growth of new tissue (10, 21-23, 23-27). Today, we might add these principles to the list for successful pain management.

The aim of this study was to evaluate post-operative pain in a sample of patients undergoing implant prosthetic rehabilitation. Moreover, we wanted to conduct a literature review about pain perception and pain management in implantology to evaluate patient satisfaction according to current studies.

MATERIALS AND METHODS

Retrospective observational study

This is a retrospective observational study. The sample of patients consisted of 23; all of them met the inclusion and exclusion criteria. The type of implants employed for the prosthetic rehabilitation was anodized, ultra-hydrophilic, and multi-zone; moreover, all implants were characterized by a gradually changing topography from the collar to the apex, becoming porous and moderately rough towards the apex. To fulfill the research inquiries, the patients completed an ad hoc questionnaire to assess postoperative pain. The questionnaire included the Visual Analogue Scale (VAS) from 0 to 100 and assessed the patient's pain from the surgery date until day 7 (Table I).

Table I. *Visual analogic scale.*

1- Indicate pain intensity from 0 (no pain) to 100 (maximum pain) in the 24 hours following implantology.
0_____50_____100

2- Indicate pain intensity from 0 (no pain) to 100 (maximum pain) 2 days after implantology.
0_____50_____100

3- Indicate pain intensity from 0 (no pain) to 100 (maximum pain) 3 days after implantology.
0_____50_____100

4- Indicate pain intensity from 0 (no pain) to 100 (maximum pain) 4 days after implantology.
0_____50_____100

5- Indicate pain intensity from 0 (no pain) to 100 (maximum pain) 5 days after implantology.
0_____50_____100

6- Indicate pain intensity from 0 (no pain) to 100 (maximum pain) 6 days after implantology.
0_____50_____100

7- Indicate pain intensity from 0 (no pain) to 100 (maximum pain) 7 days after implantology.
0_____50_____100

In addition, information about pain medications was noted down by the patients in order to record the adopted analgesic regimen (Table II).

Table II. *Painkillers survey.*

- How many and which analgesics did you take in the 24 hours after surgery?
- How many and which analgesics did you take on the 1st day after surgery?
- How many and which analgesics did you take on the 2nd day after surgery?
- How many and which analgesics did you take in the 3rd day after surgery?
- How many and which analgesics did you take on the 4th day after surgery?
- How many and which analgesics did you take on the 5th day after surgery?
- How many and which analgesics did you take on the 6th day after surgery?

Once data were collected, statistical analysis was performed to determine the influence that each considered patient's variable had on pain management following implant surgery. The considered items were gender, rehabilitated arch, implant location in the maxilla (anterior, posterior, both anterior and posterior or All-On-Four), surgical technique (classic or guided), the timing of insertion, mini sinus lift performance, use of membrane and bone substitutes (e.g., heterologous). Diagrams and tables with data from patients who joined the study are presented below. The sample is homogenous in terms of patients' gender and treated arch. At the same time, there is less homogeneity concerning implant location in the maxilla, surgical technique adopted, and timing of implant insertion, as well as there is little or no homogeneity in the sample for patients undergoing mini lift of maxillary sinus and treated with heterologous bone substitute and membrane.

Patient satisfaction: literature review

A systematic literature review was conducted to identify relevant studies on the topic. Initially, 107 studies were identified, and afterward, 13 papers met the inclusion criteria and were selected for review. All studies were published in PubMed, Scopus, Ovid, and Cochrane. Results are presented in the dedicated section.

RESULTS

In the sample of patients, there were 11 males and 12 females; 48% of patients underwent inferior arch treatment, 52% underwent superior arch treatment, 91% had classic implantology, and 9% had prosthetically guided implantology (Fig. 1).

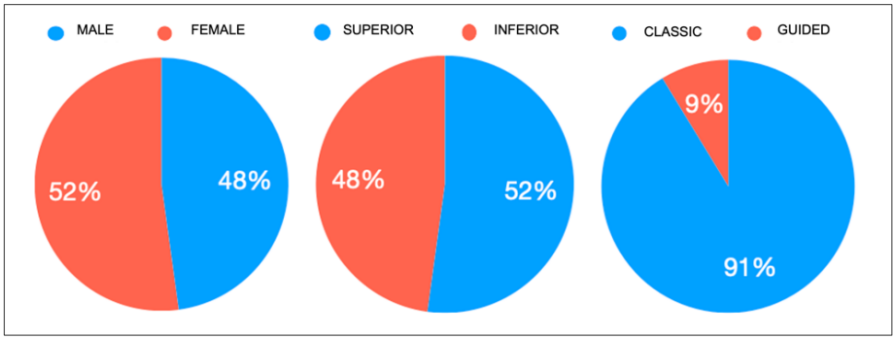

Fig. 1. *The graphs present the following data: gender percentages within the sample (on the left); percentages of the treated dental arch upper or lower (in the center); percentages of applied implantology planning.*

To collect data about postoperative pain, an Excel spreadsheet was created and filled in with patient data and information about surgery type. Graphs were then created, and statistical analyses were performed. Figure 2 shows the pain trend from the day of surgery (t0) to day 7 (t6). Pain was scored on a VAS scale from 0 to 100.

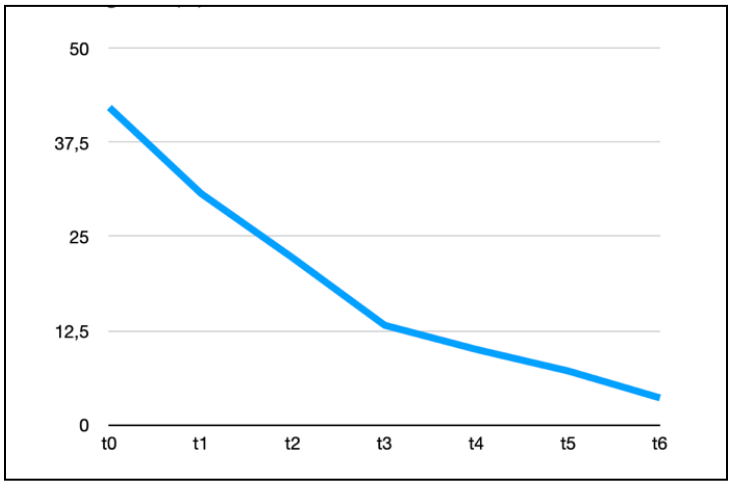

Fig. 2. *Pain trend from implantology day (t0) to the 7th day after the procedure (t6). Values were assested on a Visual Analogic Scale from 0 (no pain) to 100 (extreme pain).*

The graph analysis shows that pain peaks 24 hours after surgery, contrary to the common belief that it occurs between 24 to 48 hours following the procedure.

Statistical analysis

ANOVA test was employed to perform statistical analysis of the collected data. ANOVA evaluates whether there are statistically significant differences between the average value of considered variables among different groups of observations. Multiple variables were considered (gender, sex, implant location, type of surgery, etc.); moreover, the pain score for each patient at different pre-fixed time points was evaluated (t0, t1, t2, t3, t4, t5, t6). The aim was to determine whether there was a statistically significant difference in the pain experienced by patients relating to explanatory variables.

To perform the ANOVA test, dedicated statistical software was used: the software automatically calculated p-values corresponding to each variable. The p-value represents the probability that the observed differences between the groups are due to chance rather than to a true difference in means. A p-value inferior to the predetermined significance level (typically 0.05) indicates that the observed differences are statistically significant (Table III).

Table III. *Statistical analysis of the collected data (ANOVA test).*

Item	Test ANOVA
Gender	0.3969
Involved Arch	0.6895
Maxillary localization	0.1274
Number of Implants	0.0581
Surgical Technique	0.2085
Implantology timing	0.3493
Mini-sinus-lift	0.1368
Membrane and synthetic bone	0.0496

The following inferences can be drawn:

- *Sex*: The p-value obtained for the variable "Sex" is 0.3969. The study also determined whether there were any statistically significant differences in pain experience depending on patient gender. The p-value indicates that there were no statistically significant differences between male and female patients.
- *Upper arch vs Lower arch*: The p-value for this item is 0.6895, indicating that there are no statistically significant differences related to the dental arch involved in implantology.
- *Maxillary Localization*: The p-value obtained for this variable was 0.1274, indicating that there are no statistically significant differences in the pain experienced by patients according to the area of the arch involved in implantology.
- *Number of implants*: The p-value for the variable “Number of implants” is 0.0581, indicating no statistically significant differences in the pain experienced by patients depending on the number of implants.
- *Surgical technique*: The p-value obtained for the variable "surgical technique" was 0.2085. This indicates that there are no differences between surgical approaches to implantology.
- *Timing of Insertion*: The p-value for the variable "Timing of Insertion" is 0.3493, indicating that there are no statistically significant differences in pain levels based on the timing of insertion.
- *Mini Rise*: The p-value obtained for the variable “Mini Rise” is 0.1368. This indicates that there are no statistically significant differences in the pain experienced by patients undergoing or not Mini Rise.
- *Membrane and heterologous bone substitute*: The p-value for the variable "membrane and heterologous bone substitute" is 0.0496, below the 0.05 significance level, indicating that there are statistically significant differences in the pain experienced by the patient depending on the use of the membrane or heterologous bone substitute.

Considering the results, the only factor that can be regarded as statistically significant is the use of membrane and heterologous bone substitutes, with a p-value of 0.0496. It is important to note that the number of implants also contributed to the analysis. A value approaching significance ($p = 0.0581$) was observed. Another study with a larger sample size (n=137) indicated that the number of implants is associated with greater pain in the 24 hours postoperative ($p<0.05$). The result was statistically significant at the 0.001 level (7).

Table IV summarizes the study results. The table reveals that the duration of surgery is a significant factor affecting the pain experienced by patients in the 24 hours following the procedure.

Table IV. *Study results of pain experienced by patients.*

Related factors	Case	NRS score 24 h after operation	t	P
Number of implants				
Single	110	1.78±0.49	7.229	0.000
Multiple	27	2.55±0.52		
Gender				
Male	76	2.11±0.42	1.781	0.077
Female	61	2.25±0.50		
Degree of education				
High school and below	81	2.35±0.87	1.685	0.094
College or above	56	2.11±0.74		
Smoking history				
Yes	36	2.22±0.39	1.539	0.126
No	101	2.09±0.45		
Operation time				
<1 h	95	1.47±0.43	15.160	0.000
≥1 h	42	2.60±0.33		

Related factors	Case	NRS score 24 h after operation	t	P
Experience of implant surgery				
Yes	25	2.05±0.66	1.759	0.081
No	112	2.26±0.51		
Postoperative ice compress				
Yes	103	2.10±0.52	1.509	0.134
No	34	2.26±0.47		
Preoperative anxiety				
Yes	39	2.29±0.55	1.678	0.096
No	98	2.08±0.70		

Analgesic therapy: study results

In the sample of 23 patients, 17 declared having taken analgesic therapy. Data regarding the drugs taken by patients are summarized in the graph below (Fig. 3).

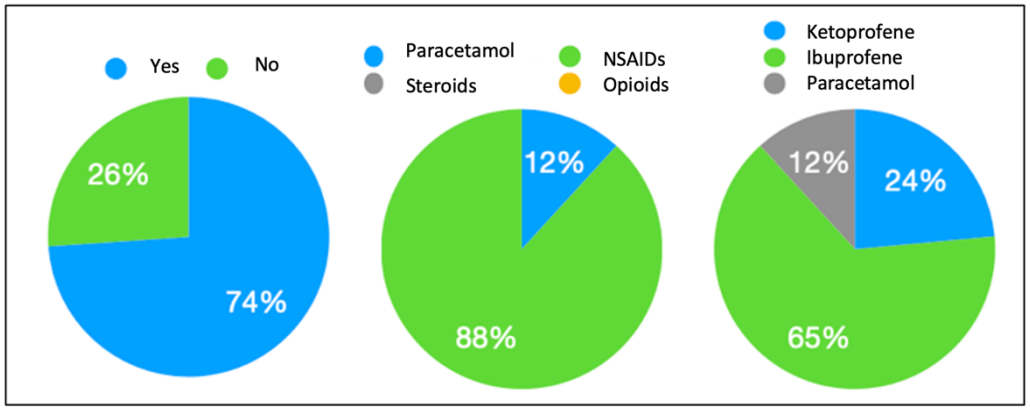

Fig. 3. *The graphs present the following data: percentages of patients who did and did not took drugs after implantology (on the left); percentages of patients who took non-steroidal anti-inflammatory drugs and paracetamol, respectively (in the center); percentages of painkillers taken by the patient within the sample.*

Nonsteroidal anti-inflammatory drugs (NSAIDs) were taken by 15 patients. Among the patients who took NSAIDs as analgesics, 11 patients employed ibuprofen, 4 patients took ketoprofen, Paracetamol was taken by 2 patients, and Corticosteroids as well as Opioids were not taken by any patient. Overall, 74% of patients received analgesic therapy after implantology. Among non-steroidal anti-inflammatory drugs (NSAIDs), 88% utilized ibuprofen, followed by ketoprofen. Finally, the number of tablets taken per day on different days was recorded: the graph below illustrates the trend. Data clearly demonstrate a reduction in analgesic intake over time (Fig. 4).

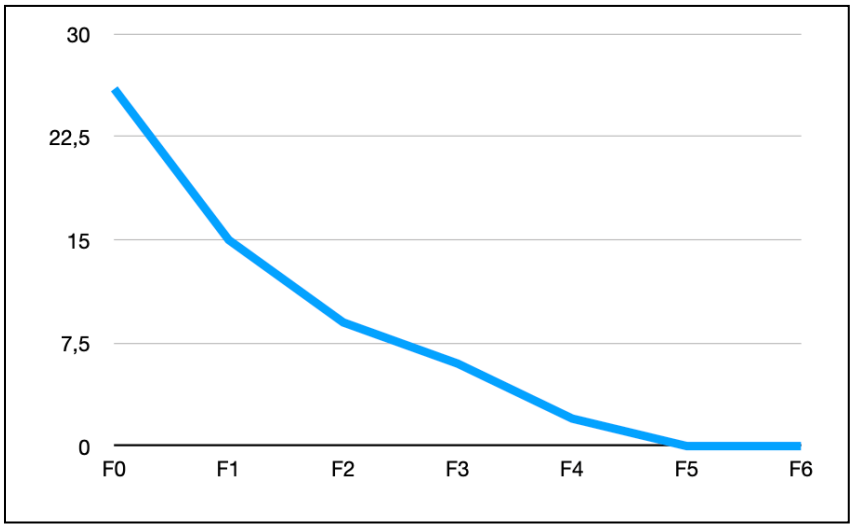

Fig 4. *Decreasing trend in analgesics intake in the hours/days following the procedure.*

Patient satisfaction: literature review

The literature review found that patients' satisfaction with comfort ranged from 75.3% to 99.5%, with a mean of 90.8% and a standard deviation of ±2.6% (Fig. 5). The perception of improved chewing function takes satisfaction values ranging from 69.9% to 100%, with a mean of 92.1% and a standard deviation of ±2.4%. Table V shows the results of the 13 studies included in the review.

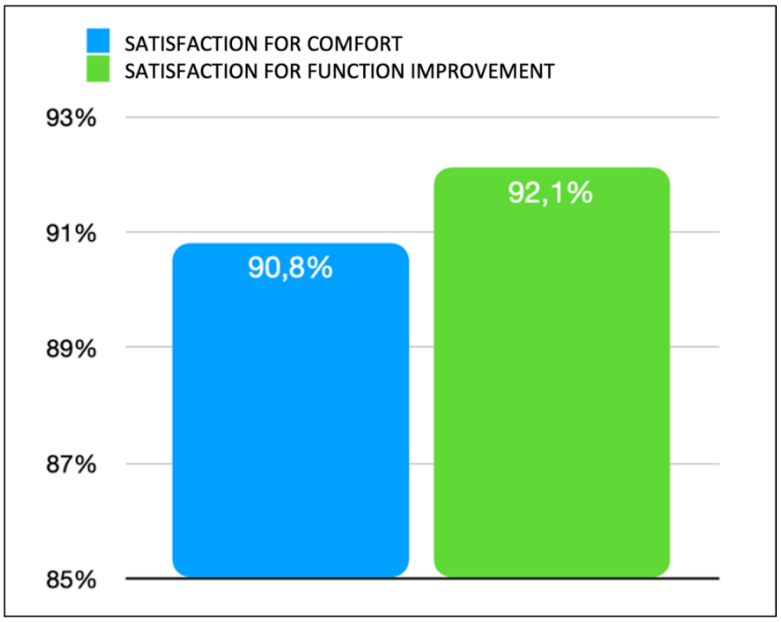

Fig. 5. *Data reported from literature: average extent of patient satisfaction in terms of comfort and function improvement.*

Table V. *Results of the 13 studies included in the review.*

Author	Sample size	Intervention	Comfort outcome	Function outcome
(**Hammerle et al. 2011**)	127	Single implants. Submerged versus transmucosal healing	Submerged: 75% excellent 24% good 0% fair 1% poor Transmucosal: 80% excellent 20% good 0% fair 0% poor	Submerged: 72% excellent 28% good 0% fair 0% poor Transmucosal: 76% excellent 24% good 0% fair 0% poor
(**Cochran et al. 2011**)	200	Single or multiple implants for fixed partial arch restoration	Submerged: 92.1% excellent 7.4% good	Submerged: 92.4% excellent 6.8% good
(**den Hartog et al. 2011**)	62	Single implants; Immediate non-occlusal loading versus conventional loading	N/A	18 months: 97% satisfied
(**Adler et al. 2016**)	400	Single or multiple implants for screw or cement retained crowns	'I have experienced felt problems with my implants": Yes: 10% Yes once: 22% I don't know: 4% No: 64%	'I am comfortable chewing with my implants": Yes: 81% Enough: 15% I dont know: 2% No: 2%
(**Pjetursson et al. 2005**)	104	Single or multiple implants for crowns or fixed partial dentures	"Chewing comfort": Definitely: 90% Enough: 7% I don't know: 1% Not so: 0% Definitely not: 1% No answer: 1%	N/A
(**Hartog et al. 2014**)	153	Single implants in the maxillary esthetic zone	N/A	18 months: 4.8
(**Dierens et al. 2009**)	50	Immediate loading of dental implants with a provisional bridge and then a fixed prosthesis	One year (mean): 94.2%	One year (mean): 97.5%
(**Derks et al. 2015**)	3827	Single or multiple implants for implant-supported restorative therapy	Have you experienced any complications?: Never: 64.6% Yes, but rarely: 24.7% Yes, frequently: 6.0% No answer: 4.7%	Greatly improved: 53.9% Somewhat improved: 16.0% No improvement: 28.1% No answer: 2.0%
(**Bruyn et al. 1997**)	61	Single or multiple implants for implant-supported restorative therapy	N/A	"Eating comfort" after 3 years: 5: A&B 92%, C85% 4: A&B 5%, C 15% 3: A&B 0%, C 0% 2: A&B 0%, C 0% 1: A&B 3%, C 0% 0: A&B 0%, C 0%
(**Kronstr et al. 2004**)	42	21 with tooth and implant supported fixed prosthesis and 21 with implant supported fixed prosthesis	TISP: 8.5 ISP: 8.4	TISP: 8.2 ISP: 8.8

(Tey et al. 2016)	206	Single or multiple implants for implant-supported single crown	23.8% felt more secure with teeth 50.5% perceived no difference 24.8% preferred implants	83.6%
(De Lima et al. 2012)	52	Single or multiple implants for implant-supported fixed partial treatment or single crowns	Mean: FPDs: 9 Implant- Supported Single Crowns: 9.4	Mean: FPDs: 9 Implant- Supported Single Crowns: 9.3
(Preciado et.al 2013)	131	Patients wearing screw-retained implant restorations	N/A	91.6%

DISCUSSION

Postoperative pain

Data analysis revealed that the intensity of postoperative pain reaches its peak within the first 24 hours following surgery. This finding is contrary to the commonly held belief that postoperative pain persists for a far more extended period. Diversely to what is generally reported in the literature, the peak in the study group postoperative pain lasts 24 hours after surgery, as rarely infections and inflammations hesitate in persistent nerve damage (28). Statistical analysis demonstrated that using a membrane and heterologous bone substitute significantly impacted postoperative pain. In contrast, other variables, including gender, arch involvement, maxillary location, surgical technique, timing of insertion, and the presence of a mini sinus lift, exhibited no statistically significant differences. Finally, as reported in a study with a larger sample size, the number of implants inserted might increase postoperative pain.

Therapy management

In their systematic review of randomized clinical trials, Khouly et al. stated that postoperative pain following implant surgery might be effectively treated by a short-term therapy; notwithstanding, the authors could not precisely identify what the most effective analgesic medication in dental implant surgery is. According to the authors, there is insufficient evidence to recommend or discourage painkillers or analgesics after dental implant surgery(1). In the present study, 74% of patients received drug therapy as part of their treatment protocol. Of these, 80% utilized nonsteroidal anti-inflammatory drugs (NSAIDs), and the remaining 20% of patients opted for paracetamol. No statistically significant differences emerged between the use of NSAIDs and steroids. Drug intake decreased gradually in the 6 days following the procedure. Undoubtedly, we concord with the findings by Khouly et al., who affirmed that analgesic prescription should always consider the patient's medical history as this often increases the success of pain treatment and shortens the treatment period, reducing potential adverse effects. Owing to these results, an algorithm for pain management was developed to optimize analgesic and anti-inflammatory therapy and to minimize side effects in implantology.

Patient satisfaction

Most studies included in the review reported high levels of patient satisfaction, with an average of 90.8% of patients. Functional results were also highly evaluated, averaging 92.1% of satisfied patients. A comparison of submucosal and transmucosal healing methods revealed that both methods are valid and produce satisfactory results in terms of comfort and function. However, transmucosal healing appears to offer additional advantages in terms of aesthetic results.

In our study, most patients expressed a high level of satisfaction with treatment outcomes. Moreover, both single and multiple implants have demonstrated a high success rate, with a low incidence of complications in the long term. Patients reported a high degree of comfort in the chewing and good function of implant-supported fixed prostheses. Moreover, the technique of immediate loading seemed to achieve optimal outcomes both in terms of aesthetics and functionality.

CONCLUSIONS

The study broadens the knowledge of postoperative pain in implant-prosthetic rehabilitation and offers an assessment of patient experiences, most used pharmacological therapies, and pain-management strategies. The quality of care provided to implantology patients in the postoperative period should never be underestimated. Adequate pain control seems to guarantee greater patient satisfaction.

- implantology patients' satisfaction is a key indicator of the success achieved by implant-prosthetic rehabilitation. Patients' satisfaction is generally high, and both function, comfort, and aesthetics are scored positively.
- the number of positioned implants, the duration of surgery, and the use of a membrane and heterologous bone substitute have been associated with an increase in postoperative pain.
- in the postoperative period, patients taking nonsteroidal anti-inflammatory drugs or corticosteroids seemed to obtain adequate control of postoperative pain. No significant differences in terms of efficacy have been observed between these molecule categories. Selective COX-2s have been proven to interfere with the osseointegration process.
- the proposed algorithm considers the multiplicity of treatment variables: we suggest considering it to manage pain and potentially reduce implant failure risk.
- further research is recommended to ascertain the efficacy of specific drugs, particularly anti-inflammatory and anti-edematous drugs, which will undoubtedly require further investigation to better identify key factors that influence the degree of patient satisfaction in implant surgery.

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Preliminary Study

New titanium mesh design method in customized bone regeneration of the jaws: preliminary study on a sample of 11 patients

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ABSTRACT

The aim of this study is 1) to present a new method of virtually-designed custom made scaffolds to be employed in customized bone regeneration (CBR) for segmental jaw atrophies and 2) to evaluate long-term clinical results in terms of bone regeneration success and implant rehabilitation success. A total of 11 patients with edentulousness and bone atrophy in a localized area of the mandible or the maxilla were recruited for the study. To fulfill the research inquiries, CT images of the pre-regeneration mandibular or maxillary arch of each patient were collected. A dedicated Mevislab 2.4 software was employed to virtually design custom bone regeneration meshes designed to fit the atrophic sector of each patient's mandible or maxilla. Subsequently, a second Meshmixer software was used to refine the margins of each of the designed meshes. All patients underwent oral surgery, during which a mixture of autologous and heterologous bone in a 1:1 proportion was grafted into the atrophic site, a custom-made mesh was placed, and a resorbable membrane was inserted. The mesh was removed after this procedure, and implant rehabilitation was performed. All patients underwent the bone regeneration procedure, with eight undergoing titanium mesh removal. A total of seven patients completed implant rehabilitation. Average horizontal bone augmentation was 3.525 ± 1.36 mm; average vertical bone augmentation was 4.45 ± 2.22 mm. Implant survival was 92.85%. During the healing phase, complications occurred in 9.09% of patients. The use of dedicated software, Mevislab 2.4 and Meshmixer, for titanium mesh design is an accurate, predictable, effective, and quick-to-use method. The learning curve for design is uncomplicated and rapid. Mesh exposure does not necessarily lead to bone graft failure; this complication can be treated by chlorhexidine aids.

INTRODUCTION

Conceived and introduced by Dahlin in 1988, Customized Bone Regeneration (CBR) (1, 2) is a bone regeneration technique used in dental and maxillofacial fields to recreate adequate bone tissue regeneration as a preliminary step to the placement of dental implants in implant-retained jawbone rehabilitation (3–7). Generally, bone defects are due to post-extraction sites, post-excision cyst sites, bone sites damaged by peri-implantitis, or sequelae of dental trauma in childhood (8). CBR requires three-dimensional augmentations of the alveolar ridge. Given that implants require an adequate tissue quantity surrounding the implant surface, proper implant placement cannot be separated from adequate bone rehabilitation.

Whatever the defect to treat (5, 9), two fundamental elements are mandatory in successful bone regeneration: bone augmentation materials and membranes. In recent years, several bone regeneration techniques using different materials, both resorbable and non-resorbable, have been proposed to restore bone volumes for implant placement (10, 11), given that nowadays, the minimal bone quantity is related to the type of implant rehabilitation being considered for the specific patient (12).

Tables I and II show that multiple regeneration materials and resorbable scaffolds are available for CBR (13-15); titanium meshes are classified as non-resorbable scaffolds (16-20). Titanium mesh creates and maintains the space necessary for bone regeneration: it protects the bone defect from the proliferation of rapid epithelial and connective tissue cells (6, 21) so that osteoprogenitor cells are capable of growing. CBR is a promising method for the rehabilitation of alveolar bone defects due to its replicable protocol and excellent results achieved in the long term.

Table I. *Resorbable and non-resorbable membranes.*

REASORBABLE MEMBRANES		NON-RESORBABLE MEMBRANES
Biological Origin	Synthetic Origin	Synthetic Origin
Collagen I and III Silk	Ac. Polylactic (PLA) Ac. Polyglycolic acid (PGA) Ac. Polylactic + Polyglycolic Polyurethane Polyethylene glycol (PEG) Polyester (POE)	Politetrafluoroetilene (PTFE) Expanded Politetrafluoroetilene (e-PTFE) Dense Politetrafluoroetilene denso (d-PTFE) Expanded Polytetrafluoroethylene (e-PTFE) + Titanium Grade 2 Titanium modelled at the time of surgery Custom-made Titanium

Table II. *Bone augmentation materials.*

BONE AUGMENTATION MATERIALS	
Autografts	Obtained from the same individual.
Allografts	Obtained from another individual within the same species.
Xenografts	Obtained from another species.
Alloplastic materials	Synthetically derived

A site treated by CBR heals similarly to a fracture. In the first days, the hemostasis phase occurs with the formation of a blood clot; the coagulation cascade leads to a fibrin clot that stops the bleeding. In the following three weeks, macrophages remove the clot, and granulation tissue takes place; this tissue is rich in blood vessels and allows the migration of endothelial and mesenchymal cells. The third phase involves osteoconduction; finally, preosteoblasts migrate toward the site where bone neoformation will occur. The fourth phase occurs after four to six weeks with the formation of primary bone, known as woven bone or woven bundle bone, which is the result of rapid expansive growth (up to 60μm per day) to fill the spaces initially occupied by blood clots (22). Subsequently, the woven bone will be remodeled and replaced with secondary lamellar-structured bone from the sixth week of the healing process.

The aim of the study is to describe a new design method of scaffolds for customized bone regeneration. The study also aims to compare the advantages and disadvantages of this protocol. We were interested in verifying whether the in-house-project of scaffolds results in better surgical planning and saves time in scaffold design and fabrication. Furthermore, this preliminary study is meant to pave the way for realizing resorbable scaffolds and have them printed with type I and III collagen bio-inks (23, 24).

MATERIALS AND METHODS

A preliminary retrospective longitudinal study was conducted on a sample of 11 patients with edentulous mandibular or maxillary sectors with residual bone size inferior to 8mm in height and 5mm in width. These parameters made the mandible unsuitable for implant treatment. Medical history and CT scans were collected for each patient enrolled in the study. Titanium meshes were designed following the steps described below.

Mesh design

Preliminary design steps were performed in Mevishlab 2.4, then Meshmixer was employed to finalize mesh contours. Detailed design phases are presented below.

1. *Selection of region of interest.* Using a visualization tool to analyze the three-dimensional CT image in the three orthogonal planes, the operator selects the orthogonal plane of work and the minimum volume affected by the defect (Region of Interest, ROI), which will be the subject of guided bone regeneration (Fig. 1).

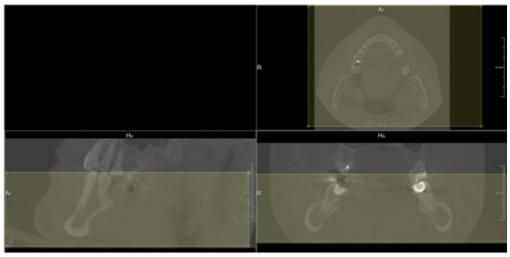

Fig. 1. *Region of Interest (ROI) selection on CT.*

2. *Hard Tissue Segmentation.* This step is accomplished through a semiautomatic procedure called Region Growing, which requires the operator to select one or more voxels defined as seeds and the range of Hounsfield values (Fig. 2).

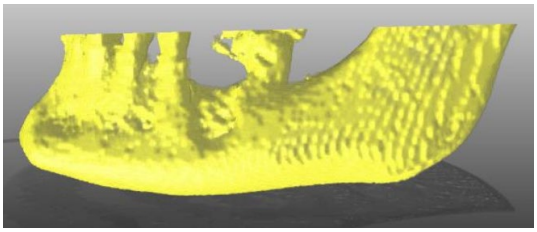

Fig. 2. *Mandibular segmentation: a 3D model of the mandible is created by the dedicated software Mevishlab 2.4.*

3. *Membrane profile design.* The design of the three-dimensional membrane profile is accomplished by interpolation of two-dimensional figures drawn by the operator in specific sections of interest. The operator performs several steps in each section:
   Step 1. The initial step is delineating the fundamental contour, represented by an ellipse of variable dimensions (Fig. 3).
   Step 2. The subsequent step involves the positioning of the contour, which can be enhanced through the application of rototranslation operations (Fig 3).

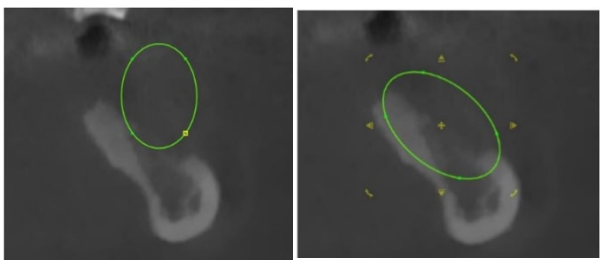

Fig. 3. *Delineation of the fundamental contour.*

Step 3: The contour shape is modified.
The shape of the ellipse can be modified to align with the patient's morphology through a variety of operations, including scaling, local deformations with variable size, augmentation, and/or subtraction of areas drawn freehand (Fig. 4). In order to facilitate the design process, the operator may utilize measurement tools that provide the distance in millimeters between two user-selected image points.

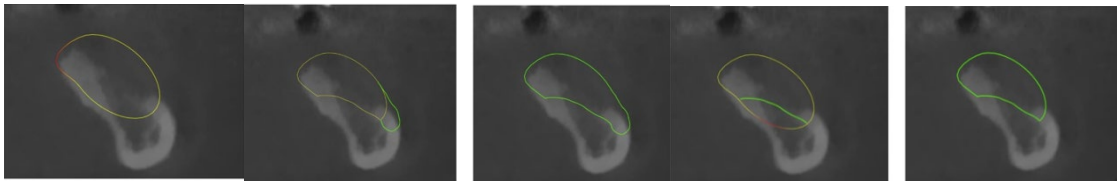

Fig. 4. *The contour shape is modified.*

4. *Interpolation*. The two-dimensional shapes thus created will then undergo an interpolation process, resulting in a three-dimensional object (Fig. 5). The hard tissue will be subjected to a morphological dilation filter with a spherical kernel of variable size, determined by the operator. The "object" will then be subtracted from the volume obtained from the interpolation operation (Fig. 6). The accuracy of the work is verified using a three-dimensional rendering tool that allows simultaneous visualization of the three objects: the original CT, the segmentation result (hard tissue), and the membrane profile (Fig. 7). The fusion of the three objects can then be visualized by roto translation or zoom operations, clipping according to orthogonal planes, and orthogonal plane transparency operations. In addition, the tool allows for the variation of the degree of transparency of the three objects, which aids in the analysis.

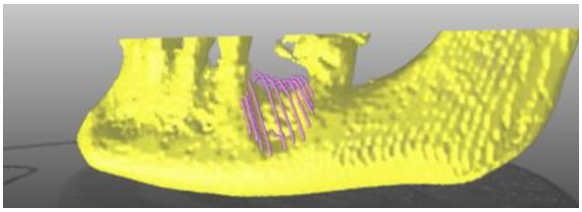

Fig. 5. *Design before interpolation.*

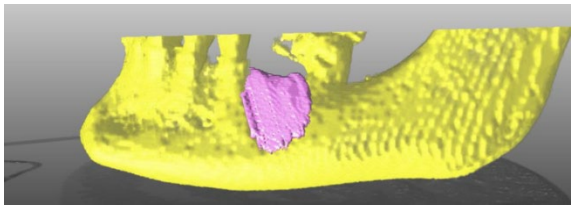

Fig. 6. *Result after interpolation.*

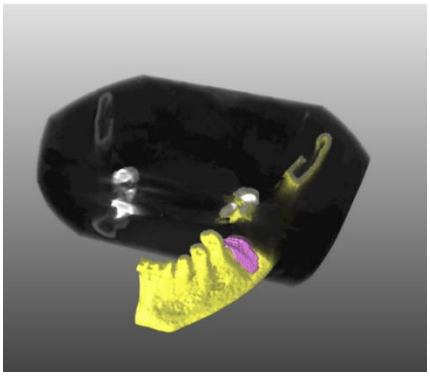

Fig. 7. *Rendering tool in three dimensions.*

5. *Thickening*. The obtained profile is then processed by means of a morphological dilation filter with a variable-size spherical kernel (3 voxels in x, y, z). This process creates an initial design of the membrane (Fig. 8).

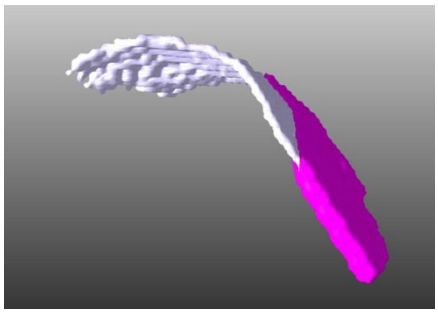

Fig. 8. *Membrane thickening.*

6. *Finishing the design in Meshmixer*. The final stage of the design process consists of completing the surface obtained in Meshmixer. The final shape is achieved by using dedicated tools within the software, including Flatten, Inflate, RobustSmooth, and ShrinkSmooth, which all aim to sculpt 3D objects (Fig. 9).

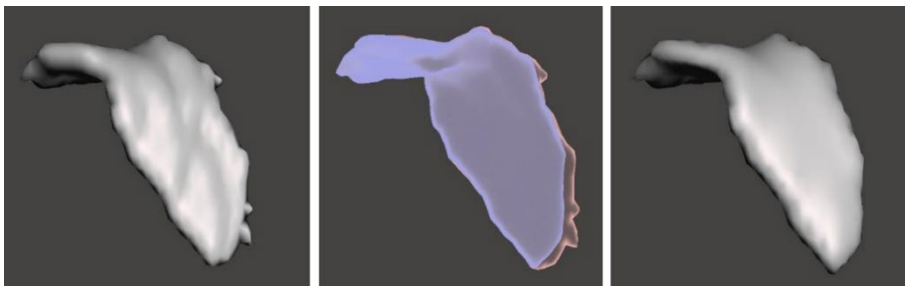

Fig. 9. *Membrane refinement with Meshmixer.*

The mesh design is finally checked by the team of oral surgeons who will perform the CBR procedure. Once the virtually designed membrane is deemed ready for printing, it is sent to the manufacturing company. It is sterilized in a steam autoclave and ready for clinical use.

Scaffold printing

The pivotal point of the study was scaffold printing using a BIOX Cell Ink 3D printer and bio-inks. As described in the previous paragraph, the scaffolds are designed starting from the TC scan; once the project is completed, the scaffolds are ready to be printed. The BIO X 3D printer represents a significant advance in 3D printing, developed to enable the fabrication of complex objects using biological and biocompatible materials. This printer combines the precision of printing with the ability to work with biomaterials, paving the way for new applications in regenerative medicine (Fig. 10).

Fig. 10. *Bio X printer.*

Its robust structure provides a stable foundation for printing; components might be added to customize the printing process. With a touchscreen display, the user interface enables intuitive control of the printing process, from material loading to parameter configuration. The printer works with diverse biological materials, including hydrogels, biocompatible polymers, and live cells. This printer is designed to maintain the integrity of biological materials during the extrusion process, thereby ensuring high cell survival and uniform distribution of materials. It is equipped with three bioink ports. These features allow for independent or simultaneous use with other features, with a single or multiple materials. The printer parameters can be modified by the operator; sensors are in place to detect the working pressure and working temperature. The pressure that can be used is up to 700 kPa, and the temperature can be set from 7°C to 60°C for the base up to 250°C for the upper portion. The printer is also equipped with an advanced cooling system that ensures the rapid solidification of the material, thereby enabling the creation of complex geometries without deformation (Fig. 11).

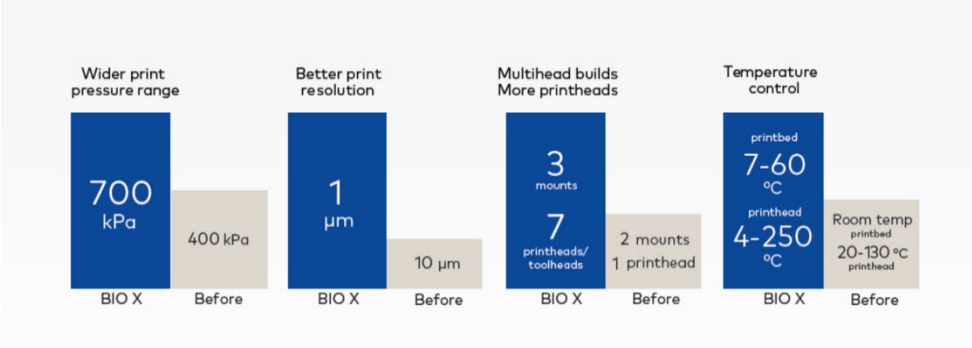

Fig. 11. *Bio X printer parameters; previous printer characteristics are indicated in grey.*

Surgical technique

The initial incision should be designed in accordance with the extent and location of the site undergoing CBR in a manner that increases bone volume while respecting adjacent anatomic structures such as the maxillary sinus, nerve structures, vascular structures, and ligaments. A mucoperiosteal flap with a wide base allows for an adequate blood supply. The periodontal condition of adjacent teeth and their prosthetic support should also be considered. The healing process is positively affected by making a full-thickness incision avoiding tissue compression during mobilization of the flap and a marginal incision, especially if one is in an esthetic area. When the titanium grid / resorbable scaffold is inserted, it is essential to ensure that the periosteum and flap are not damaged or perforated and that mobilization of the flap is passive. The incision should be made in a manner that allows for the comfortable placement of the scaffold, considering the presence of a larger graft volume. Following suture removal and throughout the course of wound healing, the soft tissue situation was clinically monitored on a regular basis to detect the presence of dehiscence or signs of inflammation at an early stage.

In case a titanium non-resorbable mesh is used, after a healing period of approximately nine to twelve months, the mesh is removed. The same initial incision line is recommended to be used when removing the mesh. Following the preparation of the mucoperiosteal flap, a well-vascularized volume increase and possible osteoblast/osteocyte growth through the grid can be observed. The grid is mobilized via the facilitated removal function by lateral extrusion movements without affecting the achieved bone augmentation.

RESULTS

Of the 11 patients involved in the study, 7 were female, and 4 were male (Table III); 5 were treated for atrophies in the upper jaw, and 6 were treated for mandibular atrophies. All patients performed the bone regeneration procedure, 8 performed titanium mesh removal, and 7 completed implant rehabilitations.

Table III. *Results of patients involved in the study.*

Patient	Gender	Age	CBR site
1	F	43	22-23-24
2	F	51	36
3	F	62	13-11-23-24
4	F	51	36
5	F	48	11-12-13-14
6	M	49	14-15-16
7	F	49	36
8	M	55	46
9	M	36	46
10	M	58	15-12-22-25
11	F	38	11-12

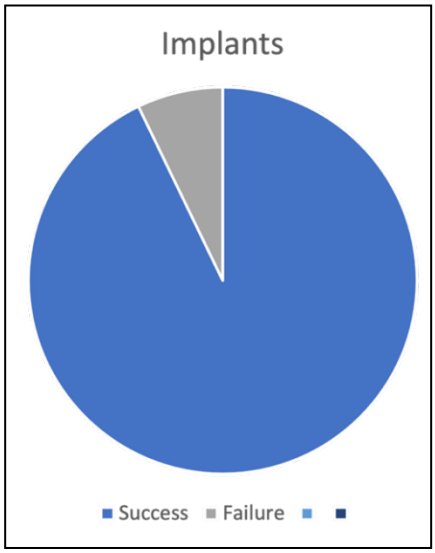

Fig. 12. *Implant survival.*

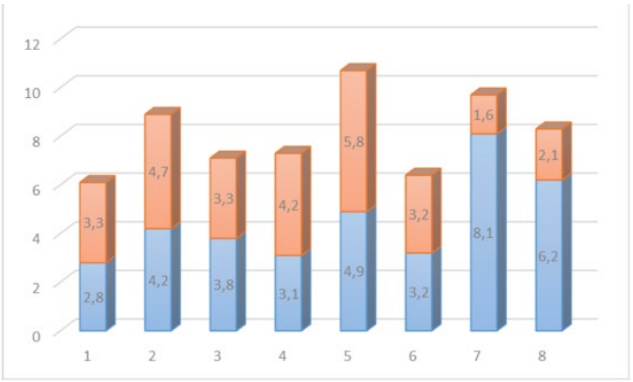

Fig. 13. *In blue, the initial width of the alveolar ridge. In red is the extent of width augmentation after treatment.*

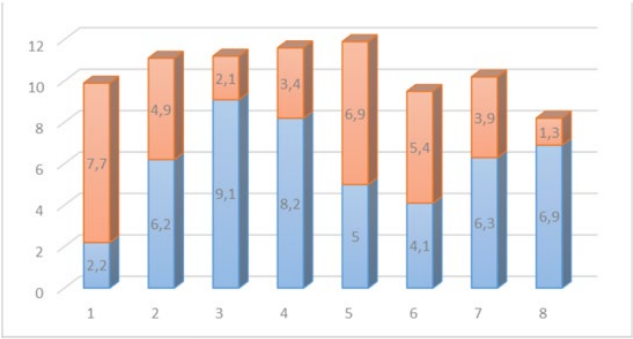

Fig. 14. *In blue, the initial height of the alveolar ridge. In red is the extent of height augmentation after treatment.*

Each patient had a CBCT performed to study atrophy and to allow for a titanium mesh design. The surgeries were performed under loco-regional anesthesia using one of the following surgical techniques for flap setup;

"ridge incision", "poncho technique," and "modified poncho technique". A non-resorbable YXOss CBR titanium membrane was used, filled with a mixture of homologous/heterologous bone in a 50:50 ratio as graft material, and covered with a resorbable membrane.

All patients were followed in the healing phases; of these, 8 patients completed the regenerative phase. Seven patients undertook the implant-prosthetic phase. The healing phase was smooth in the 9-12 months postoperatively; therefore, the implants were placed at the same time as the titanium mesh removal surgery. Only one patient reported membrane exposure during the healing period; the complication was treated with chlorhexidine 0.2% mouthwash and chlorhexidine 1% gel. Fourteen dental implants were placed, and only one implant was lost less than 1 year after placement. No other implants were lost after that. On average, patients after the implant-prosthetic phase were followed for 4 and 6 months (minimum follow-up of 3 years and 6 months, maximum follow-up of 5 years and 6 months).

CT scans performed before and after guided bone regeneration surgery evaluated bone augmentation in terms of change in horizontal and vertical measurement of the bone itself.

The mean horizontal augmentation was 3.525 ± 1.36 mm; the mean vertical augmentation was 4.45 ± 2.22 mm. Implant survival was 92.85%. Complications during the healing phase were 9.09%.

DISCUSSION

Guided bone regeneration of horizontal and vertical defects is a challenging surgical procedure, particularly in the presence of extensive bone atrophy (10). Studying residual bone tissue's morphology, quantity, and quality is essential to successfully plan customized bone rehabilitation and achieve satisfactory rehabilitation goals.

A review of the literature by Patil indicates that both resorbable and non-resorbable membranes are effective in guided bone regeneration (25). According to the literature, type I and III collagen is the most widely used material for resorbable membranes (26, 27). It is mainly obtained from animals such as pigs or cattle. The use of this material has several advantages. For instance, there are fewer postoperative complications, the resorbable scaffold is not exposed during the healing process, and it does not require a second surgical procedure to remove the membrane. However, it has disadvantages, including poor stiffness, which necessitates the use of dedicated screws or specific sutures to maintain the scaffold in its appropriate position. Additionally, there is a lack of control over resorption over time, with resorption varying between 4 and 24 weeks. Finally, the authors stated that micromovement of the resorbable scaffold is possible during the healing phases (26).

This study hypothesizes the possibility of printing custom-made scaffolds with type I and III collagen bio-inks, which have already been approved for use on humans. In addition to the previously described advantages, the use of custom-made resorbable membranes could reduce operative time, considering that the scaffolds available in commerce are resorbable, have standardized dimensions, and the operator must modify them to fit the site to be regenerated during surgery. Furthermore, precise custom-made support could reduce the problem of micromovements during the healing phases. Moreover, the surgeon might be able to directly modify the scaffolds, taking into account the importance of soft tissue and noble oral cavity structures that must not be damaged in surgical procedures (28), coming to a point where scaffolds could also be in-house made (29).

Today, the only custom-made scaffolds for guided bone regeneration available in the commerce are titanium meshes. The fabrication process for these membranes involves several steps and takes approximately 21 days.

The operator's role in these stages is to forward CT files of less than 128MB in size to the manufacturing company and then request design changes. In our study, the operator himself utilizes the software to virtually create the custom-made scaffold, and this step requires a far shorter time, which is estimated to be of approximately two to three days. In most cases, the time required for the scaffold design depends on the intricacy of the bone atrophy to be regenerated. The following passage will be scaffold-printing with bio-inks, and the patient will then undergo surgical intervention. According to Troeltzsch (30), the utilization of resorbable membranes is associated with a reduced incidence of complications in comparison to titanium meshes, with a rate of 10.2% in the former versus 21% in the latter, which is an additional advantage of in-house projecting and printing of resorbable scaffolds to be used in CBR. The feasibility of our design is also confirmed using easily manageable programs like Mevislab 2.4 and Meshmixer. To confirm the research, continuing the CBR study by printing the membranes in collagen and experimenting with them on patients is recommended.

Regarding the experiment on CBR with titanium mesh, the decision to use a 50:50 mixture of autologous and heterologous bone was guided by the results found in the literature; in fact, Troeltzsch states that in GBR procedures, bone formation in the regenerated areas increased by 33.1% ± 14.9% with the use of allogeneic grafts and 56% ± 25.6% with the use of autologous grafts mixed with other graft material. In the same work, the average horizontal gain was 3.7 mm ± 1.2 mm with a difference of 2.2 mm ± 1.2 mm using synthetic material alone and 4.5 mm ± 1 mm using a mixture of autologous/heterologous bone (30).

In the present study, the mean horizontal bone gain was 3.525 ± 1.36 mm, a value consistent with the average result obtained by Troeltzsch and higher than his horizontal bone gain obtained using only synthetic material.

In their literature review, Rasia Dal Polo et al. evaluated the reliability of titanium mesh in GBR procedures by considering 17 articles; the author found a mean horizontal gain of 4.36 ± 1.29 mm and a mean vertical gain of 4.91 ± 2.35 mm, which is in line with our results for a mean horizontal gain of 3.525 ± 1.36 mm and a vertical gain of 4.45 ± 2.22 mm. The variability may be due to the small case series of our study (31, 32).

In terms of complications, only one titanium mesh was found to be exposed during the healing period in the present study, and such a limited percentage of complications was probably due to treatment with chlorhexidine 0.2% mouthwash and chlorhexidine 1% gel. In fact, no titanium mesh was removed prior to the predetermined bone healing period.

In terms of implant survival, the results obtained here are also better than those reported in literature, with a survival rate of 92.85% at a mean follow-up of 4 years and 6 months, compared to 89.9% found by Rasia Dal Polo at a mean follow-up of 9 months. The positive result is likely to confirm the viability of the applied method (31).

CONCLUSIONS

The use of dedicated software, Mevislab 2.4 and Meshmixer, for titanium mesh design is an accurate, predictable, effective, and quick-to-use method in customized bone regeneration. The operator acquires sufficient expertise with the software in relatively short time, making the learning curve rapid and uncomplicated.

Future research will focus on the comparison between the size of a resorbable-3D-printed scaffolds to the size of titanium meshes. Preliminary results seem to confirm the validity of this procedure, owing to the almost negligible discrepancy between traditional titanium mesh and resorbable-3D-printed membranes.

According to the findings of this study, mesh exposure does not necessarily lead to bone graft failure; anyway, this is a possible complication that can be promptly treated by chlorhexidine aids.

To substantiate the efficacy of this procedure, further research and clinical employment of new technologies are recommended.

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Retrospective Observational Study

Cephalometric variation of vertical dimension in patients treated with hyrax-type and McNamara-type rapid palatal expander. Study on latero-lateral teleradiography

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ABSTRACT

To analyze changes in the vertical dimension of the lower third of the face studied on teleradiograph in L-L following rapid palatal expansion achieved by four-band Hyrax-type rapid palatal expander (RPE) and by acrylic-bonded McNamara RPE to identify the most appropriate therapeutic choice based on the patient's facial growth pattern. 30 patients were selected, of whom 20 (9 males and 11 females with a mean age of 8.285 ± 1.216) were treated using McNamara RPE (Group D), and 10 (6 males and 4 females with a mean age of 8.562 ± 1.152) were treated with Hyrax RPE (Group B), for an average treatment time T0-T1 of 0.96 ± 0.501 years. According to Tweed and Ricketts, Cephalometric tracings obtained from lateral cephalograms at T0 and T1 were analyzed to study changes in the vertical dimension of the lower third of the face. For this purpose, 6 cephalometric landmarks were considered: convexity (distance of point A to the NPg plane), Ricketts' total face height (angle between the NBa plane and Xi-Pm plane), lower face height (angle between the ANS and Xi-Pm planes), facial axis (angle between the NaBa plane and PtGn plane), ANB angle, and FMA angle. No statistically significant differences were found between the measurements at T0 and T1 for any of the 6 cephalometric measurements considered, neither within the single groups nor when comparing the two. However, a greater increasing trend was found for some variables between the two groups, such as Ricketts' total facial height, lower facial height, and FMA angle, although not statistically significant. Hyrax and McNamara's RPEs have provided minimal changes in the vertical component during palatal expansion treatment, thus demonstrating their ability to preserve the vertical dimension of the face. Therefore, there are no contraindications for using either appliance for patients with dolichofacial growth patterns.

INTRODUCTION

Rapid palatal expansion is a treatment option commonly used in orthodontics to increase the maxilla's transverse deficit and correct skeletal crossbites (1). The rapid palatal expander (RPE) on resin splints and the RPE on bands are two appliances used for maxillary expansion, which determine skeletal effects on the maxillofacial complex through the opening of the median palatine suture through a dental anchorage. The rapid expansion aims to solve the transverse discrepancy of the bone bases by increasing the width of the upper arch while limiting the orthodontic effect on the anchoring teeth as much as possible (2).

Numerous skeletal and dental effects obtained following palatal expansion mediated by a RPE anchored on bands and/or resin splints are reported in the literature. Some authors have reported that, in addition to the opening of the median palatine suture, the rapid palatal expansion obtained with an RPE appliance anchored on bands determines the antero-inferior dislocation of the maxilla, the vestibular inclination of the alveolar process and the extrusion and vestibular inclination of the posterior teeth (3-5).

These effects result into a posterior-inferior rotation of the mandible, with a consequent increase in the vertical dimension of the face (6-8). Over time, this phenomenon has promoted the use of alternative rapid palatal expansion appliances, such as the RPE anchored on resin splints, with the belief that it could guarantee greater control of the anterior facial height of the face compared to what happens with appliances anchored on bands (4, 5, 9, 10).

According to other authors, both RPEs on splints and bands have been considered capable of minimizing vertical changes as a consequence of the expansion (2,11-14), a fundamental feature for those patients who

have an increased anterior facial height and/or mandibular plane angle before the orthodontic treatment, with a hyperdivergent growth trend.

The RPE on bands promotes a distal rotation and a vestibular expansion of the molar region, which is also transmitted to the elements of the premolar and anterior region thanks to the extension of the steel arms. However, the mechanism of action of this appliance determines an extrusive migration and a vestibular-inclination of the lateral-posterior dental elements (15), a posterior-rotation of the bispinal plane, and an increase in the craniomandibular angle, negative effects if patients with an increased anterior vertical dimension of the face are considered (16).

The RPE on resin splints promotes a vestibular expansion of the posterior elements included in the resin splints, which perform a "bite-block" function: thanks to the intrusive occlusal force directed at the posterior elements, they minimize their extrusion (2), and consequently, the backward and downward movement of the mandible is limited (4, 17). According to this theory, the greater control of the vertical dimension is due to the advancement of the mandible, which is no longer in a constrained position due to maxillary hypoplasia, and it will tend to rotate upwards and forwards (10, 18).

The skeletal effects and increases in width on the transverse plane, as a result of distraction of the midpalatine suture, have been widely discussed and confirmed in the literature (19), while there is less concordance of results compared to effects of palatal expansion on the variation of the vertical dimension. It is known, in fact, that an increase in the transverse width of the maxilla is also accompanied by changes in the vertical and sagittal direction, where the rotation of the mandible has been recognized as one of the most frequent effects (20).

This aspect has a particular relevance in those patients who present a class II, in which a clockwise rotation of the mandible can lead to a worsening of the skeletal class on the sagittal plane, or in patients with increased anterior facial width, whose profile would be further worsened on the vertical plane, as a consequence of a posterior-inferior rotation of the mandible. The sagittal component is inverted for third class patients requiring palatal expansion (21)

As reported by several authors (10, 20), the most significant changes on the vertical plane are observed in the first phases of palatal expansion, in which there is a clockwise rotation and a retrusion of the mandible, probably correlated to the presence of pre-contacts of the overly expanded palatine cusps and the downwards and forwards displacement of the maxilla, caused by the V-shaped opening of the median palatine suture (3).

During the subsequent retention period, the tendency to increase the vertical component decreases, a phenomenon related to the anti-clockwise and upward rotation of the mandible due to the correction of the transverse deficit and the settling of the occlusal relationship (22). From these observations, it can be deduced how the vertical repositioning of the maxilla due to palatal expansion influences the movement of the mandible on the sagittal and vertical plane; this correlation is influenced by numerous factors, such as the observation of skeletal and dental effects, the facial type of the subject and the orthodontic appliance used, which justifies the absence of unanimity in the literature regarding the final effect on the vertical dimension.

The objective of the present study is to analyze the variations in the verticality of the lower third of the face through cephalometries performed on L-L teleradiographs, following rapid palatal expansion mediated by two different appliances, such as Hyrax and McNamara RPEs, to identify which one is the most suitable therapeutic choice in relation to the initial clinical conditions, or whether there are contraindications to the use of one or the other appliance in patients with a tendency to hyperdivergent facial growth who would benefit from a palatal expansion therapy.

MATERIALS AND METHODS

The present study compared the effects of the expansion of the maxillary arch using an RPE with dental anchoring through resin splints (McNamara type) and on bands (Hyrax type), analyzing the variations in the verticality of the lower third of the face in patients who presented transverse skeletal deficit.

Thirty patients with transverse deficiency of the maxilla were selected; 20 of them (9 males and 11 females with an average age of 8.3 ± 1.22) were treated with a McNamara RPE (Group D), and 10 (6 males and 4 females with an average age of 8.56 ± 1.15) were treated with a Hyrax RPE (Group B), for an average treatment time T0-T1 of 0.96 ± 0.50 years. The treated patients had a cervical vertebral maturation stage (CVMS), according to Baccetti and Franchi (21), lower than CS 3, therefore before the peak of pubertal growth.

At T0, 20% of patients had a bilateral posterior crossbite, while the remaining 80% had a unilateral posterior crossbite as shown (Fig. 1).

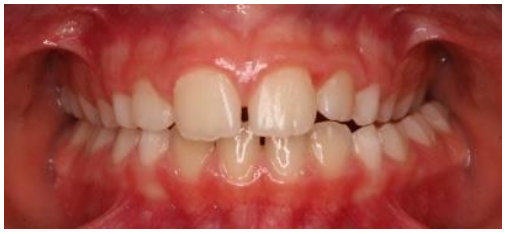

Fig. 1. *Unilateral posterior left crossbite.*

The choice of one or the other type of RPE occurred randomly, and all the appliances were manufactured by the same dental laboratory. The inclusion and exclusion criteria of the sample (23, 24) are shown in Table I.

Table I. *Inclusion and exclusion criteria of the sample.*

Inclusion criteria	Exclusion criteria
Skeletal class type I or II	Skeletal anomalies and/or craniofacial asymmetries
Transverse skeletal deficiency of the maxilla	Genetic diseases or endocrine pathologies that could interfere with the orthodontic treatment
Presence of mono or bilateral cross-bite	Previous orthodontic treatments
Transverse dental discrepancy between 5 and 6 mm	Dental anomalies
Complete radiographic documentation	Labiopalatoschisis
Pre-pubertal stage of maturation	Poor oral hygiene

	Periodontal defects of the anchoring teeth
	Oral pathologies
	Severe adenotonsillar hypertrophy
	Mouth breathing, obstructive sleep apnea syndrome and other respiratory disorders

The subjects were treated by the same orthodontist at the Orthodontics department of the Dentistry and Maxillofacial Surgery clinic of the G.B. Rossi Hospital in Verona. Before starting the orthodontic therapies, informed consent to treatment was requested and collected from the parents of the patients included in this study. All subjects were treated until the correct transverse widths of the dental arches were achieved (the vestibular cusps of the upper teeth were located in a more labial position to the antagonist tooth, and lingual cusps of the lower elements located at the level of the central fossa of the upper antagonist element), specific to the individual case. This study was approved by the Clinical Investigation Ethics Committee of Verona and Rovigo, Italy (protocol number 70252). The procedures were in accordance with the Helsinki Declaration of 1975, as revised in 2000.

Types of rapid palatal expanders

RPE on resin splints was introduced in the 1970s and perfected in its clinical management by McNamara (25) (Fig. 2). The appliance consists of a central expansion screw with lateral arms incorporated into grooves made of acrylic material that completely cover the palatal, occlusal and vestibular surfaces of the anchoring teeth (generally extending from C or D to the upper first or second molars).

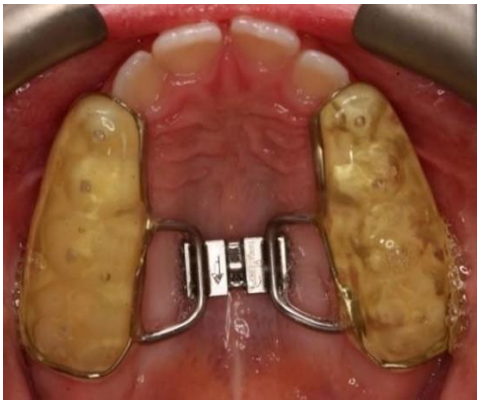

Fig. 2. *Example of McNamara-type RPE with resin splints extending from the first molars to the deciduous canines.*

The expansion screw used has a thread pitch of 0.8 mm, corresponding to four activations (a single activation is therefore 1/4 of a turn, i.e. 0.2 mm), and it is positioned at the level of the medial palate at approximately 2 mm from the palatine mucosa and as distal as possible, so as to bring it closer to the center of resistance of the upper jaw located at the base of the two zygomatic processes.

Hyrax RPE

The Hyrax® RPE (OIS Orthodontics, Aston, PA, USA) (14) is composed of a metal structure that has four orthodontic bands, two positioned on the permanent maxillary first molars and/or premolars (alternatively, on the E elements), and two arms in contact with the palatal surfaces that extend from the banded elements up to the C and/or upper second molars (26). It is equipped with a midline screw with characteristics and position similar to the McNamara expansion appliance described previously (Fig. 3).

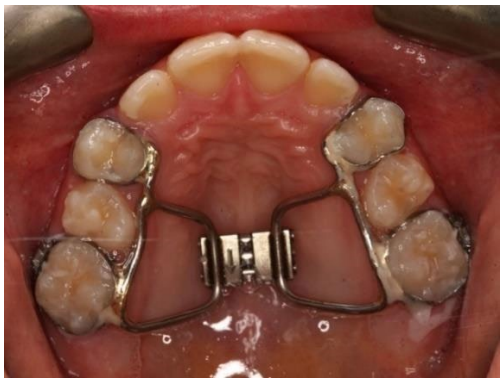

Fig. 3. *Example of Hyrax RPE with two bands cemented on the first molars and two on the first premolars.*

Therapeutic protocol

For each treated patient, a case study was initially performed to diagnose and formulate the treatment plan. During the first visit, alginate impressions were taken for the study models, and an orthopantomography and a teleradiography with lateral-lateral projection (L-L) at the start of treatment (T0) were prescribed and taken. A cephalometric tracing was performed according to Ricketts and Tweed, and the maturation stage of the cervical vertebrae was analyzed according to the system by Baccetti and Franchi (27).

The degree of transverse discrepancy (TD) was determined by measurements on the models of the dental arches using a fine-point caliper with a precision of 0.1 mm, calculating the difference between the mesio-palatal cusp of the right and left upper first molars and the central fossa of the right and left mandibular first molars. Furthermore, the Wilson curve was analyzed using the study models to identify the posterior crossbite's skeletal or dental nature and the palatal vault's width.

The amount of correction necessary to achieve a correct transverse relationship was calculated based on the millimetric measurement of the TD; moreover, an overcorrection was added (28) to obtain the vestibular aspects of the palatal cusps of the upper molars in proximity to the lingual sides of the buccal cusps of the lower molars.

During the second visit, for Group D (subjects treated with McNamara RPE), new alginate impressions were taken to construct the orthodontic appliance. In contrast, for Group B treated with Hyrax's RPE, adequate bands were selected, and then an alginate impression with bands on the teeth was taken to create the appliance.

On the third appointment, the RPE was cemented with self-photo-polymerizable dual-type glass ionomer cement (GC Fuji PLUS® Radiopaque Reinforced Glass Ionomer Luting Cement). After removing all the excess cement, light curing was performed for 120 seconds on each side.

Patients underwent a standardized expansion protocol involving 4 activations at the time of cementation and, subsequently, 3 daily activations (two in the morning and one in the evening) until the desired correction was

obtained. Each activation of the appliance requires 1/4 turn of the screw (equivalent to 0.2 mm), which corresponds to 1 mm of expansion every 5 activations.

Indications on home oral hygiene, correct nutrition (29-31), the maintenance of the appliance, and the use of a key to carry out the activations were given to the parents, who were also warned of the physiological appearance of the inter-incisor diastema after a few days, a sign that the palatal expansion had occurred (32) (Fig. 4).

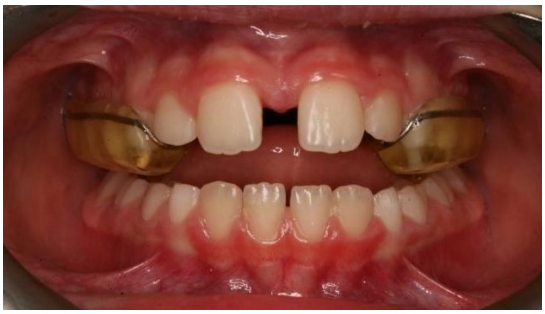

Fig 4. *Frontal intra-oral photography at the end of the activations.*

During the treatment, the patients were checked after a week. At the end of the activations, and once the desired expansion was achieved, the screw was blocked with a metal ligature with a diameter of 0.01 inch and flowable composite.

During the following 6 months, the appliance was kept in place as retention, and it was removed at the end of that phase; therefore, a further nocturnal retention appliance was created and carried at night for further 6 months for the patients in the group D if the McNamara RPE remained intact after decementation, it was used for this aim, otherwise in all the other cases, and for patients in group B, a custom made Hawley plate was manufactured. At the end of the nocturnal retention period, during which the patients were seen for control every 4-6 weeks, one end-of-treatment L-L projection teleradiography (T1) was performed for each patient.

Radiological Protocol

Two teleradiographs with L-L projection were prescribed and performed for each patient in the study:

- Initial L-L teleradiography (T0) carried out between 0 and 14 days before the positioning of the appliance.
- Final L-L teleradiography (T1) carried out at the end of the nocturnal retention.

All X-rays were performed by a single radiologist at the Radiology department of the G.B. Polyclinic Rossi in Verona. To carry out the X-ray, each patient was asked to assume an upright position to reproduce the natural position of the head (NHP), with the chin supported by an adjustable platform and the Frankfurt plane parallel to the floor.

Data collection and analysis

The L-L teleradiographs at T0 and T1 were loaded onto the Delta-Dent CE Outside Format software, and cephalometric tracing was performed on them according to Ricketts and Tweed (Fig. 5, 6). Each cephalometric tracing was performed by a single operator and was subsequently remeasured 10 days later according to the same protocol to minimize the possibility of mistakes in the identification of the reference points and to guarantee the highest accuracy for each cephalometric tracing.

Fig. 5. *Example of cephalometric tracing according to Ricketts and Tweed.*

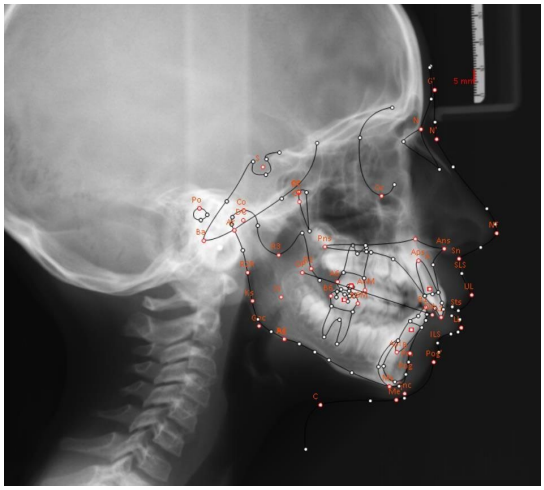

Fig. 6. *Example of Ricketts and Tweed cephalometric tracing on latero-lateral cephalometry.*

Subsequently, it was verified that there were no statistically significant differences between the two values obtained using the Student t-test for paired samples. On both occasions, the operator was unaware whether the X-rays analyzed were taken at T1 or T0. An average between the two values obtained for each measurement was used for statistical investigations.

The evaluation of the changes in the vertical dimension was made on the basis of the following six cephalometric references: convexity (distance of point A with respect to NPg plane), total height of the face according to Ricketts (angle between NBa plane and Xi-Pm plane), lower height of the face (angle between the anterior nasal spine ANS and Xi-Pm plane), facial axis (angle between NaBa plane and PtGn plane), ANB angle and FMA angle (angle between the Frankfurt plane and the mandibular plane).

Statistical analysis

Descriptive statistics, including means and standard deviations, were calculated for each of the six cephalometric measurements. To analyze the differences between the groups before treatment (T0), the independent sample parametric statistical test t-Student was used. The comparison of the changes between T0-

T1 between group B and group D was also carried out using the Student t-test. In contrast, the Student t-test for paired samples was used to evaluate whether there was a mean difference statistically significant between time points T0 and T1 within each treatment group. Exploratory statistical analyses were conducted to evaluate the distribution (Shapiro Wilk test) and variance (Sd-Test) of the six cephalometric measures. Statistical significance was tested for $P < 0.05$.

RESULTS

Since the sample examined was not equally balanced both by sex (6 males and 4 females for group B; 9 males and 11 females for group D) and by subjects belonging to each group (10 subjects belonging to group B; 20 subjects belonging to group D), the Fisher-test statistical verification test (or Fisher-Yates test) was carried out, which demonstrated that these differences are not statistically significant (p-value > 0.05); therefore the sample is to be considered suitable for comparison.

From the exploratory statistical analyses conducted, it was highlighted that all the variables were normally distributed (Shapiro-Wilk test) and had similar variances (Sd-Test). The means and standard deviations for the cephalometric variables measured before orthodontic treatment (T0) relating to the two groups are shown in Table II.

Table II. *Mean values ± standard deviation and median of group B and D. Results of T-Student test of T0 values (p-value>0.05).*

GROUPS AT T0	Bands (Group B) T0		Splints (Group D) T0		P-VALUE T0
	Mean ± SD	Median (min-max)	Mean ± SD	Median (min-max)	
Total Face Height (Degrees)	55.34±3.66	53.85	55.00±3.72	55.45	0.817
Lower Face Height (Degrees)	40.92±3.67	39.95	42.28±2.87	41.75	0.274
Facial Axis (Degrees)	91.18±1.62	91.20	91.18±0.92	91.25	0.991
Convexity (mm)	2.32±1.48	2.00	2.32±1.35	2.30	0.993
ANB (Degrees)	3.61±1.74	4.15	3.12±1.72	3.10	0.465
FMA (Degrees)	28.51±4.60	27.65	28.77±3.65	29.30	0.990

There were no statistically significant differences between the baseline measurements among the two groups, which allows us to assert that the measurements are to be considered homogeneous at T0; therefore, samples from each group are suitable for comparison.

The descriptive statistics for the changes that occurred during the treatment and the comparison between T0 and T1 of groups B and D are reported in Tables III and IV. The statistical results of the comparison between the two groups of the changes obtained between T0 and T1 are reported in Table V.

Table III. *A comparison between T0 and T1 of group B and the p-value of each variable was taken into consideration.*

Groups	RPE on bands (Group B)				
	T0		T1		P-Value
	Mean ± SD	Median (min-max)	Mean ± SD	Median (min-max)	
Total Face Height (Degrees)	55.34 ± 3.66	53.85	55.27 ± 4.38	54.90	0.9620
Lower Face Height (Degrees)	40.92 ± 3.67	39.95	41.22 ± 3.20	41.50	0.7131
Facial Axis (Degrees)	91.18 ± 1.62	91.20	91.50 ± 1.95	91.45	0.5949
Convexity (mm)	2.32 ± 1.48	2.00	1.91 ± 1.36	1.80	0.3998
ANB (Degrees)	3.61 ± 1.73	4.15	2.81 ± 1.49	3.05	0.7409
FMA (Degrees)	28.51 ± 4.60	27.65	27.88 ± 3.34	27.35	0.6153

Table IV. *A comparison between T0 and T1 of group D and the p-value of each variable was taken into consideration.*

Groups	RPE on resin splints (Group D)				
	T0		T1		P-Value
	Mean ± SD	Median (min-max)	Mean ± SD	Median (min-max)	
Total Face Height (Degrees)	55.00 ± 3.72	55.45	55.86 ± 3.49	54.85	0.163
Lower Face Height (Degrees)	42.28 ± 2.87	41.75	41.96 ± 3.82	41.20	0.549
Facial Axis (Degrees)	91.18 ± 0.91	91.25	91.12 ± 1.02	91.30	0.771
Convexity (mm)	2.32 ± 1.35	2.30	2.39 ± 1.38	2.15	0.818
ANB (Degrees)	3.11 ± 1.72	3.10	2.99 ± 1.61	3.05	0.138
FMA (Degrees)	38.77 ± 3.65	29.30	27.86 ± 4.56	27.55	0.144

Table V. *P-value of the differences between T0 and T1 of groups B and D: there are no statistically significant differences between the two groups B and D.*

Groups	P-Value (Group B e Group D)
Total Face Height (Degrees)	**0.376**
Lower Face Height (Degrees)	**0.548**
Facial Axis (Degrees)	**0.776**
Convexity (mm)	**0.744**
ANB (Degrees)	**0.243**
FMA (Degrees)	**0.153**

There were no statistically significant differences between T0 and T1 for any of the six measurements within each group B and D; the comparison between the groups also showed no statistically significant differences between T0 and T1. Analyzing the variations in measurements between T0 and T1, although there are no significant differences, a tendency towards an increase in the total facial height of the face (NBa-XiPm) is observed, more represented in group B compared to group D (respectively, in 70% of the cases in group B and 55% of the cases in group D), as well as the FMA angle, the increase of which appears to be significantly higher in group B (50% of the cases) compared to group D (25% of the cases). The lower face height (ANS-XiPm) increased in slightly different proportions for group B (30%) and group D (40%); as for the other measurements, they had a similar increase in proportion for the two groups B and D.

DISCUSSION

This study aimed to evaluate whether there are significant changes in terms of verticality after the palatal mediated by two different appliances, such as the Hyraxe and McNamara RPEs. According to our results, in agreement with other studies in the literature, no statistically significant differences were recorded for any of the variables considered, demonstrating the fact that the transverse expansion of the maxilla does not significantly influence the vertical dimensions of the face (11-14, 18) while providing adequate width augmentation not obtainable with other appliances (33).

The patients treated in our study with the Hyrax appliance (group B) did not record statistically significant changes between T0 and T1 for any variable considered. A tendency for an increase in the facial axis and facial convexity was found in 50% of cases, and an increase in the ANB angle in 30% of cases. Similarly, patients treated with the McNamara appliance (group D) did not record statistically significant changes between T0 and T1 for any variable considered. A tendency for an increase in the facial axis was found in 50% of cases and an increase in convexity in 45% of cases; the ANB angle increased in 30% of cases.

Although no statistically significant changes were recorded, observing the measurements at T0 and T1 compared between the two groups, it is possible to identify a different trend of change for some of the variables considered: the measurement that recorded the most differences between the two groups is the FMA angle,

which increased in only 25% of cases in group D compared to an increase of 50% of cases in group B; there was also an increase in total facial height equal to 55% of cases in group D compared to an increase equal to 70% of cases for group B; the lower facial height recorded an increase of 40% of cases in group D and 30% in group B. Table VI reports the average variations recorded for each variable belonging to the two groups between T0 and T1.

Table VI. *Average changes in T1-T0 difference for each of the six variables expressed as an absolute number.*

Differences T1 – T0 (mean)	BANDS (Group B) T0	SPLINTS (Group D) T0
Total Face Height (Degrees)	0.07	0.86
Lower Face Height (Degrees)	0.30	0.32
Facial Axis (Degrees)	0.32	0.06
Convexity (mm)	0.41	0.07
ANB (Degrees)	0.80	0.12
FMA (Degrees)	0.63	0.91

An increase in the FMA angle describes a clockwise (posterior-inferior) rotation of the mandibular body. At the same time, its reduction indicates an anti-clockwise (anterior-superior) rotation (34); an increase in the FMA angle with a greater frequency in patients treated with the Hyrax RPE compared to the McNamara one shows that in the first case, there is a greater tendency for posterior-inferior rotation of the mandible. In contrast, in the second case, there is a greater tendency for its rotation to be in an antero-superior direction.

From the data analysis, it can be deduced that there is a greater preservation of the total height of the face after the expansion obtained using the McNamara RPE compared to the Hyrax one.

The explanation for this phenomenon can be attributed to the different characteristics of the two appliances, where the resin in the McNamara RPE performs its function as a "bite-block" on the teeth, limiting their extrusion (4, 10, 17). Furthermore, as the resin includes the occlusal table of the dental elements, it allows the elimination of pre-contacts of the palatine cusps in the expansion phase, which has been recognized as one of the main factors promoting an anti-clockwise rotation of the mandible (20, 22). The increase in the FMA angle with greater frequency in the group treated with Hyrax RPE is likely to be correlated to the dento-alveolar effects determined by the mechanics of the appliance, whose dental anchoring through the bands and the extension of the steel arms to the premolar region determines a vestibular-inclination of the lateral-posterior sectors (15).

The lower height of the face is a parameter that reflects the tendency to have an open or skeletal deep bite; therefore, its value must be kept within a normal range to obtain an ideal skeletal bite (2). In this study, no statistically significant differences in lower facial height were found, neither considering the inter-group changes between T0 and T1 nor comparing groups B and D, demonstrating that both appliances can guarantee

the maintenance of a correct skeletal bite.

There are no uniform results in the literature regarding the changes in the vertical and sagittal planes that follow rapid palatal expansion. The variability in the results may be attributable to the timing in which the measurements were recorded during the orthodontic expansion treatment.

The rapid palatal expansion can be temporally divided into an active phase and a subsequent retention phase of variable duration, in which different movements of the maxillary and mandibular bone bases are observed: immediately after the active phase, there is a downward and forward movement of the maxilla due to the effect of the expansion on the craniofacial structures, associated with an increase in the vertical dimension as a consequence of mandibular postero-rotation (6, 19).

However, during the subsequent retention phase, long-term observations demonstrate a tendency towards a progressive return towards the initial position: during this phase, there is, therefore, only the preservation of the transverse component (16), whereas the changes on the vertical and sagittal plane are not significant (12, 14), in agreement with the present study.

The theory that the palatal expansion mediated by the two RPEs could influence the vertical and sagittal dimensions differently raised the hypothesis that choosing between one appliance or appliance was necessary depending on the patient's facial growth model. It is known that patients with dolichofacial growth patterns present a greater predisposition to an increase in the vertical component of the face compared to the brachyfacial one (34); therefore, greater control of verticality is essential to avoid a possible worsening of the facial profile following expansion orthodontic treatment.

The present study reports results in contrast with other authors in the literature, according to which the vertical dimension would be better controlled through the use of the RPE equipped with resin splints thanks to its "bite-block" action, therefore recommending its use in those patients with dolichofacial growth tendency (4, 10).

Considering the results of this study, the use of both appliances may be valid regardless of the patient's vertical conditions or facial growth pattern since the two appliances did not promote significant vertical cephalometric alterations, in agreement with other studies in the literature (11, 12).

The analysis of vertical changes in the present study was carried out on L-L teleradiographs, which involve intrinsic limiting factors such as magnification, overlap of anatomical structures, and distortion caused by the position of the head. The use of CBCT would have allowed the obtaining of a three-dimensional image on which to carry out more realistic measurements of skeletal changes without the limiting factors of magnification and distortion (3); however, CBCT does not provide additional clinical benefits for patients undergoing rapid palatal expansion orthodontic treatment alone, exposing such individuals to higher doses of ionizing radiation, and the related risks.

Another limitation of the present study is represented by the absence of a control group, which would have allowed us to determine the extent of the skeletal changes attributable to the effect of the orthodontic appliance or, otherwise, to the natural growth of the subject. However, the choice to include a control group would have resulted in unjustified exposure to ionizing radiation so that patients could obtain radiographic documentation at time T1 without having performed any treatment. However, since no statistically significant differences were found in the vertical changes of the patients, the absence of a control group is of relative importance.

A further limitation of the study is the choice to include only one operator who carried out the cephalometric tracings and related measurements. This methodological limit could have been reduced if the cephalometric tracings had been performed by independent operators, which is different from those involved in the study.

However, to overcome this limitation and achieve the highest possible degree of accuracy, the measurements were repeated 10 days later without the operator knowing the timing of the analyzed teleradiographs. In the coming years, better algorithms and new, fully automated methods of 3D comparison will probably be developed, making these measurements even more precise and dependable (35).

Finally, another limitation of the study is the small sample size. The search and selection of patients with relatively complete radiographic documentation significantly restricted the pool of suitable subjects who could be included in the present study. For a future study, it would therefore be desirable to include more subjects so that it can be considered more representative; furthermore, if a statistically significant difference in the increase in verticality is found immediately after the end of the expansion, it is advisable to carry out a follow-up at the end of the growth to evaluate the stability of the results in the long term. In patients undergoing palatal expansion, pre and post-endoscopic and polysomnographic evaluation would be interesting (36).

CONCLUSIONS

Based on the results of this clinical study, the conclusions are:

- Both the subjects treated with Hyrax and the McNamara RPEs showed a minimal increase in the vertical component.
- A trend, although not statistically significant, was recorded for greater maintenance of the verticality of the lower third of the face by the McNamara RPE compared to the Hyrax one.
- None of the 6 variables considered (Ricketts total facial height, lower facial height, facial axis, convexity, ANB angle, and FMA angle) showed statistically significant changes, both considering the variation of the measurements in T0 and T1 within each group and by comparing them between the two groups.

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Case Report

A comminuted dento-alveolar fracture with premaxillary dental avulsion. Pilot-drill guided implant-prosthetic rehabilitation: a case report and an overview of guided implant placement

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ABSTRACT

In modern dentistry, implantology is widely used; implants have a survival rate of 96.4-96.9% at 10-year follow-up. In order to obtain aesthetic, health, and performance results of implant restorations, virtual pre-surgical prosthetic planning is essential. For proper planning, the patient's CBCT data is matched to the prosthetic design in order to virtually plan the three-dimensional positioning of the implant before surgery. The patient, following trauma, had avulsion of elements 1.2, 1.1 and 2.1. The fracture is treated conservatively, and after 3 months, three implants are placed with guided Pilot-Drill surgery and prosthetically guided implant design. To achieve a clean transmucosal path and create good aesthetic profiles, the prosthetic connection's depth was adequate. Periodic professional oral hygiene recall has been essential for the long-term maintenance of the implants. At the follow-up of 6 years, perimplant bone stability and aesthetic and functional satisfaction of the patient were detected. In the field of dental implant placement, bone data, and anatomical restrictions can be processed by guided implant software. In combination with wax-up scans, implant planning will improve the predictability of implant placement. The ideal placement of implants in prosthetically guided implantology is not solely determined by bone anatomy but also by the final position and features planned for the prosthesis. A hybrid solution between traditional and total computer-guided surgery is achieved by Pilot-Drill Guided Surgery, which can combine the advantages of fully guided and free-hand approaches. The Pilot Drill Template implantology is a compromise that combines the benefits of fully guided and traditional surgery while also eliminating their limitations.

INTRODUCTION

In modern dentistry, implantology has developed into an emerging therapy in the treatment of partial or fully edentulous patients (1). Implantology has been designed to rehabilitate masticatory function and replace missing teeth and nowadays is strongly supported by systematic reviews and meta-analyses that report a survival rate of 96.4-96.9% at 10 years of follow-up (2, 3). The long-term success of dental implants can be attributed to the optimal implant position in relation to the dental arch, the alveolar ridge, anatomical structures like the maxillary sinus, inferior alveolar nerve, and adjacent teeth, and performing the surgical procedures correctly (4). Although in the past, the success of implant-prosthetic rehabilitation was primarily linked to the concept of function, today, it is not a sufficient condition, and success is evaluated according to aesthetic-functional standards (5).

The implants are not positioned only where bone is present. Still, they must be placed according to precise depth, inclination, and position criteria, leading to the correct positioning of the prosthetic implant-supported crown with aesthetic, functional, and cleanable features (6). The operator is at risk of making mistakes that could compromise the final prosthetic result by not predicting the correct positioning of the implant following criteria and performing free hand surgery (7).

Accurate prosthetic planning is necessary for implant placements, as it optimizes the aesthetic, health, and performance outcomes of implant restorations. Implant placement that is not adequately planned with prosthetics can interfere with vital anatomic structures, make restoration more complex, and may lead to more significant marginal bone loss. Different methods are available to determine the final position of the implant, ranging from free-hand positioning, simply guiding the pilot drill, guided preparation of the implant cavity, to full-guided insertion of the implant (8). With the Nobel Clinician® software, the patient's Cone Beam Computed Tomography (CBCT) data is overlapped with the final prosthetic rehabilitation model so that the

clinicians can virtually plan the three-dimensional placement of the implant before the surgery. The preoperative virtual plan aids in transferring the surgical template fabricated using computer-aided design and computer-aided manufacturing (CAD-CAM) technology to the actual surgery (9). The purpose of this study is to present a Pilot-Drill guided surgery case report and highlight the advantages and disadvantages of this technique when compared with fully guided surgery.

MATERIALS AND METHODS

Following a road trauma on 10 March 2017, the patient arrived at the emergency service of the Department of Maxillo-Facial and Dentistry of the University Hospital of Verona, reporting dental-alveolar fracture with avulsion of elements 1.1, 1.2, 2.1 (Fig. 1) and a complicated crown fracture of tooth 1.3 and enamel-dentin fracture of tooth 2.2 (10).

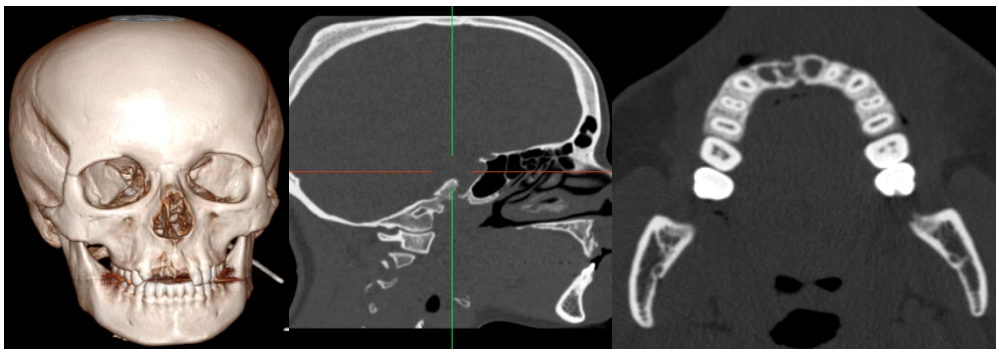

Fig. 1. *CBCT axial, coronal, and 3D trauma reconstruction.*

The study was conducted in accordance with the Helsinki Declaration of 1975, revised in 2013, and the protocol was approved by the Local Ethical Committee (1935CESC).

A 19-year-old patient with a negative medical and pharmacological history. On the oral examination, the complete avulsion of the above elements was detected; the patient was sutured with Vicryl 5.0 and medicated. The comminuted alveolar fracture was treated conservatively (Closed treatment). At the same time, endodontic treatment was done on element 1.3, and a temporary composite reconstruction was performed on element 2.2.

After two weeks, the sutures were removed. Due to the loss of dental substance and the need to provide the patient with a temporary fixed anterior prosthetic bridge, elements 1.3 and 2.2 were prepared (Fig. 2).

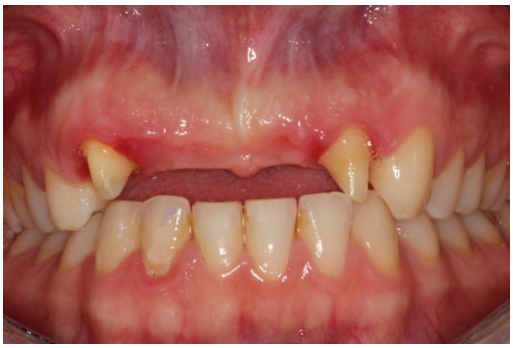

Fig.2. *Preparation of the prosthetic abutments of elements 1.3 and 2.2.*

The temporary prosthesis was designed and built with ovate pontics at levels 1.2, 1.1, and 2.1 to condition the soft tissues and preserve the gingival architecture in the area of missing teeth. A waiting time of 3 months

has been observed for the complete stabilization of the bone at the level of the alveolar fracture. At this time, an alginate imprint of the two maxillaries was detected, and a wax-up of the edentulous area was created to redefine the morphology and the correct occlusion of missing elements. The models were scanned and processed with Nobel Procera®, with and without wax, to convert them into nxa. files.

The pre-surgical CBCT was performed with a cotton roll between the two jaws, which were separated during the scan, avoiding overlapping dental structures. The master model and diagnostic wax were then scanned to provide the data in STL format (11). STL was uploaded with the patient's CBCT into the Nobel Clinician® software for virtual implantology programming. The aim is to identify the best implant position, considering the anatomy of the patient and the diagnostic wax, for the realization of the surgical template, following the principles of prosthetic-guided surgery (Fig. 3).

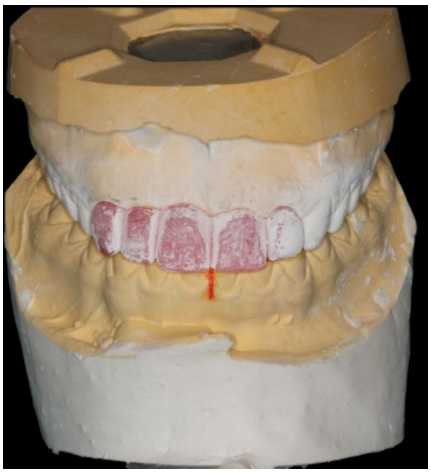

Fig. 3. *Diagnostic wax.*

The choice of the length and diameter of the implants was based on the available bone volumes, preserving its shape and its relevant anatomic structures. A virtual Pilot-Drill Template was projected, establishing a 2mm diameter bushing for each implant (Fig. 4).

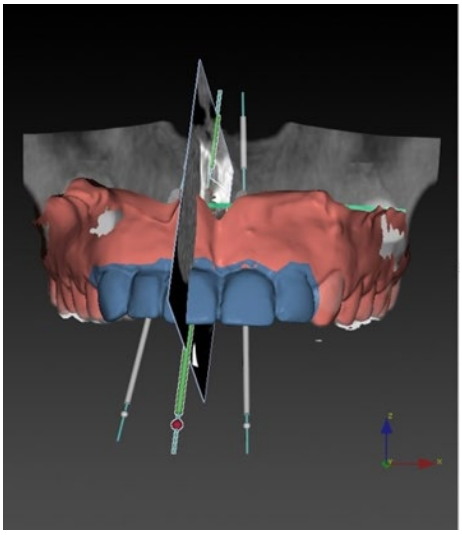

Fig. 4. *Virtual scan of pre-surgical design of the final prosthesis.*

The surgical template was realized by the Nobel Biocare® industry through the SLA technique (Stereolithography) with photopolymer material made of acrylate; later, it was sent to the dental-surgical team (Fig. 5). The accuracy of the template was checked on the master model.

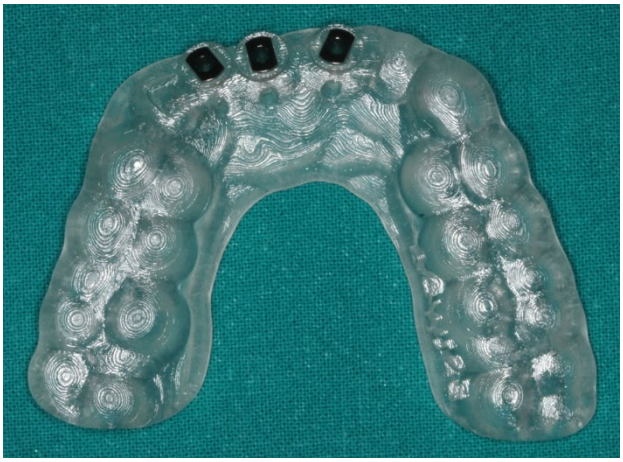

Fig. 5. *Surgical template.*

Before surgery, the patient was rinsed with 0.20% chlorhexidine for 1 minute. Local anesthesia was performed with 1,8 ml of mepivacaine HCl 2% with 1:100,000 epinephrine. The surgical template was placed on the teeth, and the correct fitting was verified. The template was removed, and a crestal incision was made with an elevation of the sub-periosteal flap. The template has been repositioned; the Guided Twist Drill Ø 2.0 has been used with the stop fixed on the virtually planned length (13.5 mm) (Fig. 6). The depth and parallelism of the plant site were verified using pins.

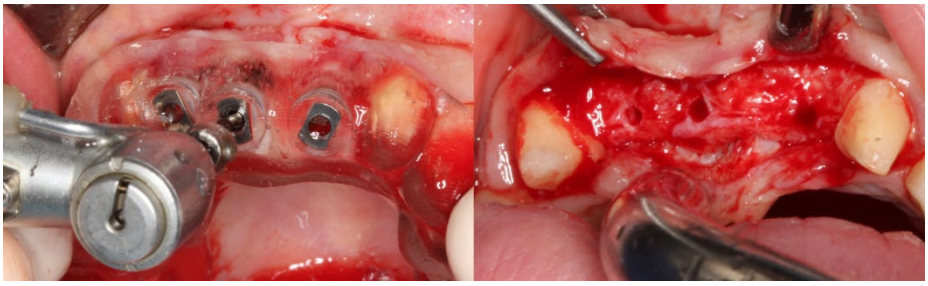

Fig. 6. *The Pilot-Drill surgical template with Ø 2.0 mm pilot drill.*

The preparation of the implant site has been completed with the next diameter drill. Three 3.5mm x 11.5mm Nobel Active® dental implants were placed. After inserting the implants, an intraoral X-ray was taken, covering screws were placed, and sutures with absorbable sutures (Vicryl 5.0) were performed (Fig. 7).

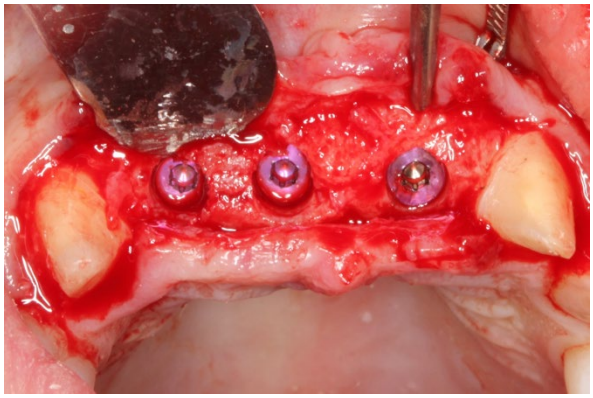

Fig. 7. *Implant placement with covering screws.*

Finally, the temporary bridge was cemented. The patient was examined at 7 days for postoperative control and at 14 days for suture removal. After 4 months, a follow-up intraoral X-ray. With local anesthesia (1,8 ml of mepivacaine HCl 2% with 1:100,000 epinephrine), a crestal incision was performed, and the healing caps were placed; the suture was performed with Vicryl 5.0 (Fig. 8). The sutures were removed 7 days after surgery (12, 13).

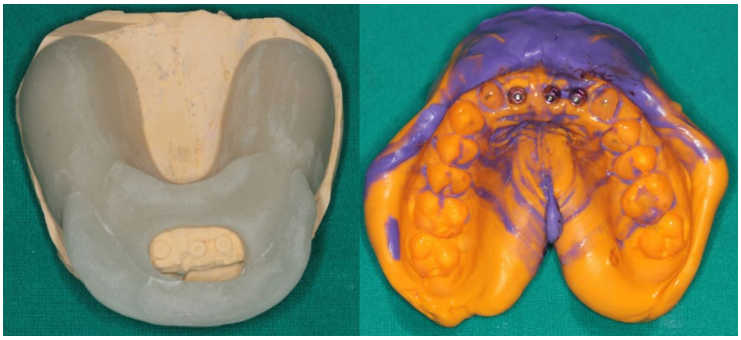

Fig. 8. *Temporary bridge.*

The imprint in alginate was taken to construct the individual impression tray. At 7 days, the transfers are screwed, and with the individual impression tray, the imprint was taken with a precision silicone with a mon ophasic technique (Fig. 9).

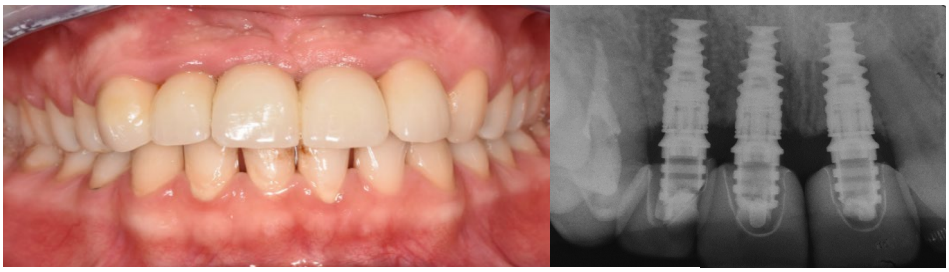

Fig. 9. *Impression tray and silicone impression (monophasic technique).*

After 7 days, single crowns in PMMA have been fitted. The crowns 1.1, 1.2, and 2.1 are screwed to the implants, and the crowns at the stumps 1.3 and 2.2 are cemented with Zinc-oxide eugenol (ZOE). After 1 month, once the aesthetic and functional goals were achieved, based on the clinical outcome and patient feedback, the temporary prosthetic manufacture was replaced with the definitive in lithium disilicate. After 20 days, the patient was re-examined to evaluate possible inadequacy (Fig. 10).

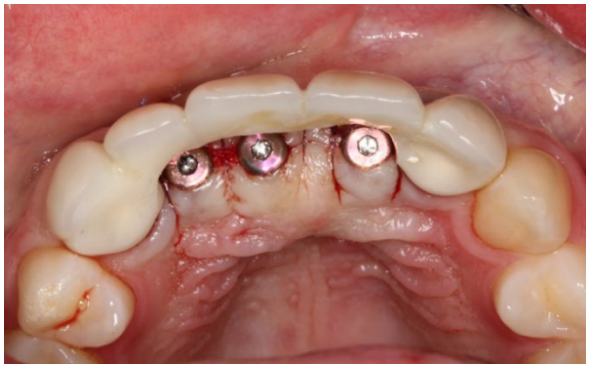

Fig.10. *Lithium disilicate single crown and intraoral radiograph.*

RESULTS

Three implants 11.5mm long and 3.75mm in diameter with Pilot Drill Surgery were placed to replace the missing elements 1.1, 1.2, and 2.1. After the first drilling with the Guided Twist Drill, a mucoperiosteal flap was performed. It was evaluated with positioning pins that modifying the preparation parameters, such as length and diameter, would not have been necessary.

Matching the final data with the virtual planning, it was considered that the three implant insertion axes allowed to place of three screwed prosthetic teeth not linked to each other, with an access hole for the driver, palatal compared with the incisal margin. It was observed that the depth of the prosthetic connection was adequate to obtain a cleanable transmucosal path and to create good aesthetic profiles.

The literature has reported that the recall of professional oral hygiene is fundamental for the long-term maintenance of implants (14). Therefore, every 6 months, the patient receives professional oral hygiene visits, which provide motivation and instructions on home hygiene from the dental hygienist (15, 16). Clinical and radiographic examination showed the stability of soft tissues and peri-implant bone levels during the patient's follow-up visits. At 6 years of follow-up, the aesthetic and functional satisfaction of the patient and the stability of the prosthetic implant rehabilitation (Fig. 11).

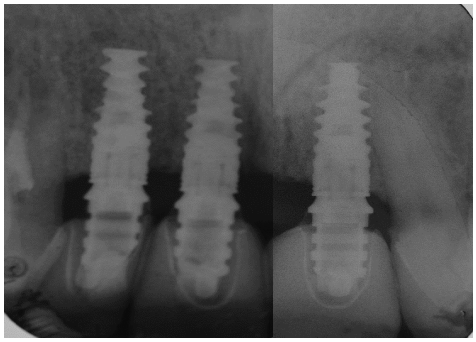

Fig. 11. *6-year follow-up intraoral radiographs.*

DISCUSSION

Specific dental skills are necessary to treat traumatic dental injuries. The teeth most commonly affected are the maxillary central incisors, with an incidence of up to 80% (17). Closed repositioning and non-internal fixation (closed treatment) are usually used to treat most segmental alveolar fractures. Cases where there is a lack of blood supply to the alveolar segments may also require closed treatment. Open reduction with or without internal fixation with plates and screws can be used to manage more extensive alveolar fractures (Open treatment) (18).

Other reasons for open reduction with or without internal fixation are dentoalveolar fractures, which cannot be reduced using closed methods, and/or those where postoperative MMF (maxillo-mandibular fixation) is undesirable. In our case, we chose closed treatment to preserve the periosteum attached to the bone fragments, ensuring sufficient blood supply to the pre-maxilla. This is mandatory to avoid bone necrosis and a consequent reduction of bone volume that could result in insufficient residual bone for implant rehabilitation (19).

Nowadays, the placement of osteo-integrated dental implants is a standard procedure in clinical dental practice, which is more predictable when implants are fully inserted into the bone. The integration of digital diagnostic technologies and tools has become a fundamental aspect of decision-making, guiding both diagnostic and therapeutical phases (20).

The most widely used 3D diagnostic technique in dentistry is CBCT (21, 22). This system must always be used in implant surgery, as it acquires detailed information and can also produce a stereolithographic model to analyze the anatomical situation. Data on bone volume, quality, or anatomical restrictions can be processed and evaluated in virtual implant simulation software.

The use of CBCT three-dimensional anatomical images and the prosthetic information obtained from the diagnostic wax-up scans, in combination with implant planning software, has improved the predictability of implant placement (23). Computer-assisted, model-driven implantology is one possible technique that makes implant placement more accurate (24). The virtually designed implant position is transferred to surgery with a drill guide, made using CAD-CAM technology in a production center, specialized dental laboratory, or in-office (6).

The literature has reported that three-dimensional guided implant surgery protocols can position dental implants more accurately than conventional free-hand implant surgery (25). A systematic review by Moraschini et al. and Laleman et al. reported a cumulative survival rate of 97,2-97,8% after 1-4 years of follow-up implant placement with guided surgery (26, 27). Moreover, Velasco-Ortega et al., in a recent study on guided implantology, reported that the cumulative survival rate of 198 implants was 97.5% (28).

In a study by Bernard et al., there was no statistical difference in three-year survival between implants placed by guided surgery and free-hand (29). The systematic review of Hultin et al. concluded that survival rates for placement of implants with and without guided surgery appear to overlap (30). However, it is known that the aesthetic success of the prosthesis and the long-term survival of dental implants strongly depend on proper placement in the bony space (31). Computerized surgery allows the clinician to place the implants in their ideal position, anatomically and prosthetically, reducing the risk of possible complications (25).

It is possible to categorize static surgical guides into fully-guided, half-guided, and Pilot-drilled protocols. A surgical guide is utilized in Fully guided surgery to assist the clinician in every procedure stage, from the initial drill to implant placement, using guide sleeves attached to the guide. The Half-guided protocol is the same as the guided one except for the final stage, where the guide is removed, and the implant is installed independently. In the Pilot-Drill guided surgery, a surgical guide is used for the initial drill, which can be stopped using an integrated guide sleeve, either with or without stopping the drill (31).

When the cumulative mismatch at the implant base and tip is detected in the comparison between the fully guided and Pilot-drill guided protocols, it is found that the Pilot-Drill group has a more significant mismatch in both areas (1, 31). On the other hand, a systematic review by Tahmaseb et al., considering only partially edentulous patients, fully guided and Pilot-Drill templates showed similar outcomes, allowing a precision of implant placement compared to a virtual design (32). In relation to our clinical experience with the Pilot Drill Template, the possible causes that could lead to a lower precision of the first drilling compared to virtual planning are:

- a greater difficulty inserting and positioning the drill in the posterior area in patients with a limited mouth opening. A possible solution to this problem is to insert the drill inside the template before placing it in the patient's mouth.
- a slight change of position that Guided Twist Drill can go through during the surgery has been observed.
- anatomical conditions such as low bone density can lead to the change in position of the drill, difficulties during the virtual planning to determine with precision the maxillary sinus, and the presence of an accessory branch of the inferior alveolar nerve can be perceived by the patient and can force the surgeon to modify the path of the implant.

It is important to underline those possible changes in length, diameter, type, and tilt of the implants during surgery may not be necessarily linked to the already mentioned criteria; suboptimal pre-surgical planning is associated with the clinician's normal learning curve during the first phase in approaching to a new method.

However, pilot-drill-guided surgery is a hybrid solution between traditional and total computer-guided surgery, and it can combine the advantages of fully guided and free-hand approaches (30). The pilot drill template offers several benefits if compared to a fully guided one: greater freedom of treatment and visibility, possibility to perform contextual osteoplasty or regenerative procedures, accurate torque perception, lower cost, easy use, less operator-dependent intervention, and reduction of overheating (33).

CONCLUSIONS

A limited number of articles concerning pilot drill surgery have been published in the literature, and this topic is claimed to be a valuable area of research. Pilot Drill Template implantology represents a compromise between Full-guide and traditional surgery and proposes to keep both advantages and overcome their limits. Adequate pre-surgical management can lead to successful implant-prosthetic rehabilitation with a good result both in terms of aesthetics and survival. The predictability of the prosthesis also makes computer-guided surgery a successful choice in the aesthetic areas (34, 35). Further studies are necessary to confirm the accuracy of computer-guided surgery with the Pilot Drill Template (36).

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Case Report

Post extraction palatal socket implants. A case report

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ABSTRACT

The article presents a case report of a 42-year-old man with missing maxillary left first premolar first and second molars due to endodontic treatment failure and symptomatic periapical disease. The article discusses the challenge of replacing maxillary molars with dental implants and presents a surgical approach called Post Extractive Palatal Socket Implant with a "one time one abutment" approach. The article highlights the use of a primary prosthetic implant component to combine the palatal positioning of the implant with the "one time one abutment" approach. The technique aims to optimize osteointegration and periointegration in one surgical time for challenging cases. The article discusses the advantages of such a technique for maxillary molar replacement with dental implants.

INTRODUCTION

Dental implants are an optimal treatment option for replacing missing teeth, whether the absence is due to pathological, acquired, congenital, or traumatic events, even in cases where no alveolar bone is available (1-5). Several techniques have been proposed over the years to minimize surgical invasiveness by reducing time and treatment phases (6). Timing of implant insertion was one of the most investigated topics, and immediate placement gained broad consensus since it was proposed in 1978 by Schulte (7). Implant placement can be distinguished, according to the ITI Consensus Report (8), as immediate, if an implant is placed the very day of the tooth extraction, early if soft tissue healing or partial bone healing (4-8 weeks) are to be waited before implant placement, or delayed if an implant is placed in a fully healed socket. Literature finds a high survival rate for every insertion protocol if applied under recommended indications (9).

When opting for Immediate Implant Placement (IIP), multirooted teeth pose additional challenges, such as large socket left after the exodontic procedure, reduced bone height apically to the extraction sites, difficult implant bed preparation (10) and greater occlusal forces if compared to the anterior regions. Additionally, the maxillary molar area often exhibits a Lekholm class III or IV bone quality (10), complicating the achievement of high primary stability for the implants (11), and the position determined by the post-extraction socket is not suitable for optimal implant placement (12). The combination of those factors lowers the predictability of IIP in the maxillary molar region. To predictably determine an ideal implant position when dealing with maxillary immediate implants in the molar zone, many techniques have been proposed, such as utilizing the retained roots after decoronation as surgical drill guidance during the implant bed preparation (13, 14) or the use of osteotomies to relocate the interradicular septum in combination with localized socket lifts in the upper molar region (15-17). However, maxillary molar sites are still challenging to treat without regenerative procedures (18), and conventional surgical protocols cannot achieve immediate placement (19).

Delayed protocols often involve regenerative procedures and sinus augmentation, reaching zygomatic implants for the most severe forms of atrophy (20), increasing the risk of complications, and lowering patient satisfaction (21). These factors may make palatal implants a safe and viable option (11). To further enhance results when adopting such a protocol, dedicated prosthetic solutions, such as "one time one abutment", should be paired to reduce marginal bone loss (MBL) and probing depth (22). The aim of this article is to present and discuss a novel surgical approach for post-extractive palatal socket implant placement of maxillary molar that joins the prosthetic advantages of palatal positioning with a "one time one abutment" approach.

Case report

A 42-year-old man with a noncontributory medical history needed to have his maxillary left first premolar, first, and second molar replaced due to endodontic retreatment failure and symptomatic periapical disease (Fig. 1, 2).

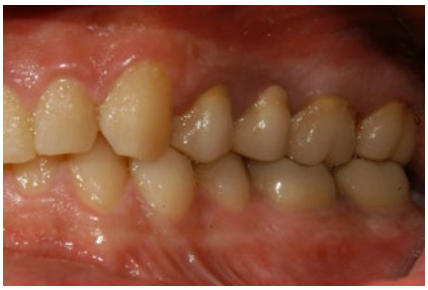

Fig. 1. *Initial situation. Posterior maxillary failing restoration with unrestorable teeth are present.*

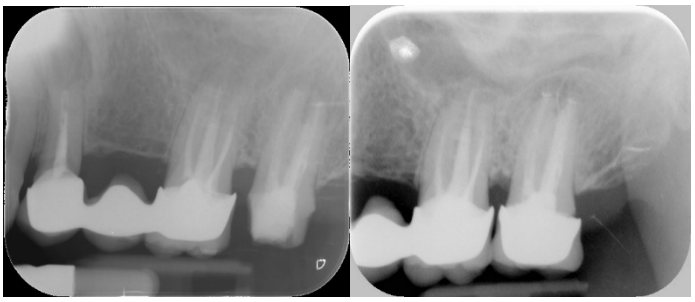

Fig. 2. *Pre-operative intraoral X-rays.*

Extractions were performed atraumatic: after infiltration anesthesia (articaine plus epinephrine 1:100,000), the crown of the molars was removed, roots were separated using a cutting drill and then removed with luxators and forceps. No incisions were made. After the atraumatic extractions, implants (4.3x6, 4.3x9, GTB, Advan, Udine, Italy) were placed in the palatal socket of the first and second molar, achieving an insertion torque higher than 35 Ncm. A periapical radiograph was performed after the insertion. (Fig. 3, 4).

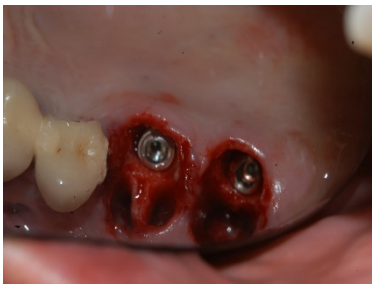

Fig. 3. *Surgical step of author's technique. Implants were placed in the palatal socket.*

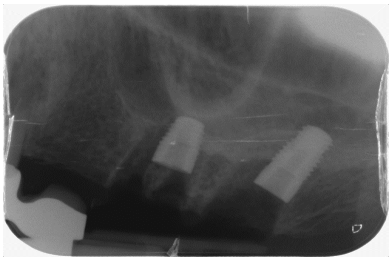

Fig. 4. *Intraoal X-rays showing implant placement.*

Implants were also placed to restore the first and second maxillary left premolars. A primary prosthetic component (gingival former (GFA), Advan, Udine, Italy) was immediately placed following the "one time one abutment" approach and left in position during all the prosthetic steps (Fig. 5).

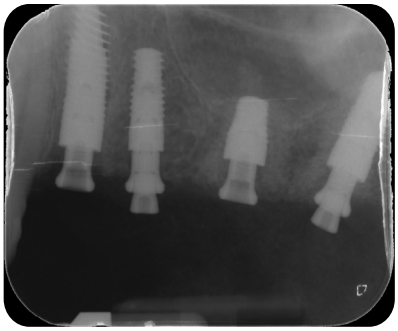

Fig. 5. *Intraoral X-rays showing the GFA in place.*

Bone graft (Bio-Oss, Geistlich) was used to fill the alveolar socket. A membrane was employed to protect the grafted site (Bio-gide, Gesitlich). Stitches were placed to stabilize the graft further. Postoperative treatment included amoxicillin-clavulanic acid 875 mg + 125 mg in tablet formulations twice daily for 6 days and ibuprofen 600 mg in tablet formulations twice daily for 3 days. The patient was instructed to rinse with 0.12% chlorhexidine mouthwash for 10 days, to apply cold packs over the treated area immediately after surgery to minimize the inflammatory response, and to sleep with two pillows to reduce postoperative swelling. Sutures were removed after 10 days. Three months after surgery, the prosthetic treatment was carried out, and the case was completed with a metal-ceramic screw-retained restoration (Fig. 6, 7).

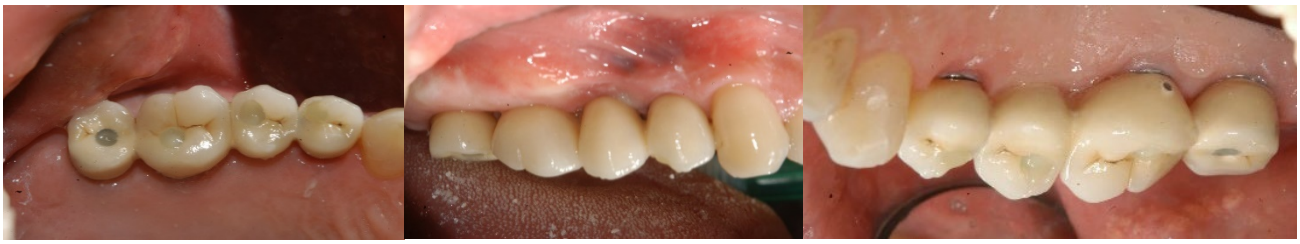

Fig. 6. *Final restoration in place.*

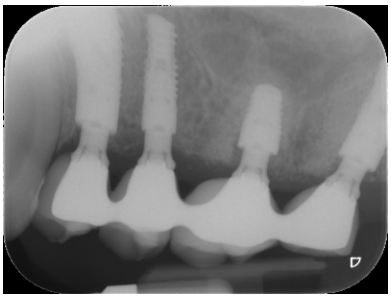

Fig. 7. *Final intraoral X-rays.*

A 5-year follow-up (Fig. 8, 9) showed optimal perio-integration and marginal bone stability. The probing depth around the implant was < 2 mm, and no prosthetic complications were reported.

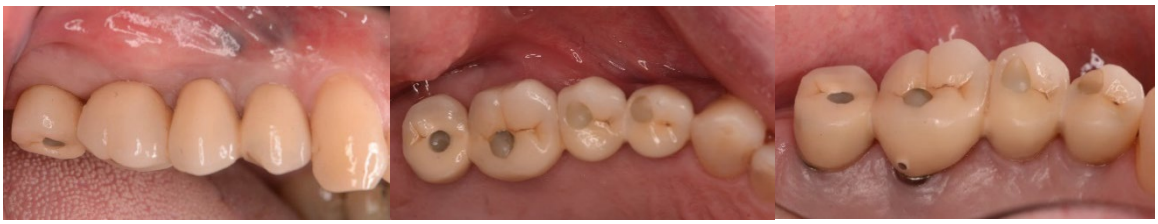

Fig. 8. *Intraoral clinical situation at 5 years follow-up.*

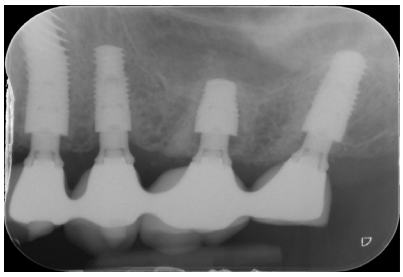

Fig. 9. *Radiograph at 5 years follow up.*

DISCUSSION

Most publications on immediate maxillary molar implants refer to centrally positioned implants using the interradicular bone (23, 24). Smith et al. (25) proposed a classification of molar extraction sockets to better assess the chance of taking advantage of the interradicular septum to stabilize immediate implants. In type A sockets, the implant's coronal portion is fully contained inside the residual septal bone, thus not requiring additional procedures to obtain adequate primary stability. On the other hand, type B sockets, where the implant's coronal portion is partially allocated in the septum, and type C sockets, where no septal bone is available, are often perceived as contraindications to immediate implant placement and require additional procedures.

A recent paper by Mustakim and colleagues (26) considered, besides the interradicular septum, the alveolar bone height (ABH) as a crucial parameter to assess immediate implant viability in molar sites, assessing that only Grade A (ABH>8.0 mm) can surely grant enough primary stability without socket lifting. Grade B (6.0 mm≤ABH≤8.0 mm) may accommodate shorter implants. Due to the aforementioned reasons, the interradicular septum may not always provide sufficient primary stability, requiring additional regenerative procedures, such

as transcrestal sinus lifting, due to insufficient torque (15). Wychowanski et al. (11) investigated 61 palatal molar implants, showing promising results in terms of both primary stability (> 60 ± 8 ISQ) and MBL after 2 years (mean 0.19 ± 0.03), suggesting that this approach may reduce the need for additional procedures in scenarios where the interradicular septum is not adequate for IIP. The aim of this paper is to propose a further enhancement by providing a predictable protocol to obtain hard and soft tissue integration through the combination of the proposed approach with the use of primary prosthetic component (GFA, Advan, Udine, Italy) as outlined in the "one time one abutment" approach (22).

A key consideration when dealing with palatal positioned immediate implants is related to proper implant-prosthetic connection selection. The authors employed, in the case presented in this paper, a one-time abutment with an 11° angled collar and 1.2 mm height (GFA, Advan, Udine, Italy) torqued to 35Ncm that uses a conometric connection and a "one abutment one-time" approach to promote soft tissue integration and hard tissue stability. These features shift the nanoleakeage coronally to the implant shoulder (27), reduce the exposure of the transmucosal path to bacteria during subsequent prosthetic phases, and minimize micromotion, which is known to be the source of detrimental mechanical stresses on connection structures and the surrounding bone (28). Notably, implants inclinations up to 15°-20° are reported to be safely manageable in posterior single crown implant-supported restorations, as reported by Lin et al. (29, 30); greater angulations may be considered unfavorable for IIP, as excessive strain is applied at the implant-bone surface, thus posing a limit on the palatal positioning of immediate implants.

CONCLUSIONS

The present paper registered optimal results combining a palatal implant positioning and "one abutment one-time" approach for immediate implant placement of maxillary molars, with no screw loosening and optimal probing depth (PPD < 2mm) after 5 years from final restoration delivery.

The planning of the implant mainly relies on hard tissue 3D reconstruction, but it should not be limited to what is immediately evident. A surgeon's clinical experience should always guide the process, with knowledge of the patient's anatomy and evaluation of the quality and of the soft tissue response being taken into consideration (31). In the coming years, better algorithms and new, fully automated methods of 3D comparison will probably be developed, making this kind of surgery even more precise and dependable (32).

Nonetheless, since there's not sufficient literature comparing traditional IIP protocols in molars with the presented approach, further investigations are required to accurately assess the clinical outcome, specifically focusing on MBL, probing depth, and prosthetic complications of the proposed protocol.

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Case Series

Tooth accidental displacement in extraction manoeuvres: a series of two cases

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ABSTRACT

Tooth displacement in bordering anatomical areas is a rare and challenging complication that might occur in the attempt at tooth extraction. Displacement may be attributed to multiple factors, including inadequate clinical evaluation before surgery, an inappropriate extraction plan, the application of excessive force, the use of an incorrect surgical technique, or a lack of experience on the part of the operator. Additionally, anatomical characteristics of the patient must be considered. In this report, we present two examples of tooth displacement and describe the surgical approach adopted to achieve tooth removal.

INTRODUCTION

Exodontia - or more generally, tooth extractions - is not a risk-free procedure and might sometimes cause a series of unpleasant complications, such as uncountable bleeding, tooth root fracture, soft tissue alterations, fracture of maxillary bone tuberosity, prolapse of Bichat fat pad and perforation of Schneiderian sinus membrane (1). Partial or complete tooth displacement, both due to iatrogenic action or trauma, in bordering anatomical areas is a rare and challenging complication (2, 3). Cases of displacement in the maxillary sinus (4), infra-temporal fossa (5, 6), pterygoid-mandibular space (7), lateral pharyngeal space (8), and buccal space (9, 10) have been reported.

PATIENTS AND METHODS

In this report, two cases of maxillary and mandibular teeth that were displaced accidentally during extraction maneuvers are described. This complication was diagnosed by clinical examination and computed tomography (CT). Patients were treated in the Department of Maxillofacial Surgery at the Azienda Ospedaliera Universitaria Integrata of Verona, Italy, from 2018 to 2023. Declaration of Helsinki guidelines were followed.

Case 1

A 32-year-old male patient was referred to our department after his dentist had attempted to extract the right mandibular third molar and a cystic lesion. The tooth was accidentally displaced in the left infratemporal fossa during the procedure. Tooth displacement caused the patient paresthesia of the left border of the tongue, pain, and discomfort during swallowing (11). The tooth could not be identified by intraoral examination or palpatory maneuvers. CT scan was performed to detect tooth position and revealed that the dental element was dislocated medially to the mandibular ramus, between masticatory and lateral pharyngeal space (Fig. 1). Surgery was performed under general anesthesia. The pre-existing mucosal incision was enlarged, the subperiosteal flap was reflected carefully on the lingual side from the second premolar to the anterior border of the ramus region, the lingual nerve was identified and preserved (Fig. 2). The dislocated tooth was identified onto the pterygoid muscle and reached by blunt dissection of peri-mandibular soft tissues on the lingual right side of the mandible and removed using Pean forceps. Irrigation and suture of the surgical site was performed. The patient was discharged the following. Follow-up after 2 weeks showed improvement of lingual nerve paraesthesia.

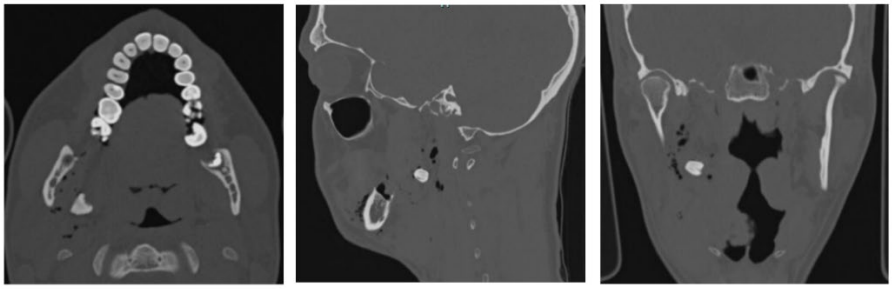

Fig. 1. *CT scan showing the displaced tooth in ITF (axial, sagittal, and coronal projections).*

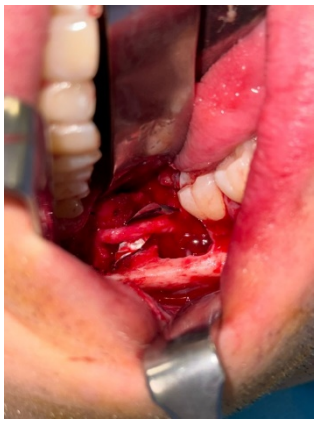

Fig. 2. *Preservation of lingual nerve.*

Case 2

A 54-year-old female patient with a history of extraction of dental element 2.7 and apicectomy of 2.6 was referred to our department for chronic maxillary sinusitis refractory to antibiotic therapy. CT scan showed an obliterated left maxillary sinus with a high-density foreign body (Fig. 3). Intra-oral examination showed an oral-antral fistula secreting pus. Two surgical approaches were performed: with an intraoral approach, we extracted element 2.6 and removed the fistula. With endoscopic sinus surgery, the apex of element 2.6 was visualized after wide maxillary antrostomy and was removed from the sinus (Fig. 4).

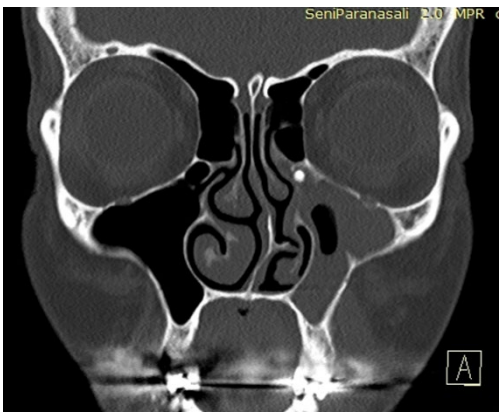

Fig. 3. *Foreign body in the left maxillary sinus.*

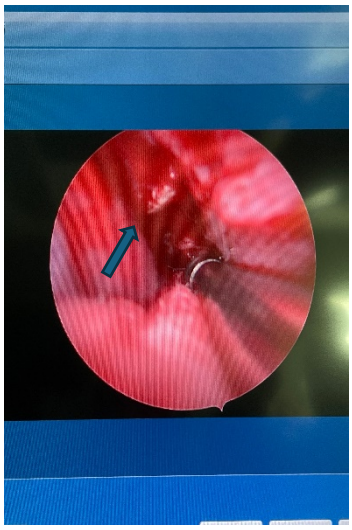

Fig. 4. *Endoscopic sinus surgery; apex of element 2.6 (blue arrow).*

DISCUSSION

Complications associated with surgical teeth extraction have been widely described in the literature: osteitis, alveolar bone fracture, tooth fracture, tuberosity fracture, bleeding, oro-nasal communication, injury of adjacent teeth, infection, and accidentally displaced teeth. In most cases, the tooth is displaced in the infratemporal fossa, followed by the maxillary sinus. Displacement may be attributed to inadequate clinical and radiological evaluation before surgery, inappropriate extraction planning, application of wrong and excessive force, poor selection of surgical technique, or lack of operator experience. In addition, anatomical characteristics of the patient must also be considered. This may cause perforation of the maxillary sinus floor and Schneiderian membrane, lingual alveolar bone, or soft tissues of the mouth (12).

The retrieval of the displaced teeth can be challenging, and their exact position must be assessed precisely with radiological exams (CT scan or CBCT scan are the gold standard). The surgical approach depends on the localization of the displaced tooth, patient anatomical characteristics, and surgeon experience. Regarding the optimal timing for surgical intervention, some authors advocate for a delay of at least two weeks to allow for the formation of fibrous tissue that can immobilize the teeth, preventing further dislocation during the retrieval process. However, a comprehensive review of the literature reveals that postponing surgery may increase the risk of infection (13-15).

A variety of surgical approaches are available to remove a displaced tooth: intraoral, extraoral, and combined approaches are used to access the submandibular space, buccal space, and lateral pharyngeal space (12). Bozkurt et al. used an extended lingual mucoperiosteal flap for the treatment of mandibular displacements. The lingual pouch approach was supported by extraoral compression to raise and stabilize the displaced fragment successfully (7).

Different approaches to the maxillary sinus are described in the literature: endoscopic retrieval and the Caldwell-Luc approach are the two most frequently described surgical methods (16, 17), even if other open approaches may be employed (18). A study by Huang et al. (19) reported 24 patients with accidentally displaced root fragments in the maxillary sinus. All patients underwent the Caldwell-Luc procedure with no complications. The most involved tooth was the first upper molar. The authors asserted that the Caldwell-Luc procedure is a safe, simple, and fast option for the retrieval of foreign bodies from the maxillary sinus. The

Caldwell-Luc approach has been the treatment of choice for a long period due to its simplicity of execution, low complication rate, and the advantage of facilitating the closure of the oroantral fistula (20).

A common complication of tooth displacement into the maxillary sinus is maxillary sinusitis, produced by the presence of oroantral communication or the infection caused by the displaced teeth (16). Management of displaced teeth in the maxillary sinus associated with sinusitis includes the removal of the tooth and removal of the infected sinus mucosa (21). In this case, an endoscopic approach may be used. Endoscopy might be either transnasal, through a bone window in the canine fossa, or the socket. This technique allows visualization of the maxillary sinus and a simple way to remove the displaced tooth non-invasively (22).

The infratemporal fossa is an anatomical space containing significant structures such as the third branch of the mandibular nerve, the maxillary artery with its branches, and the pterygoid venous plexus; this is why the infratemporal fossa represents a challenging area to operate in (23). Approaches to infratemporal fossa described in the literature include intraoral access with extended buccal sulcus incision, trans-sinusoidal approach, and extraoral approach. Wide incision in the maxillary sulcus and blunt dissection are reported to have lower success rates and a risk of recurrence of hemorrhage during the exploration of the infratemporal fossa (24). Due to poor visibility of the region, to avoid blind exploration of ITF proposed the use of active navigation image guidance system to facilitate continuing monitoring of the position (15, 24, 25). It is evident that a navigation system can be a valuable tool in determining the position of an object within the body while operating. However, it is essential to note that surgery is still conducted without directly visualizing the tooth and the surrounding structures. A trans-sinusoidal approach can be a good option, thus quite traumatic, the removal of displaced teeth from the infratemporal fossa (15).

CONCLUSIONS

The displacement of a tooth into the surrounding tissues is a rare but potentially serious complication that requires prompt diagnosis and management to reduce morbidity. Suppose the tooth is inadvertently displaced into adjacent anatomical spaces during the attempted extraction. In that case, it is the responsibility of the treating surgeon to verify the exact location of the tooth fragment through clinical examination and imaging and to formulate a treatment plan based on clinical characteristics, size, location, and adjacent structures.

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Review

Comparison of different flap designs in soft tissues periodontal healing after lower third molars extraction: a descriptive review

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ABSTRACT

The purpose of this descriptive review was to assess post-operative periodontal outcomes of adjacent molar sites after the extraction of lower third molars, comparing different surgical techniques. The electronic search strategy was conducted on different databases (PubMed, Scopus, and Web of Science) fitting the following selection criteria: clinical human studies (RCTs, retrospective and prospective); studies comparing different flap designs (e.g., envelope, triangular, and trapezoidal flaps) for surgical extraction of lower 3rd molars; studies assessing clinical outcomes of periodontal healing at adjacent molar sites. Studies included had to present a minimum follow-up of 1 month and at least variations of probing pocket depth (PPD) at 2nd molar site between baseline and follow-up. The search strategy considered a total of 148 records: based on the predetermined eligibility criteria, 24 articles were read, and 9 were finally identified. Regarding the primary outcome considered (PPD at 2nd molar site), no significant differences in its reduction between baseline and follow-up were found comparing different flaps designs. However, the greatest clinical attachment loss (CAL) was generally reported using a trapezoidal flap. Considering the heterogeneity of studies included, after 1 to 6 months of follow-up, no substantial evidence can be assumed for or against the use of a particular flap design for the extraction of lower third molars.

INTRODUCTION

Surgical removal of semi/fully impacted lower third molars usually require a surgical flap, ostectomy, and division of the tooth and suture of the soft tissue. Manipulation of the hard and soft tissues surrounding the impacted third molars can cause post-operative pain and swelling, together with periodontal pockets involving the adjacent molar sites (1), which may require further investigations to be solved (2). If signs of the post-operative course are transient, periodontal pocket often causes a chronic inflammatory process, which can turn into an established disease, which can severely compromise the stability of the tooth. In this proposal, care should be given to prevent and minimize tissue damage associated with the extraction of third molars by performing techniques highly respectful toward the periodontal complex (3).

Among flap incisions proposed (1, 4), which vary in terms of pattern and design, the envelope (marginal) flap provides an intrasulcular vestibular incision starting from the first molar and continuing distally to the second molar and a second release incision in the distal vestibular direction; the triangular flap is characterized by an additional releasing incision from the distobuccal side of the second molar; the trapezoidal flap provides a mesial-releasing incision starting from the first molar and a distal one to allow easier flap dissection; in the para-marginal flap incisions are made approximately 4-5 mm from the free gingival margin. Moreover, modifications of the commonly used flaps mentioned above were proposed as a more conservative approach with limited flap reflection: flap with papilla detachment and papilla decapitation (3, 4) are both modifications of envelope design. At the same time, the 3-cornered laterally rotated flap, and Szmyd flap are both modified standard triangular flaps (5).

Different authors in the literature evaluated the influence of a specific surgical flap design as a possible significant factor interfering with post-surgical periodontal healing (6, 7). No consensus and conflicting results were found regarding the ideal flap design for lower third molars extraction in terms of absolute worse or better clinical outcomes: despite some flap designs (e.g., triangular and marginal) registered irrelevant variations of PPD or CAL, others (e.g., trapezoidal flap) demonstrated worse outcomes in terms of CAL and gingival recession(1, 3, 4). In light of these considerations, the aim of this descriptive review was to investigate

potential differences in terms of periodontal healing at the second molar site after surgical extraction of the lower third molars.

MATERIALS AND METHODS

This study followed the PRISMA 2020 statement guidelines (8). The review was conducted according to the population, intervention, control, and outcome (PICO) format (9). We analyzed articles involving patients who underwent extraction of lower third molars, together with an assessment of periodontal conditions and postoperative healing.

Focused question

The current review attempts to answer the following question: "In patients undergoing surgical extraction of lower third molars, is there sufficient and adequate evidence in the scientific literature that a specific flap design can affect periodontal healing of the adjacent mandibular second molar during at least 1 month of follow-up?"

Search strategy

An electronic search was implemented to retrieve all relevant studies using the following databases: PubMed, Scopus, and Web of Science. The electronic search was conducted applying the following filters: publication date "10 years" up to the time of the search, 15/04/2024.

The research on PubMed was conducted using the mesh term: "third molar" (Title)" OR "third molars (Title)" AND "flaps (Title)" OR "flap "Title"); on Web of Science, the search terms were: third molar (Title) AND Flap (Title); on Scopus, the search terms were: third molar (Article Title) AND flap (Article Title).

Study selection

Two independent examiners reviewed titles from previously described research to minimize reviewer biases. In case of disagreement, the two reviewers analyzed the title jointly to arrive at a final decision concerning inclusion or exclusion. Articles identified as helpful in answering the research question were selected to read the abstract.

The following inclusion criteria were applied to carry out the study selection:

- human studies
- articles published exclusively in English
- randomized controlled trials (RCT), prospective studies and retrospective studies
- studies comparing different flap designs (e.g., envelope, triangular, and trapezoidal flaps) for surgical extraction of lower third molars
- studies assessing the postoperative course and clinical outcomes of periodontal healing at adjacent molar sites (1): (i) PPD at the second molar site as primary outcome; CAL, BOP (bleeding on probing), PI (plaque index) and REC (recession) as secondary outcomes.

In vitro studies, animal studies, case reports, case series and systematic reviews, and studies with less than one month of follow-up were all excluded. In examining the abstract, attention was paid to assessing the study's compliance with the inclusion criteria. The selected studies were saved as a digital or paper version and submitted to a full-text analysis. In this way, only articles that conformed to all the criteria were included.

Data extraction

The reviewer extracted the details on the characteristics of the studies using an Excel paper, filling in a table with the following data: PMID, Title, Authors, Type of Flap, N participants, Mean PPD preoperative, Mean PPD 1 week, Mean PPD 2 weeks, Mean PPD 1 month, Mean PPD 2 months, Mean PPD 3 months, Mean PPD 6 months, ΔPPD preop-1m, ΔPPD preop-2m, ΔPPD preop-6m, Mean GR preoperative, Mean GR 1 month, Mean GR 3 months, Mean GR 6 months, ΔGR preop-1m, ΔGR preop-6m, Mean CAL preoperative, Mean CAL 1 month, Mean CAL 2 months, Mean CAL 3 months, Mean CAL 6 months, ΔCAL preop-1m, ΔCAL preop-2m, ΔCAL preop-6m, Mean PI preoperative, Mean PI 1 week, Mean PI 1 month, Mean PI 2 months, Mean PI 3 months, Mean PI 6 months, ΔPI preop-1m, ΔPI preop-2m, ΔPI preop-6m, Mean BOP preoperative, Mean BOP 1 week, Mean BOP 1 month, Mean BOP 6 months, ΔBOP preop-1m, ΔBOP preop-6m, Pain Day 1, Pain Day 2, Pain Day 3, Pain Day 4, Pain Day 5, Pain Day 6, Pain Day 7, Pain 1st month, Dehiscence Day 2, Dehiscence day 7, Dehiscence 2 months, Mouth opening Day 1, Mouth opening Day 3, Mouth opening Day 7, Mouth opening 1st month, Wound healing Day 1, Wound healing Day 3, Wound healing Day 7, Wound healing 1st month, Swelling preoperative, Swelling Day 0, Swelling Day 1, Swelling Day 2, Swelling Day 3, Swelling Day 7, Swelling Day 30, Conclusion.

RESULTS

The electronic search through the PubMed, Scopus, and Web of Science databases identified 75 publications till the search date (15/04/2024). After reading all the abstracts, 24 studies were positive for eligibility and were read entirely. The analysis full text allowed for the exclusion of 15 articles with wrong outcomes, so the electronic search identified 9 articles (3-5, 10-15). A flow chart summarizing the study selection procedure was constructed in accordance with PRISMA guidelines 2020 (Fig. 1).

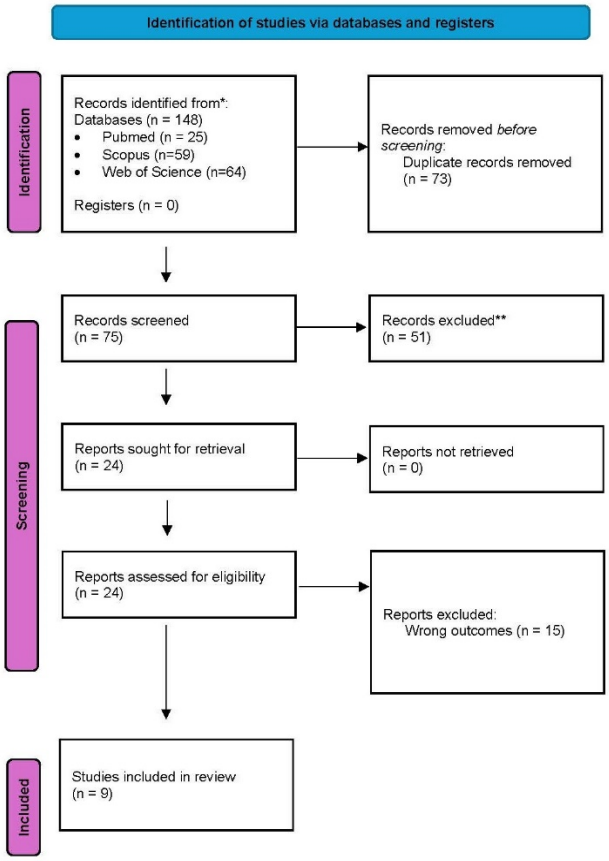

Fig. 1. *PRISMA flow chart of the search strategy and selection of studies*

Characteristics of the 9 included studies are summarized in Table I. The total number of participants reported was almost 30 (range 12-60), while the average number of sites registered was 66 (range 24-120). Furthermore, 7 studies were RCT, while 2 were retrospective. Post-operative conditions at 6 months were evaluated only by 3 studies, with the others shorter evaluations at 1, 2, or 3 months. The mean value for pre-operative PPD was 2,88 mm (range 2.35-3.31 mm), while the mean value after 6 months was reported equal to 3 mm. The other studies reported mean PPD values superior to 3 mm in the case of follow-ups less than 3 months (4.31 mm after 1 month; 3.18 mm after 2 months), equal to 3.16 mm in the case of follow-ups of at least 3 months.

Table I. *Characteristics of the included studies: Pocket Probing Depth (PPD), CAL (clinical attachment level), BOP (bleeding on probing), plaque index (PI), recession (REC), keratinized tissue (KT).*

Authors	**Year**	**Study Design**	**Country**	**N Patients**	**N Sites**	**Surgery Groups (Test vs Control)**	**Follow-up**	**Periodontal outcomes**	**Postoperative course**	**Others evaluation**
Korkmaz YT et al. (10)	2015	RCT (Split mouth)	Turkey	28	56	3-cornered Laterally Rotated Flap **vs** Envelope Flap	3 months	PPD, REC, PI, gingival index	Pain, swelling, infections	
Laurito D et al. (5)	2016	RCT (Parallel groups)	Italy	24	24	3-cornered Laterally Rotated Flap **vs**	2 months	PPD, PI, BOP, KT	/	

						Triangular Flap				
Alqahtani NA et al. (11)	2017	RCT (Split mouth)	Saudi Arabia	60	120	Modified Triangular Flap **vs** Envelope Flap	3 months	PPD	Pain, swelling, dehiscence	
Sridharan G et al. (12)	2020	RCT (Split mouth)	India	25	50	Triangular Flap with vertical anterior releasing incision **vs** Triangular Flap with oblique releasing incision	1 month	PPD	Pain, mouth opening, swelling	
Ahmad M et al. (13)	2021	RCT (Parallel groups)	Paki-stan, Saudi Arabia	30	60	Modified Triangular (Smzyd) Flap **vs** Envelope Flap	6 months	PPD, CAL	/	Bone loss
Passarelli et al. (14)	2022	RCT (Parallel groups)	Italy	60	60	Triangular Flap **vs** Envelope Flap	6 months	PPD, REC, CAL	/	
Castagna et al. (2)	2022	Retrospe ctive	Italy	80	80	Trapezoida l Flap, Envelope Flap, Marginal Flap with Papilla Detach-ment, Flap with Papilla Decapita-tion	2 months	PPD, CAL, PI,	/	
Zhao J et al. (15)	2023	RCT (Parallel groups)	China	100	100	Modified Triangular Flap **vs** Triangular Flap	2 months	PPD, PI, BOP	/	Bacterial character-rization, inflamma-tory, and immuno-logical indexes
Pardo et al. (4)	2023	Retrospe ctive	Italy	40	40	Marginal Flap with Papilla Detachmen t **vs** Trapezoida l Flap	6 months	PPD, CAL, PI, BOP, REC	/	

DISCUSSION

The pattern of post-operative periodontal healing after extraction of lower third molars is widely reported (6, 7) to depend on the chosen surgical technique, as the design of the access flap directly affects the healing of both soft and hard tissues. Apart from the characteristics of the surgical site (e.g., periodontal conditions of the adjacent second molar, position of the third molar and inclination of its roots, relationship between the third molar and the inferior alveolar nerve, relationship between the third molar and the second molar), which are directly linked to the visibility during the surgical intervention, other factors related to patient's age and health status can influence post-operative wound healing (14, 16-19)

Considering post-operative periodontal conditions of the adjacent molar sites, no relevant differences in flap designs performed to extract impacted third molar are reported in the literature (20-23). The purpose of this descriptive review was to analyze this aspect, aiming to suggest possible strategies to minimize post-operative complications and discomfort for the patient.

Studies included in the final analysis were nine (3-5, 10-15): as homogeneous comparisons regarding follow-up, primary clinical outcome (PPD), and type of study were not possible, primary considerations regarding periodontal healing focused on follow-ups from 1 to 6 months, RCT prospective and retrospective studies, other clinical parameters (e.g., CAL, BOP, VPI). In this proposal, even if CAL, being less affected by gingival inflammation (1), represents a relevant clinical parameter, the most frequently one assessed by authors for the evaluation of soft tissue healing was PPD at the second molar site, chosen in the present review as the primary outcome. This site usually presents a greater risk for developing notable iatrogenic post-surgical periodontal pockets, which are easily measurable through direct probing (24).

The mean number of participants reported in the 9 included studies was almost 30 (range 12-60), while average number of sites registered was 66 (range 24-120). Furthermore, 7 studies were RCT (4, 9-14), while 2 were retrospective (3, 4). Post-operative conditions at 6 months were evaluated by 3 studies (3, 4, 13), with the others shorter evaluations at 1,2 or 3 months (10-12, 14, 15). The mean value for pre-operative PPD was 2,88 mm (range 2,35-3,31 mm), while the mean value after 6 months was reported by Ahmad et al. (13) as 2,7 mm, by Passarelli et al. (14) as up to 3 mm, and by Pardo et al. (4) as 3,14 mm. The other studies (3, 10-12, 15) reported mean PPD values superior to 3 mm in case of follow-ups less than 3 months (4,31 mm after 1 month; 3,18 mm after 2 months); equal to 3,16 mm in case of follow-ups of at least 3 months. In this regard, the choice to set PPD (usually registered as an average value of vestibular and lingual sides) as a primary clinical outcome was influenced by the relatively short follow-ups of the included studies: an increasing pattern of PPD is compatible with an early post-surgery period (7), usually followed by its slight decrease or stabilization after 6 months, as demonstrated by other investigations with longer follow-ups, even with data at one-year after surgery (1, 22, 25).

Regarding the other clinical parameters collected, REC was evaluated only in 3 studies (4, 10, 14). Mean values of CAL at 6 months were reported by Passarelli et al. (14) as up to 3.6 mm and by Pardo et al. (4) as 2.55 mm, in accordance with a general trend found in the literature by other systemic reviews (1).

Concerning comparison between different surgical techniques, studies appear widely heterogenous, including, in most cases, triangular flaps (also with modifications, according to the direction of releasing incision) (5, 11, 12, 14, 15) envelope flaps (3, 10, 11, 14), trapezoidal flaps (3, 4), marginal flaps (also with modifications, according to papilla detachment or decapitation) (3, 4).

As already reported by several authors (3, 4, 16, 26), the trapezoidal flap is reported to cause the greatest loss of periodontal attachment compared to other designs due to the mesial discharge incision, which leads to a greater laxity of the wound, particularly evident in terms of increasing PPD and REC not only at second but

also at first molar site (1, 3, 4), as a consequence of the reduced vascular supply at sutures points (27). On the other side, the repositioning of this flap can be easily obtained since the releasing incision at the level of the central-buccal part of the first molar preserves the papilla and facilitates the suture. Pointed out this issue, even using other flaps, more respective of papillae healing (e.g., marginal flaps, flaps with the detachment of the papilla), the second molar site appears to be anyway subjected to REC (4), as this element represents in both cases the site for the incision aimed to surgical access.

Regarding the use of triangular flap variants (12), it can be underlined that a closure of the surgical site with an anterior oblique release leads to buccal tissue displacement, which can interfere with the healing distal to second molar in terms of post-operative periodontal pocket formation: this can be effectively avoided by using a straight anterior release incision instead. Furthermore, the modified triangular flap design (13) showed better PPD, CAL, and bone loss outcomes for second molars compared to the envelope flap design regardless of the patient, tooth, and operative factor.

On the other hand, it was suggested (14) that a triangular or envelope flap design may not be preferred for surgical extraction of the lower third molars to improve periodontal outcomes of the adjacent second molar, as no statistically significant differences between the two techniques were found regarding PPD, CAL, and REC.

Considering the comparison between trapezoidal, marginal, and modified marginal flaps (3), no relevant differences between techniques were found in terms of PPD or CAL, even if some designs, e.g., flap with papilla decapitation, demonstrated a greater consideration for the interdental papilla (28) between first and second molar, leading to better post-operative healing.

Other investigations evidenced that using either type of flap during third molar extraction increased probing depth, changes in the relative abundance of subgingival microbiota, and the levels of inflammatory factors within 4 weeks (15). In this regard, indexes of gingival inflammation, especially BOP, seem to assume importance for longer follow-up evaluations (4, 22): BOP was demonstrated to increase more in the first molar site with a trapezoidal technique for the eventual excessive tissue manipulation due to the mesial-releasing incision (29).

Regarding post-operative evaluation of pain and swelling (11), the envelope flap design was better than the modified triangular flap. At the same time, this last one was more efficient in limiting the dehiscence following the wound healing.

Finally, analysis according to different pre-operative degrees of inclusion (30), almost all studies (3) declared that this variable does not represent a critical issue in periodontal healing after surgery apart from the technique used (19).

Cases subjected to radiotherapy or antiresorptive and antiangiogenic drugs would deserve a more in-depth discussion beyond this review, where complex extraction can transform into dramatic cases requiring extensive demolitions and complex reconstructions (31). The preparation of the mucosal flap must allow the best possible view to avoid complications such as tooth dislocation (32).

CONCLUSIONS

The review of different flap designs does not allow a univocal interpretation of clinical outcomes for heterogeneity of surgical techniques employed, follow-ups, and soft tissue variables collected related to periodontal healing. In light of these considerations, no strong evidence after 1 to 6 months of follow-up can be assumed for or against the use of a particular flap design for the extraction of lower third molars.

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Review

Peri-implantitis: a comprehensive review of recent findings

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ABSTRACT

Peri-implantitis is a growing concern as dental implants become increasingly popular. This review paper aims to present the current understanding of peri-implant disease and provide insights into its management and prevention. Material and Methods: The study followed PRISMA guidelines and conducted an extensive electronic search for relevant articles. Only systematic reviews published in Q1 and Q2 journals were considered. Results: Eighteen systematic reviews have been selected from the 63 initial studies. The prevalence of peri-implantitis is estimated at around 19.53% of patients with implants and 12.53% of implants placed. Specific bacteria and MMP-8 levels have been associated with peri-implantitis, highlighting potential diagnostic markers. Conclusions: The review emphasized the need for consensus in research to estimate the epidemiological parameters of peri-implantitis accurately. Additionally, the adjunctive use of local antibiotics showed promising results in improving probing pocket depth and bleeding on probing compared to surgical treatment alone. Overall, this paper provides a comprehensive overview of the current knowledge on peri-implantitis and emphasizes the importance of precise diagnostic markers and effective treatment modalities.

INTRODUCTION

Dental implants have become a cornerstone in modern restorative dentistry, providing a durable and aesthetically pleasing solution for replacing missing teeth. Clinical applications of dental implants span diverse scenarios, from single-tooth replacements to complex full-arch rehabilitations. While in the early years of implantology, there was much focus on improving osteointegration and primary stability, to date, enormous efforts have been made to try to understand how to maintain osteointegrated implants and how to prevent or treat peri-implantitis.

Peri-implantitis is a pathological condition affecting dental implants, and as dental implant therapy continues to gain popularity as a reliable and aesthetically pleasing solution for tooth replacement, the prevalence of peri-implantitis has also witnessed a parallel rise. This multifactorial inflammatory condition involves the progressive loss of supporting bone around dental implants, jeopardizing their long-term stability and success (1). Given the complexity of peri-implantitis, a thorough understanding of its etiology, pathogenesis, accurate diagnostic methods, and effective treatment modalities is imperative for clinicians and researchers alike. The etiological landscape of peri-implantitis is intricate, encompassing factors such as microbial colonization, host response, biomechanical issues, and systemic influences (1–5).

Peri-implantitis can be visualized in radiographic images, such as X-rays (RX), commonly used in dental implant assessments. The radiographic appearance of peri-implantitis typically involves changes in the bone around the implant. Furthermore, additional imaging modalities, such as cone-beam computed tomography (CBCT), may provide three-dimensional information about the extent of bone loss and help in treatment planning for cases of peri-implantitis.

The 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions defined peri-implantitis as “a plaque-associated pathological condition occurring in tissues around dental implants, characterized by inflammation in the peri-implant mucosa and subsequent progressive loss of supporting bone” (6).

The impact of patient-related factors, including smoking habits, systemic diseases, and genetic predispositions, has been explored by Schwarz et al. (7), providing valuable insights into the host-mediated aspects of peri-implantitis.

Many efforts have been made, especially on the therapeutic front. Sanz-Sanchez et al. (8) and Tomasi and Derks delved into various treatment modalities, including nonsurgical interventions, antimicrobial agents, and regenerative approaches (9). These studies contribute to the ongoing efforts to establish evidence-based guidelines for managing peri-implantitis.

This review aims to clarify knowledge about peri-implant disease and try to draw a future perspective on its management and prevention. To obtain the broadest possible view, we have attempted to compare the oldest literature with the most recent systematic reviews to see every aspect of this disease from multiple perspectives.

MATERIALS AND METHODS

This study followed the PRISMA statement guidelines (2020). This systematic review was conducted according to the population, intervention, control and outcome (PICO) format. We analyzed systematic reviews involving patients affected by peri-implantitis, searching for what's new in the field of epidemiology, diagnosis, correlations, treatment, and outcome. The following inclusion and exclusion criteria were applied to conduct study selection.

Inclusion Criteria

- Systematic reviews and meta-analyses only
- Human studies
- Articles published exclusively in English

Exclusion Criteria

- In vitro studies, animal studies, retrospective studies, case reports, case series, literature reviews, systematic reviews without meta-analyses and meta-analyses without systematic reviews
- Non open-access article

Information Sources

Electronic research was performed through the MEDLINE (PubMed) database.

Search Strategy

The electronic search was conducted by two independent examiners to minimize reviewer biases, applying the following filters: date of publication starting 01/01/2020 up to the time of the search 20/12/2023, journal quartile including "Q1" and "Q2", and type of article including "systematic review" and "meta-analysis". The research on PubMed was conducted using the mesh term peri-implantitis.

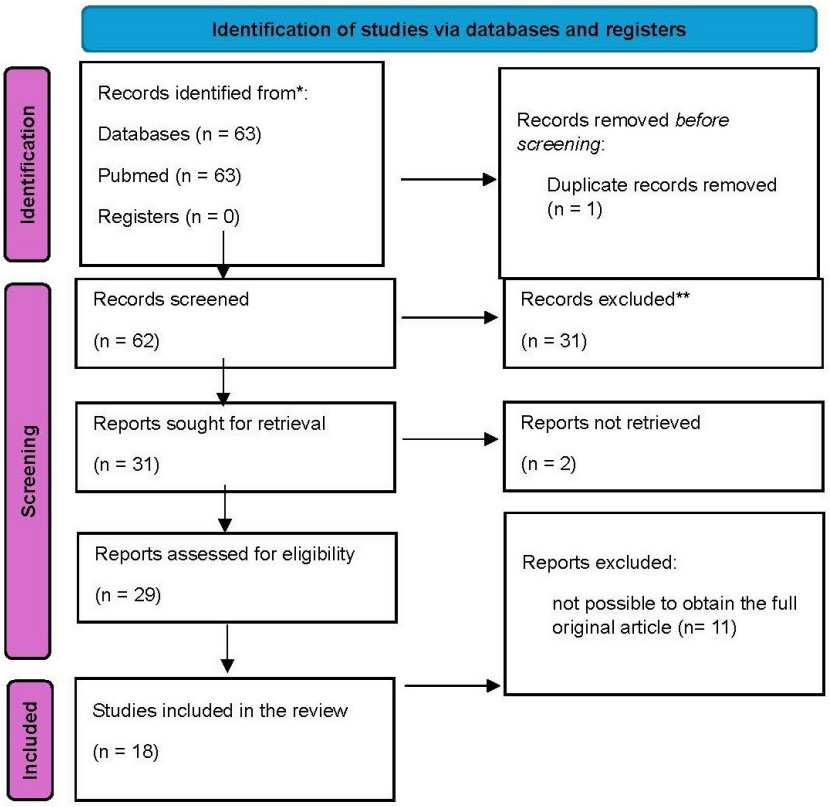
Study Selection

Titles deriving from the research previously described were reviewed by two examiners. In the case of disagreement, the two reviewers analyzed the title jointly to arrive at a final decision concerning inclusion or exclusion. Articles identified as helpful in answering the research question were selected to read the abstract. In the examination of the abstract, attention was paid to assessing the compliance of the study with the inclusion criteria. The selected studies were saved as a digital or paper version and submitted to a full-text analysis. In this way, only articles that conformed to the above criteria were included.

RESULTS

The electronic search initially produced 63 articles, and after a first reading of the titles, 1 article was deleted. After an analysis of the title and the abstract, the number of articles decreased to 29 (Table I).

Table I. *Initial electronic search and analysis.*



Starting with a full-text analysis, we found that 11 were not available in free access mode, so they were discarded. We have thus arrived at 18 systematic reviews, as shown in Table II.

Table II. *Articles selected for inclusion.*

PMID	Authors	Journal/Book	Journal quartile	Publication Year	DOI	N. of Studies
37508319	Baus-Domínguez M et al.	Antibiotics (Basel)	Q2	2023	10.3390/antibiotics12071223	14
35682086	Toledano-Osorio M et al.	Int J Environ Res Public Health	Q2	2022	10.3390/ijerph19116502	18
36551424	Grusovin MG et al.	Antibiotics (Basel)	Q2	2022	10.3390/antibiotics11121766	6
37296382	Barbato L et al.	BMC Oral Health	Q2	2023	10.1186/s12903-023-03058-z	16

32683389	Liu S et al.	Med Oral Patol Oral Cir Bucal	Q2	2020	10.4317/medoral.23633	7
36217689	Karlsson K et al.	J Clin Periodontol	Q1	2023	10.1111/jcpe.13732	16
37287463	López-Valverde N et al.	Front Cell Infect Microbiol	Q2	2023	10.3389/fcimb.2023.1149055	5
33487962	Saneja R et al.	J Indian Prosthodont Soc	Q2	2020	10.4103/jips.jips_144_20	11
34455016	Toledano M et al.	J Dent	Q1	2021	10.1016/j.jdent.2021.103790	12
37076816	Cheng J et al.	BMC Oral Health	Q2	2023	10.1186/s12903-023-02956-6	13
33562820	Roca-Millan E et al.	Viruses	Q1	2021	10.3390/v13020250	5
35207724	Dioguardi M et al.	J Pers Med	Q1	2022	10.3390/jpm12020235	7

10 papers were published in Q2 journals (source: Journal Citation Reports by Clarivate), while 8 were published in Q1 journals. 9 papers were published in 2023, 5 in 2022, 2 in 2021 and 2 in 2020.

Each analyzed systematic review deals with the issue of periimplantitis from a different point of view, since this paper aims to be a literature review, the aim was not so much to arrive at absolute truths but rather to provide a transversal knowledge of what is at present of this issue.

DISCUSSION

Prevalence

As Berglundh argued in 2002, the prevalence of peri-implantitis remains challenging to assess because data on implant BoP are rarely reported in various studies. The prevalence of peri-implantitis varies across studies and populations, reflecting the multifactorial nature of this condition. Recent systematic reviews and meta-analyses estimate the overall prevalence of peri-implantitis to range from 1% to 47%, depending on the definition criteria and follow-up periods employed in different investigations (10, 11). Such variations underscore the need for a standardized diagnostic framework and consistent reporting methodologies to accurately assess and compare peri-implantitis prevalence worldwide.

Understanding the prevalence of peri-implantitis is crucial for clinicians and researchers alike, as it emphasizes the necessity of preventive measures, early detection, and effective management strategies (12). As the population ages and the utilization of dental implants continues to rise, a comprehensive grasp of peri-implantitis prevalence becomes paramount for ensuring the long-term success of implant-supported restorations.

From the latest data of the systematic review made by Diaz et al., in which they analyzed 57 articles, the prevalence of periimplantitis is around 19.53% of patients who received implants and 12.53% of implants placed (13). In addition, the Diaz article highlighted the need for more accurate disease classification. It

recommended using consistent periodontal measurements based on the 2017 World Workshop's definition of peri-implant diseases for future studies.

The review also discussed the limitations of the current definition, severity, and prevalence of peri-implantitis, emphasizing the need for consensus in research to estimate its epidemiological parameters accurately. The outcome of his study suggested that individual risk factors, follow-up time, and the use of probing depth as a diagnostic criterion influenced the prevalence of peri-implantitis. The review recommended the use of more consistent periodontal measurements and the adoption of standardized diagnostic criteria for accurate estimation of peri-implantitis prevalence. In conclusion, the review underscored the importance of identifying precise diagnostic markers for improved disease classification and accurate estimation of peri-implantitis prevalence. Trying to track a guideline through this data is even more complicated when we try to assess the prevalence and diagnosis criteria on the short and ultra-short (14), implants positioned in free fibula flaps (15), or zygomatic implants (16, 17).

Correlations

Over the years, the etiology of periimplantitis has been extensively investigated. In addition to the traditional periodontal bacteria, correlations have been sought with other microorganisms that could better explain the rapid evolution of this disease and the degree of destruction of the peri-implant tissues.

Elisabet Roca-Millan et al., in their systematic review, aimed to investigate the potential association between the presence of Epstein–Barr virus (EBV) and the development of periimplantitis (18). The analysis encompassed five cross-sectional and case-control studies. It concluded that no statistically significant association was found between the prevalence of EBV in the peri-implant sulcus and the presence of peri-implantitis, and the results did not support a significant link between EBV and peri-implantitis. Furthermore, the review emphasized the bidirectional interaction between EBV and bacterial periopathogens, suggesting that EBV may play a role in the initiation and progression of peri-implant tissue breakdown by contributing to the overgrowth and aggressiveness of bacteria. The findings underscored the need for further research to develop more effective treatments for peri-implantitis and to better understand the potential association between EBV and peri-implant diseases.

The research paper of Érika B S Carvalho et al. intended to investigate the differences in bacterial presence and count between peri-implantitis and peri-implant health/mucositis in systemically healthy human subjects (19). The study included 12 cross-sectional studies with 1233 participants and 1513 implants. The findings suggested that peri-implantitis was associated with the presence of specific bacteria, including *S. epidermidis, F. nucleatum, T. denticola, T. forsythia, P. intermedia,* and *P. gingivalis*. Conversely, the presence of *A. actinomycetemcomitans, S. aureus,* and *C. rectus* was not associated with peri-implantitis. Meta-analyses revealed strong associations between peri-implantitis and the presence of S. epidermidis and specific periodontopathogens.

Mario Dioguardi et al.'s systematic review aimed to identify the relationship between peri-implantitis inflammation indices and glycemic levels in patients with and without diabetes who have undergone dental implant treatments (20). The review included seven studies and revealed worse outcomes in patients with diabetes in the short period (six months) for peri-implantitis inflammation indices such as marginal bone loss, bleeding on probing, probing depth, and plaque index. The meta-analysis indicated a statistically significant difference in peri-implant inflammation indices between the control group and the diabetes group, particularly after a six-month follow-up. The review also highlighted the importance of considering individualized information from translational research and analyzing all risk factors to provide evidence-based treatment options in the era of personalized medicine. Factors affecting peri-implant health, such as high body mass

index, history of periodontal disease, oral hygiene, and smoking, were identified as important but not well-researched, especially in diabetic patients (21, 22). The review emphasized the need for standardized clinical and radiological indicators for peri-implant diseases and recommended longitudinal studies with globally accepted case definitions and monitoring of blood glucose levels for more homogeneous, quantitative data.

Markers

One of the most important factors in the management of peri-implantitis is timing. Several efforts have been made to identify the molecular markers associated with this disease and determine if they are. Some study investigates the potential use of salivary biomarkers for early detection of peri-implantitis by analyzing the levels of CXCL9 and CXCL14 in saliva samples of patients with and without peri-implantitis (23). Other studies investigated the correlation with miR-4484 expression, identifying it as a biomarker for peri-implantitis (24). The findings of this research suggest that CXCL14, in combination with miR-4484, can differentiate peri-implantitis patients with 100% success.

Hani S Almoharib et al.'s systematic review and meta-analysis on the relationship between changes in matrix metalloproteinase-8 (MMP-8) levels in peri-implant crevicular fluids (PICF) and peri-implantitis (1). The diagnosis of peri-implantitis typically involves assessing inflammation, pocket depth, bleeding, and bone loss, but these methods mainly determine the history of the disease rather than its present activity or susceptibility. Therefore, the potential use of MMP-8 as a diagnostic marker for peri-implantitis is explored in this study. The research involved a comprehensive search for original cross-sectional and longitudinal studies comparing MMP-8 biomarkers in crevicular fluids around healthy implants with those around implants affected by peri-implantitis. The meta-analysis showed a significant increase in MMP-8 levels in individuals with peri-implantitis compared to those with healthy implants. The study concluded that MMP-8 levels in PICF were significantly elevated in peri-implantitis cases compared to healthy controls, indicating a potential link between MMP-8 and peri-implantitis. However, the meta-analysis did not provide evidence for MMP-8 as a diagnostic test for peri-implantitis. The paper provides a comprehensive overview of the potential role of MMP-8 in the inflammatory process and progression of peri-implantitis, highlighting the need for further research to establish its diagnostic value and understand the underlying mechanisms associated with peri-implantitis.

Other studies compared the immunological features of peri-implantitis (PI) and periodontitis using fluorescence-activated cell sorting (FACS) analysis with a wide panel of antibodies to identify and quantify immune cells in human PI and periodontitis lesions (25). The comparison showed similar immune cell compositions and ratios, with a higher proportion of T-cells in PI compared to periodontitis lesions. The study revealed similarities in the immune responses of both pathologies, suggesting similar immunological features, despite some subtle differences in the proportions of certain immune cell types. The authors highlighted the potential clinical relevance of flow cytometry analysis for identifying and quantifying immune cells in PI and periodontitis, including the sub-classification of T cells and the detection of immune cells requiring multiple markers for identification.

Non-surgical treatment

Periimplantitis treatment has been largely investigated, and one of the most proposed therapies is non-surgical. Ritu Saneja et al. systematic review and meta-analysis assessed the efficacy of laser therapy and photodynamic therapy (PDT) as adjunctive or primary therapies in the treatment of peri-implantitis and peri-implant mucositis (26). Peri-implant diseases result in pathological changes in the peri-implant tissues and loss of osseointegration, posing potential problems and complications for implants. The review included 11

randomized controlled clinical trials, comparing the effectiveness of various lasers and PDT to conventional procedures. Statistical analyses were conducted to assess mean difference and confidence intervals for probing depth (PD) and clinical attachment level (CAL). The literature search yielded 113 articles, with 11 included for quantitative analysis. The findings suggest that laser treatment as an adjunctive therapy or monotherapy in peri-implantitis does not show superior effects compared to conventional measures, as it came out from the 2017 Consensus report. However, laser therapy has shown more promising results in treating peri-implant mucositis compared to peri-implantitis.

Luigi Barbato et al. evaluated the clinical efficacy of different adjunctive methods/therapies to the non-surgical treatment of peri-implantitis (27). The review included 16 randomized clinical trials comparing non-surgical treatment alone versus non-surgical treatment plus any adjunctive method. The primary outcome was probing pocket depth (PPD) reduction. The outcomes revealed that non-surgical treatment with or without adjunctive methods may reduce PPD and bleeding on probing (BoP), but complete resolution of the pocket is unpredictable. The review highlighted that systemic antimicrobials were associated with higher PPD reduction and treatment success compared to non-surgical treatment alone. However, adjunctive local antimicrobials and lasers did not show significant differences in PPD and BoP reduction. The recurrence and progression rate of peri-implantitis was reported to be 44%, with 27% implant loss even after treatment. The most effective adjunctive method proposed for implant surface decontamination was systemic antibiotics, although caution should be exercised in their usage due to potential antibiotic resistance. The review concluded that non-surgical treatment with or without adjunctive methods may reduce PPD and BoP, but complete resolution of peri-implantitis is unpredictable. Systemic antibiotics may provide further benefits, but their usage should be considered cautiously.

Considering the contradictory findings of previous studies, the objective of the research paper by Siyan Liu et al. was to assess the efficacy of chlorhexidine (CHX) in enhancing outcomes for non-surgical management of peri-implant mucositis and peri-implantitis. The systematic review and meta-analysis included seven studies, four of which evaluated CHX in peri-implant mucositis and three in peri-implantitis. The findings indicated that the use of CHX did not significantly improve probing depths in peri-implant mucositis or peri-implantitis. Moreover, results on the effectiveness of CHX in reducing bleeding on probing (BOP) in peri-implantitis were conflicting. The included studies utilized different forms and concentrations of CHX, as well as variations in treatment protocols, which may have influenced the overall results. The paper also discussed the limitations of the review, including the small number of available studies, methodological heterogeneity, and variations in the treatment protocols. It emphasized the need for high-quality RCTs with homogeneous methodology to better understand the role of CHX as an adjunctive therapy for peri-implant mucositis and peri-implantitis. In conclusion, the meta-analysis results suggest that adjunctive therapy with CHX may not improve outcomes in the non-surgical management of peri-implant mucositis, and findings regarding its role in peri-implantitis cannot be drawn. The author stressed the importance of future research focusing on the use of CHX in peri-implant diseases and the need for more conclusive evidence.

Antibiotics

Antibiotics are frequently employed in conjunction with mechanical debridement to deal with the infectious component of peri-implantitis. The microbial etiology of peri-implantitis involves a complex interplay of various bacteria, including periodontal pathogens such as Porphyromonas gingivalis and Aggregatibacter actinomycetemcomitans. Several studies have investigated the use of systemic and local antibiotics to combat peri-implant infections. Systemic antibiotic therapy, such as amoxicillin and metronidazole, has demonstrated efficacy in reducing inflammation and controlling bacterial load in peri-implantitis cases. Local antibiotic

delivery systems, such as minocycline microspheres or doxycycline gel, have gained attention for their targeted approach in treating peri-implant infections (28). These localized treatments aim to achieve higher antibiotic concentrations at the implant site while minimizing systemic exposure. Despite the widespread use of antibiotics, controversies exist regarding the optimal dosage, duration, and choice of antibiotics for peri-implantitis treatment. Additionally, the emergence of antibiotic-resistant strains raises questions about the long-term effectiveness of antibiotic therapy in this context.

Maria Gabriella Grusovin et al. investigated the efficacy of using antibiotics, both locally and systemic, as an adjunctive non-surgical therapy for peri-implantitis, based on the 2017 World Workshop on Periodontal Diseases' definition of the condition (29). Six randomized controlled trials were included in the review, consisting of two studies using topical and four using systemic antibiotics. The findings indicated that adjunctive local antibiotics showed improved outcomes in terms of success rate, probing pocket depth (PPD), and bleeding on probing (BOP), while adjunctive systemic antibiotics improved PPD and probing attachment level (PAL) only. Specifically, adjunctive local antibiotics demonstrated significant improvements in PPD and BOP, leading to a success rate of 20-30%, while adjunctive systemic antibiotics led to PPD and PAL improvements, with a success rate of 2-65%. However, the findings were based on a limited number of studies, showing high heterogeneity and potential bias, thus leading to controversial results. The author emphasized the need for well-designed randomized controlled clinical trials to accurately assess the efficacy of antibiotics in peri-implantitis treatment, considering the risks of antibiotic resistance and the lack of consensus in treatment protocols.

Manuel Toledano et al. 2021 analyzed the efficacy of local antibiotic therapy in treating peri-implantitis, focusing on the reduction in peri-implant probing depth (PPD) and bleeding on probing (BoP) (30). The study involved a systematic review and meta-analysis of twelve studies with a total of 365 patients and 463 implants. The findings indicate that local administration of antibiotics led to a reduction of 1.40 mm in PPD and a 0.30 mm higher reduction in PPD compared to the control group. Additionally, the odds of BoP were 1.82 times higher when antibiotics were not locally administered. No adverse effects were found after applying local antibiotics. The research also discusses different antibiotics and their effectiveness in managing peri-implantitis. It highlights that while local application of antibiotics showed positive results, systemic antibiotics can have undesirable side effects such as dysbiosis and antibiotic resistance. The paper emphasizes the need for further clinical trials with longer follow-up periods and larger sample sizes to validate the findings and determine the sustained effects of local antibiotic administration in treating peri-implantitis. Overall, the study concludes that local antibiotic administration reduces PPD and BoP in patients with peri-implantitis without adverse effects, suggesting its efficacy in managing the condition.

In the 2022 systematic review and meta-analysis, Toledano et al. focused on the efficacy of systemic antibiotic administration in treating peri-implantitis in terms of bleeding on probing (BoP) and probing pocket depth (PPD). Despite the common use of systemic antibiotics in peri-implantitis treatment, the findings suggested that the administration of systemic antibiotics in peri-implantitis did not significantly affect BoP or PPD. The study included 18 articles, 9 of which were randomized clinical trials, and involved 605 patients and 870 implants. The results indicated that systemic antibiotic administration did not lead to any significant reduction in BoP or PPD. Various antibiotics were examined, including metronidazole, amoxicillin, azithromycin, clindamycin, and tetracycline, but none demonstrated significant efficacy in reducing BoP or PPD. Furthermore, the duration of antibiotic administration and the follow-up time did not lead to significant differences in BoP or PPD reduction. Overall, the findings suggest that the existing scientific evidence does not support the significant efficacy of systemic antibiotics in reducing BoP or PPD in peri-implantitis treatment and emphasizes the need to address the problem of antibiotic resistance.

Nansi Lopez-Valverde et al. analyzed 38, 5 of which were selected for qualitative analysis. The studies dealt with the use of metronidazole as an add-on treatment (31). The results showed confirmation of the effectiveness of using metronidazole as an additional treatment in some studies, while other studies did not show significant benefits. The results indicate that the decision to use an additional antibiotic should be made based on the condition of each patient, taking into account the severity of the disease and its consequences, and caution should be taken against possible resistance to the selected antibiotic. In conclusion, the researchers argue that long-term clinical studies using standardized methodologies are necessary to determine the role of metronidazole as an add-on treatment for dental implant infections.

María Baus-Domínguez et al. focused their research on the use of antibiotics in the surgical treatment of peri-implantitis (32). The review included 14 articles comprehending a variety of randomized controlled trials and observational studies and, similarly to the previous revisions, investigates the role and efficacy of systemic and local antibiotics in improving therapeutic outcomes for peri-implantitis, specifically in terms of probing pocket depth (PPD) and bleeding on probing (BoP). The findings indicate that the adjunctive use of local antibiotics significantly improves PPD and BoP compared to surgical treatment alone. However, the use of systemic antibiotics did not show significant improvement in PPD changes. They reported a significant reduction in PPD and BoP with the use of local antibiotics, particularly minocycline and doxycycline, as adjuvant treatments in surgical therapy. However, they also emphasize the potential complications and risks associated with antibiotics, including resistance, alteration of microflora, and hypersensitivity, which need to be carefully evaluated.

Surgical therapy

The complex etiology of peri-implantitis involves microbial colonization on implant surfaces, triggering inflammatory responses and bone resorption. Surgical interventions have emerged as a key component in managing peri-implantitis, aiming to eliminate infection, resolve inflammation, and promote tissue regeneration by removing the infected tissues, debriding the implant surface, and promoting a favorable environment for tissue healing. One of the primary surgical approaches in peri-implantitis treatment is open-flap debridement. This procedure involves accessing the peri-implant tissues through a flap, allowing thorough debridement of the implant surface and removal of granulation tissue. Open-flap debridement is often combined with regenerative techniques, such as bone grafts or membranes, to enhance tissue regeneration and restore lost peri-implant support. While surgical interventions play a crucial role in managing peri-implantitis, challenges persist, including the risk of implant surface damage during debridement and the potential for disease recurrence. Additionally, patient-specific factors, such as implant design and bone quality, influence the choice and success of surgical approaches. Surgical treatment modalities for peri-implantitis are many and evolving, reflecting the ongoing efforts to refine and optimize therapeutic outcomes.

Karlsson et al. evaluated access flap and pocket elimination procedures in the surgical treatment of peri-implantitis (33). The review included studies comparing surgical therapy to non-surgical therapy and assessed reduction of probing depth (PD) and bleeding on probing (BOP) as primary outcome measures. Meta-analysis demonstrated significant reductions in PD (standardized mean effect: 2.2 mm) and BOP% (27.0) up to 5 years post-surgery. Marginal bone level gain was also observed. Disease recurrence was high over 5 years, and implant loss was not uncommon. The evidence suggests the effectiveness of access flap and pocket elimination surgery in managing peri-implantitis, but high rates of disease recurrence and implant loss were reported over 5 years. The study highlighted the influence of baseline conditions on treatment outcomes and emphasized the need for further evidence regarding clinical and patient-reported outcomes. The review also indicated the lack of studies directly comparing surgical with non-surgical therapy and the need for more robust evidence from

randomized controlled trials. The study concludes that surgical procedures are valid options for peri-implantitis treatment and may be considered by clinicians, but it emphasizes the need for more comprehensive evidence, particularly from randomized controlled trials, to further evaluate the efficacy and long-term outcomes of access flap and pocket elimination procedures.

The research of Baima et al. sought to address the efficacy of different implant surface decontamination protocols in the surgical treatment of peri-implantitis (34). The study included 22 manuscripts reporting 16 randomized clinical trials (RCTs) that tested mechanical, chemical, and physical decontamination protocols. The findings suggested that all decontamination protocols resulted in improved clinical parameters, but no single method demonstrated clear evidence of superiority over others. However, titanium brushes and implantoplasty showed favorable results as single decontamination methods. Meta-analyses indicated that Er: Yag laser did not have a significant added effect on probing pocket depth (PPD) reduction, while systemic antimicrobials (amoxicillin or azithromycin) showed an added impact on treatment success but not in terms of PPD reduction. The study emphasized the lack of consistent evidence regarding the superiority of any decontamination protocol. It highlighted the need for well-designed RCTs to identify the most effective decontamination method for peri-implantitis treatment. The authors also noted limitations in the available trials, such as the reliance on single RCTs and the high heterogeneity among the included trials.

Asaf Wilensky et al. examined the efficacy of surgical therapy with chemical surface decontamination of implant surfaces compared to surgical therapy alone or surgery with placebo decontamination for treating peri-implantitis (35). They included six RCTs assessing the adjunctive effect of photodynamic therapy (PDT), chlorhexidine (CHX), and local antibiotics (LAbs) during surgery on clinical outcomes. The results showed that adjunctive use of local antibiotics resulted in clinically relevant reduction of pocket depth (PD) and radiographic marginal bone loss (MBL) at 12 months. PDT showed a small but significant reduction in bleeding on probing (BoP). Treatment with CHX resulted in no significant changes in PD, BoP, or MBL compared to placebo (saline solution). However, the authors found no decisive evidence showing that the adjunctive use of chemical implant surface decontamination improves the outcome of surgical therapy for peri-implantitis; in other words, for the authors, chemical decontamination of implant surfaces, in addition to surgical debridement, does not provide any additional benefit based on the current evidence. The limitations of the review include the paucity of evidence and small sample sizes in some studies, as well as variability in the definition of peri-implantitis, variability in inclusion criteria between studies, and heterogeneity in surgical techniques and outcome measurements.

At least Jing Cheng et al. investigated the effectiveness of various surgical methods for treating peri-implantitis. A total of 13 articles were included in the study, involving open flap debridement (OFD), resective therapy (RT), and augmentative therapy (AT) with and without adjunctive treatments (36). The study found that augmentative therapy improved radiographic bone fill (RBF) and clinical attachment level (CAL) more than OFD but did not outperform OFD in reducing soft-tissue inflammation. Additionally, adjunctive treatments, such as ozone therapy, improved the effectiveness of AT, but the evidence supporting this combination therapy is limited. The authors suggest that within the limitations of the study, AT was superior to OFD in improving peri-implantitis outcomes, as reported by others (37). The paper also discusses the prevalence of peri-implantitis, treatment options, the lack of reliable evidence for the most effective interventions, the rigorous methods used in the systematic review, and the assessment of the risk of bias and overall quality of evidence. The study concluded that future research should involve well-designed, high-quality, randomized controlled trials with larger sample sizes to address certain limitations in the findings.

CONCLUSIONS

The management of peri-implantitis encompasses various aspects, from understanding its prevalence and correlations to identifying relevant markers and exploring both non-surgical and surgical treatment modalities. This comprehensive review aimed to provide insights into the current state of knowledge in the field.

The prevalence of peri-implantitis remains challenging to assess due to inconsistent reporting in studies. The multifactorial nature of this condition contributes to prevalence variations, emphasizing the need for standardized diagnostic criteria. Consensus on disease classification and consistent periodontal measurements is crucial for accurate epidemiological assessments.

Correlations between peri-implantitis and various factors, including viral presence (Epstein–Barr virus) and bacterial composition, have been explored. While associations with the Epstein–Barr virus were inconclusive, specific bacteria like S. epidermidis and periodontopathogens showed strong links. Additionally, studies examining the impact of glycemic levels on peri-implantitis revealed worse outcomes in diabetic patients, emphasizing the need for personalized treatment approaches. Efforts to identify molecular markers for peri-implantitis have focused on salivary biomarkers, miR-4484, and matrix metalloproteinase-8 (MMP-8). The combination of CXCL14 and miR-4484 showed promise in differentiating peri-implantitis patients. MMP-8 levels in peri-implant crevicular fluids were elevated in peri-implantitis cases, suggesting a potential link. However, more research is needed to establish their diagnostic value.

Non-surgical therapies, including laser and photodynamic therapy, were assessed in managing peri-implantitis. While laser therapy did not show superiority over conventional measures, systemic antimicrobials, especially antibiotics, were associated with a higher reduction in probing pocket depth. Chlorhexidine's efficacy was inconclusive, highlighting the need for standardized protocols and long-term studies. Furthermore, antibiotics play a significant role in peri-implantitis treatment, with studies investigating both systemic and local administration. Local antibiotics, particularly minocycline and doxycycline, showed improvements in probing pocket depth and bleeding on probing. Despite common usage, systemic antibiotics did not significantly affect bleeding on probing or pocket depth, raising concerns about antibiotic resistance.

Surgical treatments are crucial in peri-implantitis management. Access flap and pocket elimination procedures demonstrated significant reductions in probing depth and bleeding on probing. Implant surface decontamination protocols, including mechanical, chemical, and physical methods, showed varied effectiveness. Chemical surface decontamination with photodynamic therapy, chlorhexidine, and local antibiotics demonstrated mixed results, emphasizing the need for more robust evidence. Augmentative therapy, especially with adjunctive treatments, showed promise in improving radiographic bone fill and clinical attachment level compared to open-flap debridement.

Cases subjected to radiotherapy or antiresorptive and antiangiogenic drugs would deserve a more in-depth discussion that goes beyond this review, where peri-implantitis can transform into dramatic cases requiring extensive demolitions and complex reconstructions (38).

In conclusion, the complex nature of peri-implantitis demands a multidimensional approach. As highlighted in other districts, the sharing of the skills of different specialists guarantees a complete evaluation of patients, with an improvement not only in treatment but also in quality of life (39). Standardized diagnostic criteria, personalized treatment strategies, and ongoing research are crucial for advancing our understanding and improving outcomes in peri-implantitis management. Further well-designed randomized controlled trials and longitudinal studies are essential to validate findings and establish evidence-based guidelines for optimal patient care.

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