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Evaluation Study

CHRONIC LOW BACK PAIN IN A PATIENT WITH MODIC1 OSTEOCHONDROSIS: TREATMENT WITH X-RAY-GUIDED OZONE IN THE INTERVERTEBRAL SPACE

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ABSTRACT

The definition of Low Back Pain (LBP) encompasses several vertebral pathologies. Vertebral bone marrow lesions recognizable as Modic modifications on magnetic resonance imaging (MRI) have high specificity for discogenic LBP. Furthermore, recent data indicate infectious and autoimmune etiologies in the genesis of Modic changes, both of which presuppose structural damage to the disc. In this study, we evaluate how much intradiscal/intervertebral oxygen-ozone can be a solution to this complex problem. We treated 69 patients that underwent intradiscal/intervertebral infiltration with an oxygen-ozone mixture at a concentration of 20 μg/ml under fluoroscopic guidance. The overall results were satisfactory, taking into account that a maximum of two oxygen-ozone administrations were made in 60 days. Furthermore, 70% of the patients evaluated two months after the last administration was satisfied with the treatment performed. In our opinion, the widely established and extremely safe technique justifies a more widespread use of ozone therapy and must stimulate additional applications which include more treatments with oxygen-ozone for each patient and systematic remote MRI control.

KEYWORDS: *oxygen, ozone, osteochondrosis, back, pain, Modic changes*

INTRODUCTION

Low back pain (LBP) is the most disabling pathological condition worldwide, with serious consequences for health services and essential work disability (1). Although the definition of LBP encompasses several vertebral pathologies, vertebral bone marrow lesions recognizable as Modic modifications on magnetic resonance imaging (MRI) have high specificity for discogenic origin (2).

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Recent data indicates infectious and autoimmune etiologies in the genesis of Modic changes, both of which presuppose structural damage to the disc. Clinical trials for novel non-surgical treatments of LBP associated with Modic changes have focused on suppressing inflammation/infection with intradiscal antibiotics or steroid injections (3-6). It is now widely recognized that Modic-like modifications are more than a simple discovery of random images in patients with LBP and instead represent an underlying disease that must be the real goal for more specific therapy.

In this study, we evaluate how much intradiscal/intervertebral oxygen-ozone can represent a solution to this complex problem.

MATERIALS AND METHODS

From October 2018 - August 2019, 69 patients between 32- and 81-years-old underwent intradiscal/intervertebral infiltration with an oxygen-ozone mixture at a concentration of 20 micrograms/ml under fluoroscopic guidance. The disc levels treated were 3 L2-L3, 7 L3-L4, 23 L4-L5, and 36 L5-S1. The patients were 34 male and 35 female; all complained of chronic LBP (over six months) without improvement with rest and, indeed, frequent nocturnal pain. In addition, all patients had on MRI a degenerative disc lesion (hernia or protrusion) associated with an alteration in the signaling of the bone marrow of the vertebral plate classifiable as Modic 1. The technique used for the local administration of the oxygen-ozone mixture is that commonly used for chemonucleolysis: preliminary identification of the disc space employing a fluoroscope, lateral intramuscular puncture with an angle of about 45°, lateral-medial direction up to the intervertebral space and subsequent injection of about 3-5 ml of oxygen-ozone. The patient was then left supine for about 10 minutes and asked to slowly assume a sitting and standing position (Fig. 1).

All patients were checked at 30 and 60 days after infiltration. An evaluation of changes in symptoms, overall improvement in the quality of life, and the level of autonomy was carried out. Unfortunately, a follow-up MRI scan performed approximately 90 days after oxygen-ozone infiltration was only possible in some patients.

RESULTS

The analysis of results are based on the information provided by a phone call with patients regarding an assessment of pain using a VAS-type scale, autonomy in carrying out daily chores, quality of night rest, the frequency of use of painkilling drugs. The overall results were satisfactory, taking into account that a maximum of two oxygen-ozone administrations were made in 60 days. 65% of the patients evaluated two months after the last administration was satisfied with the treatment performed. We found better results in the subgroup presenting moderate disc disease, with discs still somewhat hydrated and Modic 1 MR pictures confined to the anterior or posterior third of the involved somatic plates. (Fig. 2).

DISCUSSION

Modic modifications are alterations in the intensity of the MRI signal in the vertebral bone marrow that corresponds to lesions unrelated to medullary neoplasms or rheumatic disorders (7, 8). Almost all the degenerative bone changes

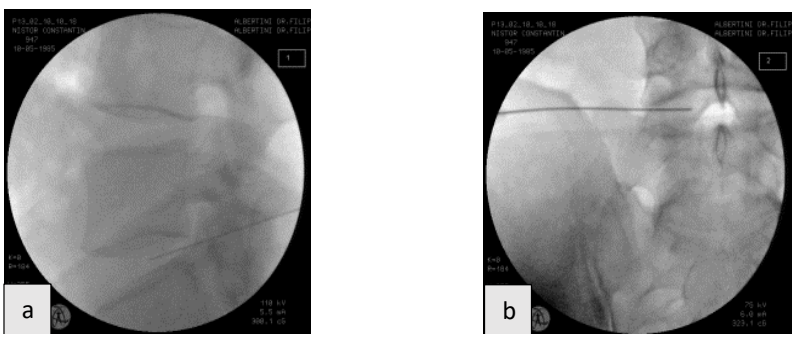

Fig 1. *A: lateral projection; B: front projection. The technique used for the local administration of the oxygen-ozone mixture.*

are localized at the disc-vertebral junction. The underlying mechanism of degeneration is chronic repeated trauma that alters the interbody disc and the opposing vertebral plates. The modifications induced by this mechanism are highlighted in an alteration of the spongy tissue of the vertebral bodies. Three types of Modic have been described based on their appearance in T1-weighted and T2-weighted images. Modic type 1 changes are hypointense in T1 and hyperintense in T2 (Fig. 3). Those of type 2 (Modic 2) is hyperintense in T1 and hyper- or isointense in T2 (Fig. 4). Finally, Modic type 3 changes are hypointense in T1 and T2 (Fig. 5).

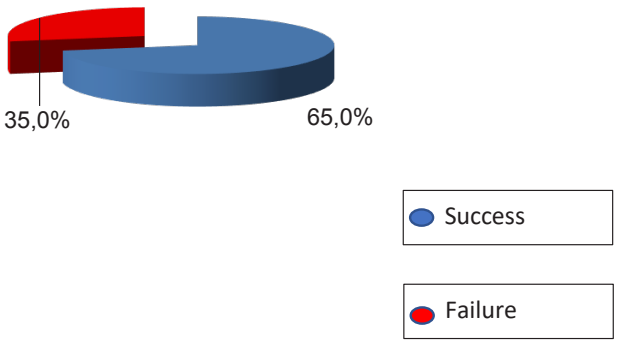

Fig. 2. *Analysis of the results obtained.*

Fig. 3. *In MODIC TYPE 1 it is possible to highlight a reduction in the MRI signal in T1 (A) and an increase in the intensity of the signal in T2 (B) which reveal the presence of edema in the cancellous tissue associated with micro-fractures of the trabeculae.*

Fig. 4. *MODIC TYPES 2 and 3 indicate chronic alterations. TYPE 2 is characterized by an increase in the MRI signal in T1 (A) and an increased signal in T2 (B). The bone marrow is replaced by adipose tissue that infiltrates the trabeculae.*

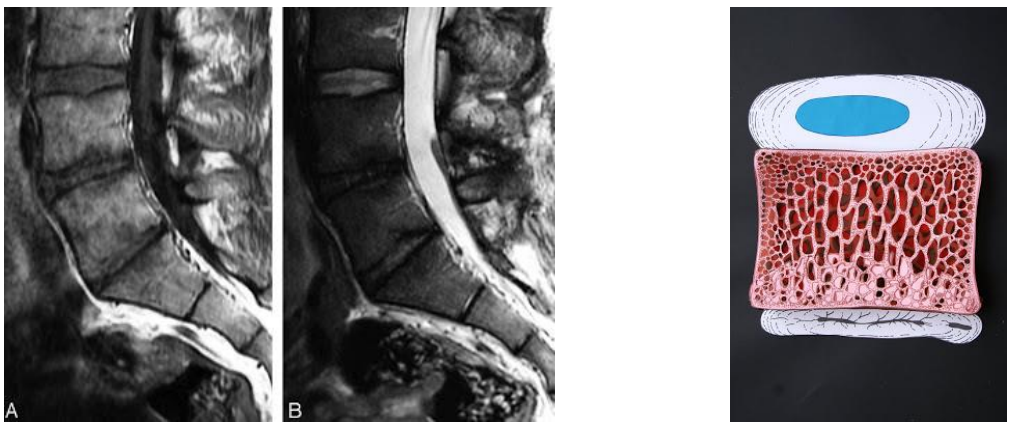

Fig. 5. *MODIC TYPE 3 shows a reduction in signal intensity in both T1 (A) and T2 (B) and is an expression of bone sclerosis.*

In general, the prevalence of Modic-like changes is high in patients with low back pain: 43% median prevalence, compared to only 6% median prevalence in the asymptomatic population (9). Furthermore, of the different types of Modic type 1 is the one more associated with LBP than the others (2, 10); Modic-like modifications are also commonly associated with disc degeneration (11), the severity of degeneration (12), and herniated discs (13).

Many studies have examined the correlation between Modic's categories and LBP. However, understanding the etiology of Modic changes is hampered by the different clinical presentations and multifactorial pathophysiology. Modic 1 and Modic 2 are interconvertible over time and can be converted into Modic 3 (10, 11, 12). Risk factors for Modic-like changes can be classified into disc / subchondral surface damage (disc degeneration, herniated disc, subchondral surface damage), systemic factors (smoking, aging, male sex, genetics), and overburden (obesity, spinal deformities, high occupational burden) (13,14). The non-ascertained and multifactorial nature is particularly true for Modic1; however, Modic 2 is mainly associated with hyperload and systemic factors (15-17).

The relationship between bone reaction and disc degeneration is still being studied; it is not clear whether the bone reaction follows or precedes disc degeneration. However, microfractures of the subchondral cancellous bone and cartilage have been frequently found even in the absence of disc degeneration. This would demonstrate how a degenerative process of the vertebral plate can be established before any disc degeneration. Two mechanisms can justify disc degeneration due to bone damage: 1) lack of diffusion of disc nutrients due to subchondral damage and 2) destructive action of releasing proteinases from inflammation with discolysis.

There is also a plausible infectious etiology deriving from the anaerobic environment of the disc. Common damage to the peripheral disc annulus could allow access to low virulence skin microorganisms that would find the absence of immune surveillance and low oxygen tension inside the disc. This context provides an ideal environment for bacterial growth, with the development of a slow-growing occult discitis and the consequent production of increasing amounts of bacterial metabolites and cytokines as the disc cell responds to infection (18). Chronic inflammation of the adjacent bone marrow can thus develop (19). However, there is only limited evidence to support a relationship between the presence of bacteria, LBP, and Modic Type 1 (20).

Finally, the possible autoimmune etiology should be remembered; after embryological disc formation, the nucleus pulposus no longer comes into contact with the systemic circulation, and subsequent peripheral damage to the disc can expose the nucleus pulposus to the immune system, where it is recognized as "non-self" and triggers an autoimmune response (21, 22).

There is a very strong correlation between Modic's type 1 sign and LBP (23). It has been shown that patients with signs of Modic 1 on MRI have different symptoms from those who do not have them. They often present with constant and persistent LBP, which does not improve with rest. During the 24 hours, pain intensity may fluctuate, but the patient is never asymptomatic. Seventy-five% of these patients suffer night pains, forcing them to get up and walk to relieve the symptom.

Recent studies show that the presence of Modic type 1 with chronic LBP is associated with poor outcomes of

conservative treatment (24, 25). Furthermore, it is evident that treating these patients is very difficult. Magnetotherapy, administration of bisphosphonates (clodronate), steroids, antibiotics, and the surgical solution through arthrodesis have been proposed and evaluated.

Considering the complex pathogenesis, based above all on inflammation, autoimmune reaction, and bacterial persistence with local infection, it is legitimate to hypothesize a conservative solution based on intradiscal/intervertebral oxygen-ozone treatments that can act on these factors. The biochemical mechanisms of ozone which counteract both cell-mediated inflammation (inhibition of the release of proteinases from macrophages and neutrophils and increased release of immunosuppressive cytokines) and biohumoral inflammation (inhibition of prostaglandin synthesis) have been known for some time (26).

CONCLUSION

The results obtained with one or two treatments may lead to considering the X-ray-guided administration of oxygen-ozone in the intervertebral space as a useful and effective technique in treating LBP associated with Modic 1 modifications to MRI.

A late control MR finding, unfortunately, evaluated only in some cases, are not of univocal interpretation. A clinical improvement does not always correspond to attenuating the inflammatory phenomena (reduction of edema) present in the initial examination. Therefore, it will be necessary to perform late MRI checks on a more significant number of treated patients to better interpret the clinical/radiological relationship of improvement.

In our opinion, however, the widely consolidated and extremely safe oxygen-ozone technique justifies a more widespread use as a valid alternative to more invasive methods or drug therapy. In addition, it must stimulate other works that include a greater number of treatments with oxygen-ozone for each individual patient and systematic late MRI control.

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Conflict of Interest

The authors declare no conflict of interest.

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Clinical Trial

OSTEOCHONDRITIS DISSECANS OF THE FEMORAL CONDYLUS TREATED WITH OZONE AND HYALURONIC ACID

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ABSTRACT

The aim of our study was to evaluate the therapeutic efficacy of treatment with oxygen-ozone therapy and hyaluronic acid in patients with osteochondritis dissecans of the knee. From September 2012 to February 2015, we treated three male patients afflicted by osteochondritis dissecans of male gender aged between 12 and 33 years (mean 21.3) with intra and peri-articular oxygen-ozone therapy and intraarticular hyaluronic acid. At the clinical check-up at the end of the treatment, we had a complete remission of the pain, with the possible return to participate in competitive sports, while the other two patients returned to amateur sports. The clinical data is supported by MRI investigations at the end of treatment. Based on the excellent therapeutic results obtained in our series, we believe that the oxygen-ozone therapy associated with the use of hyaluronic acid is to be considered a valid therapeutic alternative for the treatment of osteochondritis dissecans of the knee.

KEYWORDS: *oxygen-ozone; osteochondritis dissecans, knee, ozone, hyaluronic acid*

INTRODUCTION

Osteochondritis dissecans of the knee, or osteochondral lesion, is a pathological process characterized by the partial or total detachment of a chondral or osteochondral fragment from the articular surface of the condyles. It can be defined as a circumscribed lesion of the joint surface, characterized by aseptic epiphyseal necrosis and subsequent detachment of one or more osteocartilaginous fragments (1-3). We distinguish a juvenile form, which arises between 10 and 16 years, and a form that affects adults (4-7).

Both the conservative and surgical treatments, which depended on the subject's age, the site, and the extent of the lesion, aimed at restoring normal articular cartilage to delay as much as possible the onset of the arthritic degenerative

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process (7-16); this involves the onset of initially episodic pain (tending to become chronic), frequent presence of hydration and possible joint blockage. Suspension of sports activity and follow-up with radiography and magnetic resonance are recommended (1-16).

Evolution can lead to spontaneous healing, more frequently in children, or to the permanence and aggravation of symptoms, up to surgical indication in cases of free fragments or serious complications, such as functional impotence of the joint.

The following are the cases of a 19-year-old boy, a soccer player, a 12-year-old boy, and a 33-year-old man suffering from osteochondritis dissecans of the medial femoral condyle of the right knee, treated with oxygen-ozone therapy and acid hyaluronic.

MATERIALS AND METHODS

From September 2012 to February 2015, three male patients between 12 and 33 years (mean age 21.3), afflicted by osteochondritis dissecans, were treated with intra- and peri-articular oxygen-ozone therapy and intra-articular hyaluronic acid.

Subject to informed consent, the patients were treated with intra and peri-articular injections with oxygen-ozone. For the production of the oxygen-ozone mixture, a "Maxi Ozon Active International produced by Medica S.r.l. CE" generator device was used, equipped with a digital photometer for the regulation of ozone concentrations, with check valves for the collection of the gaseous mixture in absolute sterility. At the same time, the hyaluronic acid infiltrations were carried out at a concentration of 16mg/2ml containing 0.8 % of highly purified hyaluronic acid sodium salt with a molecular weight between 800/1200KDalton.

CASE 1

S.F., a 19-year-old boy who has been playing football since age 5, came to our observation in September 2012. The patient reported recurring episodes of mild but relapsing pain in the right knee, especially during prolonged training, starting from 2010. Due to this, in October 2010, the general practitioner decided to commission the execution of a knee X-ray, which was negative, and an MRI, which showed a hypointense area of a few mm. However, sporting activity was not suspended during this period since the pain tended to subside with rest. (Figs. 1 A-B).

Subsequently, starting from 2012, the pain recurred more frequently and, more importantly, did not resolve with rest, and the intake of NSAIDs became necessary. Finally, following the general practitioner's advice, the patient came to our observation at the beginning of September 2012, complaining of widespread pain in the right knee, especially in the medial region, which increases under load, and is now resistant to NSAIDs.

There were two episodes of hydration in the previous months, with the need for arthrocentesis (aspirates 30 cc and 35 cc respectively), and a sensation of instability, up to functional impotence, is reported. Sporting activity had been suspended for about two months. The physical examination on the first visit in September 2012 showed pain on palpation of the condyles and pain in extending the knee against resistance.

The X-ray performed in July 2012, not in possession of the patient as it was performed in the emergency room, was reported compatible with the diagnosis: the report showed the presence of edematous and hypovascularized fibro-cartilage tissue, with thickened edges and ossification evident on radiographic examination, compatible with a 1b stage.

MRI performed on 29 August 2012 confirms the diagnosis and shows

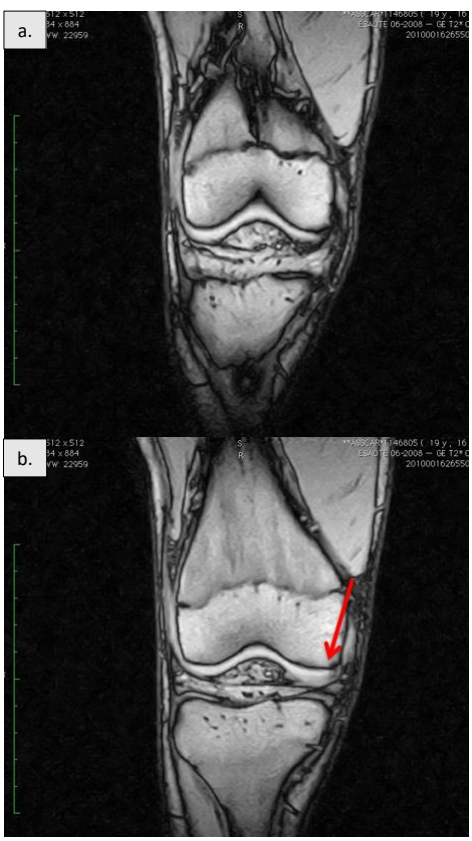

Fig 1. *(A-B): Coronal MRI October 2010: hypointense areola of a few mm.*

a lacunar shape, with a niche of the medial condyle 1.31 cm long and 1.23 cm wide (Figs. 2 A-B).

Standard treatment included, at this stage, the suspension of sports activities, instrumental follow-up, and pain control. A brace can also be associated, and if symptoms persist after 8-10 weeks, an arthroscopic evaluation of the fragment can be performed in situ. In order to alleviate the symptoms and improve the osteocartilage situation, it was decided to start a cycle of 10 sessions of local oxygen-ozone therapy, with intraarticular and peri-articular infiltrations performed every two weeks.

Intra-articular infiltration was performed with access from the external sub-quadriceps breach, while the extra-articular points treated were numerous: patella alar ligaments, goose paw, collaterals, supra-patellar region, medial compartment, patellar tendon, any supra-patellar bursa. For intraarticular injection, a 20cc syringe was used, with a 25Gx25 mm needle, at a concentration of 18µgO3/ccO2, and the dose was 5-10 cc. After each injection, the knee was flexed passively, a maneuver causing a peculiar noise due to the gas that mixes with the synovial fluid; this favors a better distribution of ozone in the joint. For extra-articular therapy, a 27Gx20 mm needle was used at a concentration of 18µgO3/ccO2 and at a 1-2 cc dose per injection.

In the third session, hyaluronic acid was used at the intraarticular level, alternating with ozone, which was instead always used in the extra-articular points. During each ozone therapy session, the patient was assessed for pain, the physical examination performed at the first visit was repeated, and he was questioned about the pain. From the third session onwards, he started reporting a gradual decrease in pain and a feeling of greater stability. Finally, having reached the tenth session of ozone therapy, the patient reported almost total disappearance of pain, recovery of joint functionality, and stability.

At the objective reassessment performed in November 2012, the patient reported an almost total well-being condition, and therefore it was decided to allow the gradual resumption of sporting activity. At the visit performed in January 2013, the permanence of well-being was highlighted, even after important training loads, and the MRI performed on 28.12.2012 shows restoration of the cartilage and bone structure of the medial condyle (Fig. 3 A-B).

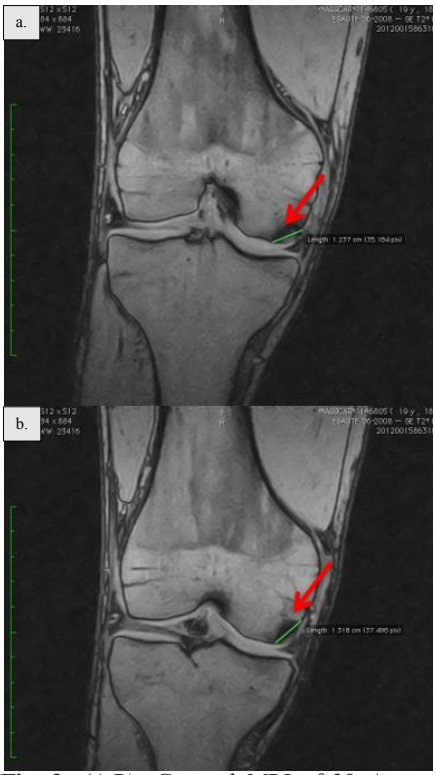

Fig. 2. *(A-B): Coronal MRI of 29 August 2012: 1.3 cm niche.*

Fig. 3. *(A-B): Coronal MRI of December 28, 2012: disappearance of the lesion.*

CASE 2

This case is of S.A., a 12-year-old boy who had been playing football since he was 7. In January 2013, he began to suffer from constant pain in his left knee, which increased under load. Despite the difficulties, he continued practicing sports until March 2013. In July 2013, following the further increase in painful symptoms, a standard radiographic examination of the knee was requested, which was reported negative.

At the next specialist check-up, it was decided to further investigate the clinical situation with an MRI of the knee that the patient performed in November 2013. MRI highlights a hypotensive area at the level of the femoral condyle with a maximum tarsal diameter of 2.1 cm that appears hypointense in the T1-weighted sequences (Fig. 4, 5). The orthopedic colleague opted for pharmacological treatment with NSAIDs, which did not result in substantial changes in painful symptoms.

The patient came to our observation in January 2014. Once the diagnosis of osteochondritis dissecans has been confirmed, we decided-with prior informed consent-to subject the young patient to a therapeutic cycle of ozone and hyaluronic acid, providing 10 therapeutic sessions with intraarticular infiltrations (hyaluronic acid 16mg/2ml and ozone at 18 µg/ml) and peri-articular only ozone, always at 18 µg/ml, performed twice a week. For intraarticular injection, a 20cc syringe was used, with a 25Gx25 mm needle, at a concentration of 18µgO3/ccO2, and the dose was 5-10 cc. After each injection, the knee was flexed passively, a maneuver causing a peculiar noise due to the gas that mixes with the synovial fluid; this favors a better distribution of ozone in the joint. For extra-articular therapy, a 27Gx20 mm needle was used at a concentration of 18µgO3/ccO2 and a 1-2 cc dose per injection.

Already from the first sessions, the patient reported a clear improvement in the clinical picture, and with the continuation of the therapeutic cycle, the complete disappearance of pain and complete recovery of functionality was achieved. Furthermore, during the MRI check-up in November, a clear improvement in the area affected by the injury was observed, with the absence of symptoms and gradual resumption of sports activity (Fig. 6).

CASE 3

S.R. man, 44 years old, practices jogging regularly but had suspended training since the summer of 2013, however, without improving symptoms. He came to our observation in October 2013, reporting pain at rest and underload in his right knee for some time. An episode of hydrarthrosis was reported in the anamnesis.

The physical examination highlighted the limitation of forced flexion. Therefore, we asked the patient to perform an MRI of the knee, which he performed in July 2013, where a hypointense area was found in the T1-dependent sequences at the level of the medial femoral condyle (Fig. 7).

Given the instrumental tests and the clinic, it was decided to subject the patient to a therapeutic cycle with ozone and hyaluronic acid, starting from January 2014. There are 10 therapeutic sessions of local oxygen-ozone therapy, with intraarticular infiltrations (hyaluronic acid 16 mg/2ml and ozone at 18 µg/ml) and peri-articular only ozone always at 18 µg/ml performed every two weeks. For intraarticular injection, a 20cc syringe was used, with a 25Gx25 mm needle, at a concentration of 18µgO3/ccO2, and the dose was 5-10 cc. At the end of the cycle, the patient reported a slight decrease in pain, not sufficient to resume sports activity.

From March to July 2014, he regularly performed muscle strengthening exercises and underwent monthly maintenance-booster sessions. As a result, the pain began to subside significantly. In addition, the control MRI performed in July 2014 documents a decrease in the width of the lesion (Fig. 8).

From September 2014 to early 2015, pain tended to occur after prolonged exertion, but the patient gradually resumed a satisfactory running activity. However, to date, pain persists after running on rough terrain or for times longer than 50-60 min. Therefore, we opted to perform maintenance sessions on a bimonthly basis.

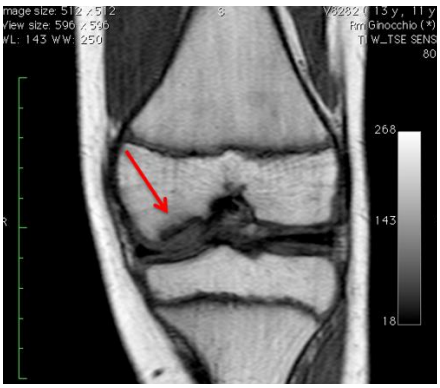

Fig 4. *Coronal MRI: osteochondritis dissecans focus of 2.1 cm. (arrow).*

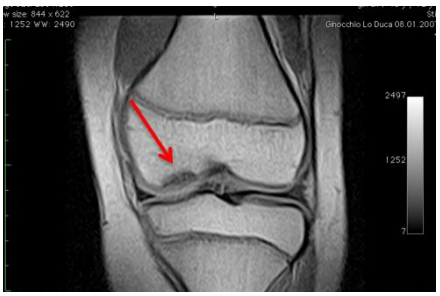

Fig 5. *Coronal MRI: osteochondritis dissecans focus of 2.1 cm. (arrow).*

Fig 6. *Coronal MRI post ozone therapy control with an almost total resolution of the osteochondritis picture.*

Fig. 7. *Coronal MRI osteochondritic focus (arrow).*

DISCUSSION

Osteochondritis dissecans of the knee (OCD) is a pathological process characterized by the partial-total detachment of a chondral or osteochondral fragment from a convex articular surface. The lesion of the articular surface is circumscribed and delimited and consists of aseptic epiphyseal necrosis, which isolates one or more osteocartilaginous fragments. These fragments initially contained in a niche are released at a later time in the joint (taking the name of "joint mouse", "Gelenk-Mause", causing joint mechanical disorders, pain, and possible episodes of hydrarthrosis (1-3). The clinical and anatomo-pathological pictures of the disease are known, while the pathogenesis is more uncertain due to numerous theories. For example, it can evolve towards complete healing with *restitutio ad integrum*, or the fragment can fall into the joint and form a free body corresponding to an empty niche on the articular surface (1-16).

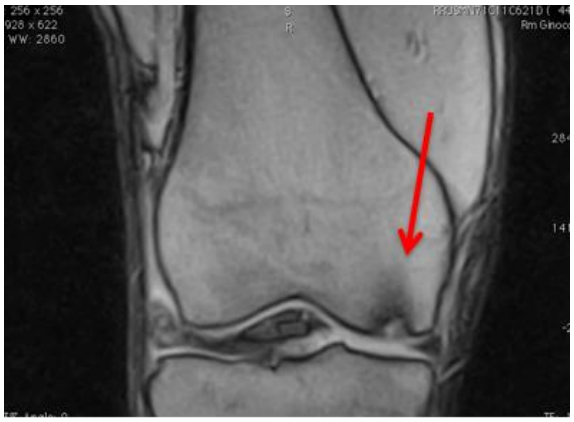

Fig. 8. *Coronal MRI noticeable reduction of the osteochondritic focus after ozone therapy (arrow).*

The process can affect many joints, such as the hip, elbow, and ankle; however, the knee is predominant. The bilateral nature of the condition is much more frequent if the external condition is involved. The male sex is more affected due to greater joint stress, and the onset of the disease occurs in puberty, but there are also cases involving adults.

Relatively frequent is the impairment of static and joint dynamics. It is usually a block in flexion, not as clear as the meniscal block (which always occurs during a specific movement), and usually transient. With chronicization of the symptoms, the ligament can be relaxed, giving the appearance of the drawer sign (anterior and posterior) (1-16). In adults, evolution is always towards the spiraling of the condition, and necrosis is accompanied by evolution into arthrosis (4-7). Diagnosis is based on a careful history, the patient's age, and habitus but is confirmed on X-ray and MRI (17-20). Often, chondral or osteochondral lesions detected on MRI or arthroscopy are asymptomatic and represent occasional findings.

The prognosis is good, especially in children; in adults, on the other hand, it is conditioned by maintaining an intact joint surface; in fact, cartilage or osteocartilage damage to the knee joint is generally considered to be a pre-arthritic degeneration. Therefore, clinical and instrumental follow-up are important (4-7). In early cases, the X-ray shows only slight prodromal structural alterations, while in full-blown cases, the necrotic fragment is surrounded by a clear halo, even more evident after detachment.

The conservative and surgical treatment, depending on the subject's age, the site, and the extent of the lesion, has changed over the years. Currently, it aims to restore normal articular cartilage to delay the onset of the degenerative osteoarthritis process as much as possible (8-16). Therefore, our protocol includes two initial sessions of intra and peri-articular ozone, followed then, in alternate sessions, by hyaluronic acid and intraarticular ozone, and peri-articular ozone at each session.

After the initial cycle, maintenance calls are performed at an increasing distance. The rationale for using ozone in numerous orthopedic pathologies lies in its anti-inflammatory, analgesic, neoangiogenic, and eutrophication properties. The anti-inflammatory action is observed in the knee since repeated trauma or microtrauma leads to cartilage damage, with an increase in PGE2 and proteolytic enzymes, which depolymerize glycosaminoglycans, resulting in edema.

Ozone acts on the mediators of inflammation and blocks the production of PGE2 (21-27). Furthermore, it increases the production of VEFG and NO, thus increasing the blood flow and the drainage of phlogogenic substances. Our experience has led us to observe better results in the case of their association, both in pathologies such as the one described and in other areas, such as neurological, osteoarticular, dermatological diseases, etc. (21-28). Therefore, it is important to observe how even the pathology affecting adults can be indicated in the associated use of ozone and ion resonance in order to improve the clinical condition and, above all, possibly postpone or avoid prosthetic replacement surgery, with important advantages for the patient from a functional point of view and an economic benefit for health.

CONCLUSION

Considering the results that can be obtained, the minimal invasiveness of ozone treatment shows how in cases of osteochondritis, without direct surgical indication, it is possible to restore a good functional and clinical situation. It is, therefore, possible to intervene in association with rest to avoid more aggressive interventions, such as arthroscopy, favoring bone and cartilage healing. Furthermore, recovery times are shortened using the described protocol compared to traditional therapy, and the results are maintained over time.

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Conflict of Interest

The authors declare no conflict of interest.

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Evaluation Study

RELATIONSHIP BETWEEN PRESCRIPTIONS OF THE ALEXANDER DISCIPLINE AND CLINICAL OUTCOMES

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ABSTRACT

The study aims to determine whether there is correspondence between the tip and torque values of the Alexander Discipline prescriptions and the clinical outcome of eight cases treated with the same technique. The study sample consists of eight pairs of plaster models (maxillary and mandibular) belonging to patients treated by the same operator with the Alexander technique and the same archwires sequence. An extra-oral optical scanner scanned the post-treatment plaster models, and the digital models were subsequently analysed by VAM 3D software. Finally, deviations in tip and torque were statistically determined between the final post-treatment measurements and the ideal target measurements. A single-sample t-test was used for each tooth and each tip value and torque to test whether the error (difference between achieved and ideal measurement) is statistically 0. Some groups of teeth have achieved tip and torque values closer to the Alexander Discipline prescription, while others do not. The most obvious differences can be appreciated in the torque values of the mandibular elements (36, 37, 46, 47) and the tip values of the maxillary elements (16, 17, 26, 27). The straight-wire vestibular orthodontic appliances used in this study cannot fully express the prescription contained in the appliance. The reasons mainly include three aspects: errors in brackets positioning, dental anatomies and inaccuracies of the appliance.

KEYWORDS: *Alexander discipline, orthodontic prescriptions, tip and torque values, straight wire*

INTRODUCTION

Modern orthodontics was born with Edward Hartley Angle, an American dentist who contributed to diagnosing and classifying malocclusions and designed innovative orthodontic devices (1). In 1928 he introduced the "Edgewise"

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technique, the first to guarantee three-dimensional tooth movements (2). However, it carries the disadvantage that all treatment mechanics must be placed on the wire through bends necessary to compensate for the anatomical differences between teeth. In lingual orthodontics, instead, the ancient mushroom's archwire form was effective, but it entailed complex clinical management (3).

In 1970, with the introduction of the Straight Wire technique by L.F. Andrews, all the information required to position the teeth tridimensionally was included in the brackets without any bends. However, over the years, some authors have pointed out some limitations. For example, it is often impossible to achieve the ideal tooth position at the end of the treatment, especially in extractive cases where strong torque control of the anterior teeth is necessary.

In 1975, to simplify the technique, Ronald Roth introduced the Roth-Prescription in which the correction of malocclusion is achieved in harmony with functional occlusion and with a reduced variety of brackets prescription in extractive and non-extractive cases (4).

This technique underwent further evolution in 1989 with the MBT technique by McLaughlin, Bennett and Trevisi (5). The MBT technique represents a highly refined system of pre-adjusted brackets, allowing extensive control of tooth movement and the opportunity to customise the technique through a wide range of prescriptions and variability of archwire forms (5).

RG "Wick" Alexander is considered a pioneer of modern orthodontics. He graduated from Texas Tech University with a thesis on the Tweed technique. In his long clinical practice, Alexander observed how some cases treated with extractions using the Tweed technique provided long-term stability and proper function. On the other hand, the extractions caused a flattening of the profile producing aesthetic deterioration and a decreased torque of the incisors (6). The challenge for him became to achieve greater control of the mandibular incisors and recovery of arch space by treating the patient without extractions (7).

In his technique, Alexander introduced the 0.018 slots that allowed the use of lighter forces with less discomfort for the patient. Moreover, the smaller slot size improved the sliding mechanics and, combined with rectangular wires, better torque control. In the Alexander Discipline, each bracket is designed to fit better the shape of each tooth. Twin brackets are used only for teeth with a large and flat surface; on the other hand, single attachments are used for teeth with a small and curved surface.

After years of experimentation, trial and error, and clinical research, Alexander completed the final prescriptions. His technique represents a valuable tool for achieving optimal aesthetics and long-term stability.

This study aims to determine whether there is a correspondence between the tip and torque values of Alexander Discipline's prescriptions and the clinical outcome of eight cases treated with the same technique. The purpose is to state if there is any statistically significant difference in tip and torque values between the teeth's final position and the Alexander Discipline's prescriptions.

MATERIAL AND METHODS

The study sample consists of plaster models (maxillary and mandibular) belonging to eight patients treated by the same operator with the Alexander technique and with the same sequence of archwires. The cases were selected from the archives of Dr Remo Benedetti, a specialist in orthognatodontics and president of "The Alexander Discipline Study Club." All cases reviewed are IBO certified.

The study sample includes Caucasian patients with the following characteristics:

- no prosthetic restorations and/or implants;
- no abnormalities of tooth shape;
- absence of congenital anomalies.

Once the post-treatment plaster models were obtained, they were scanned using a 3-Shape D800 extra-oral optical scanner with ScanITORTHODONTICS (3-Shape) scanning software. Next, the 3D virtual model files in STL format were transferred to VAM 3D digital model analysis software. Once the 3D models were uploaded to VAM 3D software, various reference points were placed on each tooth so that each could be recognised and analysed by the 3D program (8). The reference points were placed in a specific order, as suggested by the author.

For incisors and canines, six points are placed in the following positions:

- occlusal mesial point (marginal ridge);
- occlusal distal point (marginal ridge);
- gingival vestibular facc point;
- incisal vestibular facc point;
- vestibular fa point;
- gingival lingual FACC point.

For premolars, the points are the same plus another two extra that are:

- mesial point (in/out);
- distal point (in/out).

The placement of the points is the same in the two arches; the only difference is that, while in the upper jaw, the procedure starts from the first quadrant, in the mandible, it starts from the third. This way, 100 points were placed on the upper arch and 100 on the lower arch (Fig. 1).

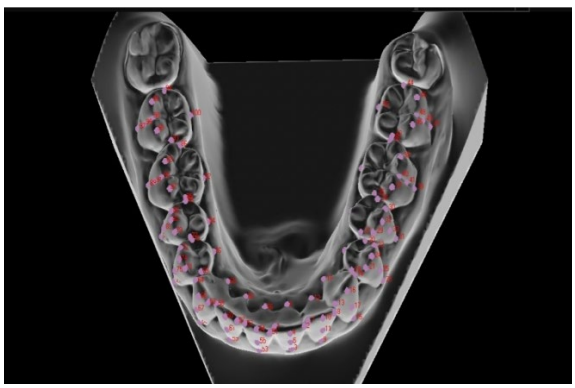

Fig. 1. *Placement of points on the teeth*

The same orthodontist always made measurements on the 3D VAM software to nullify the inter-operator variability. In the end, all measurements were repeated in four random models by the same clinician to assess the intra-operator variability. The measurement variations were statistically non-significant; this supports the repeatability of the recorded parameters and the method's validity. For each tooth reported, the final values of tip and torque achieved and the ideal ones.

Statistical analysis was performed using R statistical software (R Core Team 2015) on a data set consisting of 224 tip and torque values measured on all the teeth of each of the 8 models. In particular, the aim of the analysis is to study the deviations between the final post-treatment measurements and the ideal target measurements. For this purpose, a single-sample t-test was used for each tooth and measurement to check if the error (difference between achieved and ideal measurement) is statistically 0.

RESULTS

The results of the descriptive statistical analysis are shown in the tables below. For each tooth, the mean and the standard deviation (sd) of the achieved values and deviations from the ideal value (error) have been calculated. The teeth are sorted by decreasing the error's standard deviation because it represents each tooth's difficulty in achieving the ideal post-treatment value (Table I and Table II).

For each tooth, Table III shows the p-value of the t-test. The measure with asterisks indicates that the deviations are statistically significant from the target. The significance thresholds are as follows: weak (one asterisk, p-value between 10% and 5%), standard (two asterisks, p-value between 5% and 1%), strong (three asterisks, p-value less than 0.001).

Table I. *Error analysis of tip*

Tooth	achieved.mean	achieved.sd	Ideal tip	error.mean	error.sd
37	1.402	14.1	0	1.40	14.1
46	1.212	11.3	-6	7.21	11.3
47	4.922	10.6	0	4.92	10.6
27	-6.400	9.6	0	-6.40	9.6
17	-4.238	9.2	0	-4.24	9.2
44	-0.341	9.2	0	-0.34	9.2
26	8.782	8.3	0	8.78	8.3
36	1.678	7.7	-6	7.68	7.7
35	-1.528	6.9	0	-1.53	6.9
45	0.464	6.5	0	0.46	6.5
34	-5.411	6.0	0	-5.41	6.0
33	0.605	5.6	6	-5.40	5.6
13	7.519	4.0	10	-2.48	4.0
42	-1.272	3.7	6	-7.27	3.7
43	0.017	3.7	6	-5.98	3.7
16	12.612	3.4	0	12.61	3.4
32	-1.017	3.4	6	-7.02	3.4
24	1.296	3.3	0	1.30	3.3
14	1.875	3.2	0	1.87	3.2
23	8.279	3.1	10	-1.72	3.1
12	7.658	2.9	9	-1.34	2.9
15	4.297	2.5	4	0.30	2.5
31	-0.540	2.5	2	-2.54	2.5
41	0.292	2.4	2	-1.71	2.4
25	3.282	2.4	4	-0.72	2.4
22	5.266	2.3	9	-3.73	2.3
21	2.212	2.0	5	-2.79	2.0
11	3.563	1.3	5	-1.44	1.3

The analysis of the results showed some data particularly discordant with the Alexander Discipline reference values. The most relevant differences can be appreciated in the torque values of the mandibular elements (36,37,46,47) and the tip values of the maxillary elements (16,17,26,27).

DISCUSSION

In the literature, very few studies try to analyse the clinical expression of the prescription contained in the appliance. In particular, there is no study about Alexander Discipline's prescription. Recently, several Orthodontic theses and report (9-11) on the clinical expression of orthodontic prescriptions of different techniques have been presented. These demonstrated, with different methods (manual and software measurements), that straight wire vestibular orthodontic appliances cannot fully express the prescription contained in the appliance. From the results obtained from the statistical analysis, it is difficult to explain why some groups of teeth achieve values of tip and torque closer to the Alexander Discipline prescription, and others do not.

Errors in tip and torque may be related to incorrect placement of brackets and the significant variability in tooth morphology among patients because they can affect the faithful expression of information contained in the pre-adjusted brackets. Furthermore, as stated in the literature, the size of slots and wires on the market differs from the manufacturer's declaration, implying that the orthodontist cannot predict the actual torque loss during orthodontic treatment that exceeds expectations (9). In addition, the rectangular wires on the market do not have an angle of precisely 90° but rounded (edge bevel) angles. All these factors increase movement between the wire and the slot, leading to a non-correspondence with the appliance prescription (12, 13).

CONCLUSIONS

The straight-wire vestibular orthodontic appliances used in this study cannot fully express the prescription contained in the appliance. Several factors, such as incorrect bracket positioning, significant variability of dental anatomies and inaccuracies of the appliances, explain this failure. In addition, a limitation of this study is the small number of samples examined, which compromises the validity of the statistical analysis results. Another important aspect is the difficulties in using the software to perform the measurements, resulting in incorrect tip and torque

Table II. *Error analysis of torque*

Tooth	achieved.mean	achieved.sd	Ideal torque	error.mean	error.sd
47	-41.0	9.4	0	-41.01	9.4
46	-32.5	9.1	-10	-22.46	9.1
44	-18.7	9.0	-6	-12.73	9.0
25	-4.0	8.7	-8	4.04	8.7
37	-35.9	8.5	0	-35.89	8.5
34	-19.6	8.4	-6	-13.62	8.4
45	-20.1	7.6	-9	-11.14	7.6
41	-4.6	7.4	-5	0.36	7.4
13	-5.4	7.2	-3	-2.38	7.2
26	-9.2	7.2	-10	0.80	7.2
31	-5.1	7.2	-5	-0.11	7.2
17	-7.7	6.9	-10	2.30	6.9
43	-15.6	6.6	-7	-8.57	6.6
27	-4.2	6.2	-10	5.75	6.2
33	-19.4	6.1	-7	-12.41	6.1
32	-7.5	6.1	-5	-2.52	6.1
35	-22.8	6.0	-9	-13.85	6.0
23	-4.0	5.8	-3	-1.01	5.8
42	-6.9	5.6	-5	-1.89	5.6
11	10.0	5.4	15	-4.97	5.4
16	-9.1	5.4	-10	0.89	5.4
36	-33.2	5.3	-10	-23.19	5.3
21	9.4	5.3	15	-5.64	5.3
15	-6.9	5.3	-8	1.13	5.3
12	6.4	5.0	9	-2.58	5.0
24	-5.7	4.7	-6	0.29	4.7
14	-7.7	4.5	-6	-1.71	4.5
22	5.2	4.5	9	-3.79	4.5

Table III. *T-test*

Tooth	tip.pvalue	tip.sign	torque.pvalue	torque.sign
11	0.016092	**	0.0355735	**
12	0.233662		0.1878103	
13	0.125235		0.3836889	
14	0.145226		0.3223378	
15	0.747209		0.5641184	
16	0.000016	***	0.6529577	
17	0.234943		0.3778597	
21	0.005079	***	0.0197155	**
22	0.002404	***	0.0481821	**
23	0.164516		0.6344689	
24	0.301216		0.8694947	
25	0.422421		0.2314706	
26	0.020577	**	0.7623309	
27	0.102523		0.0334654	**
31	0.023862	**	0.9671563	
32	0.000637	***	0.2776379	
33	0.030313	**	0.0006869	***
34	0.038004	**	0.0025032	***
35	0.552637		0.0003204	***
36	0.025802	**	0.0000054	***
37	0.786808		0.0000068	***
41	0.088897	*	0.8937581	
42	0.000892	***	0.3750684	
43	0.002421	***	0.0081268	***
44	0.919495		0.0051866	***
45	0.844898		0.0044345	***
46	0.113875		0.0002135	***
47	0.228794		0.0000052	***

values. Therefore, it would be worthwhile to do further research in vivo by expanding the study sample and perhaps, a more user-friendly software could be used.

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Evaluation Study

STABILITY OF TRANSVERSE DIMENSION IN CLASS I AND II PATIENTS TREATED WITH DAMON SYSTEM

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ABSTRACT

This study aims to evaluate the stability of transversal expansion achieved with orthodontic therapy and assess if posterior contraction of the arches occurs in patients treated with Damon System after treatment. Twenty-four (N=24) healthy Class I and II subjects treated with Damon System were recruited. Dental casts have been analysed three times: pre-treatment (T0), at the end of treatment (T1) and 5,4 years after the end of treatment (T2); measurements of the diameters between first molars, premolars and canines for both upper and lower arches were performed on the casts using a scanner and software Nemocast 3D. Values gathered over T0, T1, and T2 have been compared with a parametric test to evaluate if there are statistically significant variations during time and in relation to the "lower fixed retainer" parameter. All transversal diameters increase after treatment (T0-T1) except for lower intercanine diameter, which only increases by 0.8 mm on average. Expansion is stable in the T1-T2 period except for upper interpremolar diameter and lower 5-5 and 6-6 diameters, with a slight expansion loss. In the T0-T2 period, all measures of transverse diameters undergo a statistically significant increase. Furthermore, no statistically significant differences exist between using a fixed retainer or thermoformed retainers for one year after debonding. Findings suggest that the expansion occurs mainly at the premolars level, but using a long-term retainer is still suggested to maintain the results achieved with orthodontic treatment.

KEYWORDS: *Damon system, arch expansion, transverse dental arch dimension, long-term stability, orthodontic retention*

INTRODUCTION

Nowadays, the long-term stability of the results gained with orthodontic treatment is still one of the most significant challenges. Indeed, malocclusion relapse has been much debated over the past few decades; numerous studies with long-

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term follow-up after treatment highlighted that orthodontic relapse is a very common phenomenon (1-3). In particular, anterior misalignment of the mandibular arch is the most widespread form of relapse. Also, in non-orthodontically treated subjects, starting from adolescence, there is a progressive decrease in the arch length and the intercanine diameter, with an increase in anterior crowding.

Numerous studies evaluated the relapse of anterior crowding and the decrease of the post-treatment intercanine diameter, but very little attention has been paid to the posterior transverse diameters. While canine-to-canine anterior retainers are well-known, low interest is still shown in maintaining the transverse diameters. However, the long-term use of a retainer is the only option to achieve post-treatment stability. Within this complex field, things are further complicated by other factors that contribute to causing relapse. First, the arch form, as shown by Feldman et al. (4), tends to come back to its original condition in the post-retention period. After that, there is the physiological development of the arches, which occurs in all subject's lifetime: different studies (5-8) pointed out that there is a gradual decrease of the intercanine diameter, of the arch length and an uprighting tendency of lower incisors, with a consequent increase of crowding and Little's irregularity index over the time. Age also affects relapse: in the lifetime, there is a continuous process of modification of the craniofacial structures that results in a dental compensation movement that causes growth-related instability (9). Another hypothetic relapse factor is the correlation between skeletal pattern and post-treatment crowding, but it is not universally demonstrated in the literature (10-12). Moreover, there are contrasting results concerning gender effect on relapse.

All these assessments have been investigated regarding anterior relapse, but no study precisely evaluates the modification of the posterior transverse diameters. Based on these premises, this study aims to analyse transverse modifications that occur in the upper and lower arches in patients treated with the Damon technique without using any other expansion device (13), trying to clarify these aspects: how the arches react using identical archwires and what is the stability of expansion over a few years.

MATERIALS AND METHODS

A study sample of 24 Class I or Class II division I patients treated with the Damon System was recruited from a single orthodontist's archive using these exclusion criteria:

- mixed dentition;
- previous use of expansion devices (RME, slow expansor, criss-cross elastics, etc.);
- cross-bite, even of a single tooth;
- impacted teeth;
- agenesis;
- orthodontic-surgical cases;
- tooth extraction cases;
- labial incompetence.

The sample included 24 patients (9 males, 15 females; mean age 14) with a Little's index of 5.9 mm (min 0 mm, max 15 mm) in the upper arch and of 5.4 mm (min 0 mm, max 14.4 mm) in the lower arch.

Following the technique, self-ligating brackets (Damon 3MX) were used for all patients. In the aligning-levelling and work phases, Damon Form archwires were used: they have the same arch shape and dimension for all patients and are identical for both the lower and upper arches. The used sequence was:

- 0.014-inch CuNiTi, or 0.013-inch and then 0.016-inch CuNiTi arch in the cases with the most significant crowding, for 10 weeks;
- 0.014 x 0.025-inch CuNiTi, for at least 10 weeks;
- 0.018 x 0.025-inch CuNiTi for at least 6 weeks;
- 0.019 x 0.025-inch SS with the arch shape obtained at the end of the work phase with CuNiTi archwires, registered with red wax.

At the end of treatment, all patients received upper thermoformed retainers, whilst, for the lower arch, one group (6 patients) was treated with a fixed retainer and the other group (18 patients) with a thermoformed retainer to wear at night for one year after debonding. All patients were re-evaluated at follow-up 5.4 years (min 4.8, max 6.1 years) after the end

of treatment. Measurements were made on the plaster cast of the dental arches at T0 – pre-treatment, T1- end of treatment and T2- 5.4 after the end of treatment.

Little's index was measured using a calliper held parallel to the occlusal plane, measuring and adding the linear distance between the anterior teeth' contact points and the mesial surfaces of canines on both sides (1).

The casts were scanned using the 3Shape Trios Scanner with a 1280 x 1024-pixel resolution. The obtained images were then imported to Nemocast 3D software (Nemotec, Madrid). Nemocast 3D operative protocol (Fig. 1) is divided into three phases: "preparation", "diagnosis", and "set up". During the first phase, divided into 6 parts, the model is oriented on the occlusal plane, the structure of the 3D images mesh is modified for better precision, the arch-line (passing through the posterior teeth pits and the canine and incisors' cingulum in the upper arch, and passing along the buccal cusps and incisal margins in the lower arch) is manually identified and mesh optimisation, casts smoothing, trimming, and segmentation (in which for each tooth is defined its contour) were made. During the second phase, FA points and FACC axes are identified for each tooth, and then, based on these, Andrews Plane is calculated. In the last phase, the transverse diameters are measured for each arch:

- diameter between first molars: distance between the mesio-buccal cusp of the right and left first molar (6-6 diameter);
- diameter between second premolars: distance between the buccal cusp of the right and left second premolar (5-5 diameter);
- diameter between first premolars: distance between the buccal cusp of the right and left first premolar (4-4 diameter);
- diameter between canines: distance between the cusp of the right and left canine (3-3 diameter).

Statistical analysis

Data were stored on a spreadsheet. Descriptive statistics were reported for the dataset: 144 measurements of 4 parameters (3-3 diameter, 4-4 diameter, 5-5 diameter, 6-6 diameter) measured three times (T0, T1 and T2) for both lower and upper arches. Analysis of variance with the post-hoc test was made to test for significant differences between average values of T0, T1 and T2 and how the "lower fixed retainer" parameter changes. All statistical procedures were performed using R software (R Core Team, Vienna, Austria). Statistical significance was set at p-value < 0.001. The assessments have shown that, for all parameters, the time effect is the only statistically significant, and there is no impact of the lower retainer.

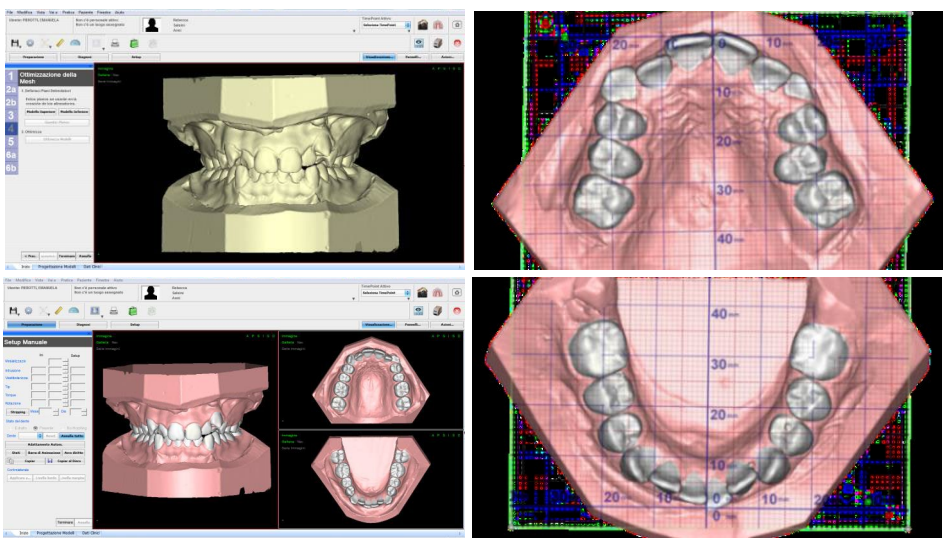

Fig. 1. *Nemocast 3D process*

RESULTS

Transverse diameters were changed in lower and upper arches in T0-T1, T1-T2, and T0-T2 periods. Table I-VIII show the progress of each measure in relation to time. Lastly, the stability of the intercanine diameter was assessed in relation to the presence or absence of the "lower fixed retainer" in the period between T1 and T2 (Table IX).

Table I. *Lower 6-6 diameter variations at T0-T1-T2*

Time	Mean	p-value
T0-T1	-2.556	0.0000000000004918
T0-T2	-1.81	0.00000001979
T1-T2	0.7462	0.01449

Table II. *Upper 6-6 diameter variations at T0-T1-T2*

Time	Mean	p-value
T0-T1	-2.792	0.000000002589
T0-T2	-2.092	0.000001986
T1-T2	0.7004	0.1424

Table III. *Lower 5-5 diameter variations at T0-T1-T2*

Time	Mean	p-value
T0-T1	-2.814	0.0000000002152
T0-T2	-1.851	0.000004223
T1-T2	0.9633	0.01621

Table IV. *Upper 5-5 diameter variations at T0-T1-T2*

Time	Mean	p-value
T0-T1	-3.907	0
T0-T2	-2.81	0.00000000007998
T1-T2	1.097	0.003937

Table V. *Lower 4-4 diameter variations at T0-T1-T2*

Time	Mean	p-value
T0-T1	-2.815	0.0000001249
T0-T2	-2.131	0.00002911
T1-T2	0.6842	0.2584

Table VI. *Upper 4-4 diameter variations at T0-T1-T2*

Time	Mean	p-value
T0-T1	-3.223	0.00000000000486
T0-T2	-1.966	0.000001645
T1-T2	1.257	0.001552

Table VII. *Lower 3-3 diameter variations at T0-T1-T2*

Time	Mean	p-value
T0-T1	-0.8679	0.0004338
T0-T2	-0.4358	0.1062
T1-T2	0.4321	0.1102

Table VIII. *Upper 3-3 diameter variations at T0-T1-T2*

Time	Mean	p-value
T0-T1	-1.659	0.000005887
T0-T2	-0.9175	0.01162
T1-T2	0.7413	0.04902

Table IX. *Interaction of the lower splinting variable with the lower intercanine diameter*

Time	Fixed retainer	Value
T1	no	26,76
T2	no	26,41
T1	yes	27,08

DISCUSSION

In the upper arch, immediately after orthodontic treatment (T0-T1), all transverse diameters increase in a statistically significant way (p-value <0.001), especially at the premolar level, with an increase of 3.9 mm for the 5-5 diameter and 3.2 mm for the 4-4 diameter, while at the first molar level is 2.7 mm and even less at the inter-canine level (1.6 mm). This expansion remains very stable over time at the level of the upper molars (p-value = 0.14) and the upper canines (p-value = 0.04), as there is no statistically significant difference in the upper intermolar and intercanine diameter between T1 and T2. Contrarily, for the 5-5 and 4-4 diameters, a loss of the expansion achieved after the orthodontic treatment was highlighted at T2. Despite the comparison between the initial values of the 4-4 and 5-5 diameters at T0 with those at T2, there are still statistically significant differences. The upper 5-5 diameter increases by 2.81 mm, while the 4-4 diameter increases by 1.9 mm.

In the lower arch during the T0-T1 phase, all transverse diameters increase in a statistically significant way (p-value <0.001), much more at the inter-premolar level (2.8 mm) and molar (2.5 mm). The lower intercanine expansion is only 0.8 mm. The expansion remains very stable over time at the first premolar and canine levels, as there is no statistically significant difference between T1 and T2. On the other hand, for the lower 5-5 and 6-6 diameters, a slight loss of the expansion achieved after orthodontic treatment was detected at T2. Comparing the initial values of the inter-premolar and inter-premolar diameters at T0 with those at T2, also in the lower arch, there are statistically significant differences except for the lower inter-canine diameter, which shows no statistically significant variations.

Considering the continuously evolving materials available on the market (14-16), this study wanted to evaluate the transversal effects related to the use of self-ligating brackets (Damon 3MX) associated with thermal wires (CuNiTi), as the Damon System establishes. This study shows that in the sample patients treated with the Damon technique, the upper and lower arches expand mainly at the premolar level, as other studies in the literature confirmed (17,18).

Regarding the more significant expansion found by this study at the interpremolar level using CuNiTi Damon Form wires, it should be remembered that Damon's arch form comes from observing the stability of transversal changes at the posterior level in the cases treated by Frankel with the function regulator (19). In the Damon System, the superelastic arches would have the function of the shields of the lip bumper and the Frankel, allowing a remodelling of the arch form in a specific shape for that patient since his muscles induce it and not imposed by the shape of the arch. In fact, in the Damon technique, the increase in the posterior width of the arch is not considered expansion but rather a remodelling; this aims

to reach a dental position physiologically determined by the balance (17) of the system on which the tongue acts with the orthodontic appliance on one side and the lips with the cheeks on the other (Frankel effect). According to Damon, the final shape of the arch will correspond to that produced by the last superelastic CuNiTi arch used, and the final SS arch, which is passive inside the slot, will only have the purpose of perfecting the 3D control of the teeth (20). The literature confirms that the greater expansion in the premolar areas found in this study is reasonably stable (21).

Regarding the parameter of the lower retainer and how this affects the variations in the transverse diameters, it was seen that there is no significant difference between the patients who wore the lower thermoformed retainer for only one year (18 patients) and the patients who still had the lower fixed retainer (6 patients) at follow-up. This evaluation could demonstrate how the lower fixed retainer effectively maintains the alignment of the lower incisors but does not affect the stability of the intercanine diameter. However, the sample is too small to support such a hypothesis. Furthermore, the use of 2 different types of retainers in the lower arch with different timing (12 months for the thermoformed retainer and long-term for the fixed one) could have created some bias in the evaluation of the lower intercanine diameter variation in T1-T2.

CONCLUSIONS

This investigation assessed that the transverse diameters increase significantly in both arches during therapy. After 5.4 years from the end of the treatment, during the follow-up phase, all the measured distances undergo slight variations that are statistically significant only at the upper interpremolar and lower 5-5 and 6-6 levels. The lower canine-to-canine fixed retainer is insufficient to guarantee the transverse stability of the orthodontic result 5.4 years after the end of therapy with the Damon technique. A lifetime retainer is recommended to maintain the achieved results. Different studies suggest that the posterior expansion achieved using a multibracket fixed appliance mainly causes crown tipping instead of a bodily tooth movement; future research could analyse this field by comparing pre and post-treatment values for tip and torque at the posterior level.

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Evaluation Study

ASSOCIATION BETWEEN SLEEP BRUXISM, DENTAL WEAR AND STRESS IN DENTISTS AND LAYPEOPLE

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ABSTRACT

To evaluate the association between sleep bruxism (SB), diagnosed through an objective method, and psychological factors, dental wear and different occlusal variables in a sample of dentists concerning a control group composed of laypeople. The study was conducted on 41 healthy subjects, 22 dentists and 19 laypeople. SB was diagnosed through Bruxoff® (OT Biolettronica, Turin, Italy), and subjects with an SB index superior to 4 were considered bruxers. Questionnaires were submitted the day after the recording with Bruxoff®, to evaluate the existence of coping strategies and anxious traits. Moreover, in order to analyse the relationship between dental wear, dental occlusion and SB, digital scans of the arches were taken for each patient and, through a specific 3D software (3D viewer), the digital models were studied in the three dimensions, and the presence of dental wear was assessed. The data obtained were confronted using the Student's t-test and Pearson's chi-squared test. The Student's t-test showed no statistically significant differences between the SB index of the two groups (p=0.28). The questionnaire's score resulted in subjects with higher scores having a higher mean number of SB episodes, although this difference was not statistically significant. Likewise, the relation between the SB index and the severity of dental wear and occlusion reported a high p-value. No correlation was found between SB and psychological factors, dental wear and some occlusal variables. Also, the two analysed groups established no statistical differences regarding the SB index.

KEYWORDS: *Sleep bruxism, Bruxoff device, anxiety, dental wear*

INTRODUCTION

Bruxism is a stereotyped movement disorder characterised by clenching or grinding of the teeth (1). According to the different circadian manifestations, there are two distinct types of bruxism: sleep bruxism (SB) and awake bruxism (AB). The latter occurs during daytime or wakefulness, a semi-voluntary clenching activity of the jaw, with usually no sound (2,

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3). Sleep bruxism manifests during sleep, and it is characterised by both clenching and loud grinding. It can cause dental wear and temporomandibular joint dysfunction (TMD) (as pain and functional limitations), headaches and the disruption of the bed's partner's sleep (2). It is a very common condition, as 85-90% of the population will grind or clench their teeth in a certain period of life (2). From the literature, the prevalence of frequent SB in adults is 8%, and that of AB is 20%, although higher percentages have been reported in other studies (4-7). It is, in fact, difficult to precisely assess bruxism prevalence since in most of the studies, especially the ones with large samples, it is esteemed considering questionnaires submitted to the subjects who are often unaware of having such disorders (2, 6).

The aetiology of SB is multifactorial, and the most recent hypothesis highlights the significant role of sleep-related mechanisms under the influence of neurochemicals (8). Research studies seem to provide a contrasting suggestion regarding the role of psychological factors in the aetiology of bruxism, even though they appear to be more correlated to AB aetiology (9, 10). In the present study, the subjects' anxiety and coping mechanisms were assessed to evaluate their correlation with SB, in a sample of dentists concerning a control sample composed of laypeople. In this way, a medical profession appraised as stressful has been considered to see whether it might have repercussions upon the psychological aspect. Furthermore, the severity of dental wear and some occlusal features were also studied in correlation with bruxism. The null hypothesis was that SB, diagnosed through an objective instrumental examination, is positively associated with psychological factors, the severity of dental wear and some occlusal features.

MATERIALS AND METHODS

The study was conducted on a sample of 41 healthy subjects divided into the experimental group (G1) and the control group (G2). G1 was composed of 22 dentists (13 females and 9 males), while G2 consisted of 19 subjects (14 females and 5 males) who were professionally non-related to the dental field. The subjects of both groups were aged between 25 and 40 years old. The following exclusion criteria were considered: TMD, positive anamnesis for neurological or mental conditions and sleep disorders. SB was diagnosed through Bruxoff® (OT Biolettronica, Turin, Italy), a compact portable device used at home that records the masseter electromyography activity and the heart rate. It was established in the literature the high sensibility (92.3%) and specificity (91.6%) of the such appliance (8). A cut-off of the hours of sleep recorded was established for a reliable diagnosis of bruxism; hence, recordings in which the hours of sleep were less than 4 were not considered. Subjects were instructed on the device used at home without assistance. If the episodes of bruxism recorded per hour of sleep (SB index) were inferior to 4, then the subject was considered normal, while subjects with an SB index superior to 4 were assessed as bruxers.

Furthermore, the types of contraction present during the recording (tonic, phasic and a mix of the two) were taken into account to see whether there was a greater frequency of episodes of grinding or clenching. The day after the recording with Bruxoff® as accomplished, questionnaires were submitted to each subject in order to evaluate coping strategies (Coping Orientation to Problems Experienced [COPE]) and the state and traits of anxiety (Spielberg State-Trait Anxiety Inventory-form Y [STAI-Y]). A score was obtained, and an analysis of the answers was carried out with the help of a specialist. The COPE questionnaire (Italian version) consisted of 60 questions to evaluate how often the subject carries out a particular coping process to overcome difficult or stressful situations; the possible answers were four, from "Usually I do not" to "I almost always do" (11) (Fig. 1).

The STAI questionnaire (Italian version) comprises two sections (STAI-1 and STAI-2) of each 20 questions. STAI-1 measures the state of anxiety (in that very moment), while STAI-2 evaluates the anxiety traits (in general) (12) (Fig. 2).

In order to study the relationship between bruxism, dental wear, and dental occlusion, digital scans of the arches were taken using an intraoral scanner TRIOS standard (3Shape, Copenhagen, Denmark). Through the software 3D Viewer, digital models were studied in the three dimensions, and various measurements were taken. The presence of dental wear was evaluated, and its severity was assessed considering the Paesani et al. classification (13). Different dental features were considered in relation to SB index, i.e., overbite>4mm, overjet>4mm, presence of anterior and/or posterior crossbite, the symmetry of canine and molar relationship and the symmetry of the median line.

The data obtained regarding the SB index, the questionnaire's scores, the severity of dental wear and the occlusal features were confronted using the Student's t-test and Pearson's chi-squared test, with a value of significant threshold ($p < 0.05$).

RESULTS

The SB index was measured using the Bruxometer software, which automatically scores the sleep bruxism events recorded. Of the 41 subjects evaluated, 21 scored superior to 4, 13 in G1 and 8 in G2; hence, the prevalence for G1 was 54% and that of G2 47%. The total mean value of the SB index was 4.50 (SD 2.61). G1 had a mean value of 4.92 (SD 2.7) and a range between 0.4 and 10.9, while G2 had a mean value of 4.02 (SD 2.39) and a range between 0.8 and 9,4. The data of the two groups were analysed through Student's t-test, and the values were not statistically significant (p=0.28). Furthermore, the number of phasic, tonic and mixed contractions was assessed (Table I).

From the t-test, no statistical differences (p=0.92) resulted regarding the mean number of masseter contractions per night of sleep between G1 (94.4±56.09) and G2 (98.05± 56.09). In the total sample, phasic contractions represented 58% of contractions, the tonic ones were 31,34%, and the mix contractions were 10.13%. For what concerns the questionnaires, answers were analysed for each question, but no significant relation resulted between the two groups for the three tests (COPE-IV, STAI-1 and STAI-2). Furthermore, the t-test also found no correlation between the SB index and these questionnaires' scores, even though subjects with higher psychological scores had a higher mean number of SB episodes (Table II).

The total mean value of dental wear, according to Paesani et al. classification (13), was 1.47 (SD 1.14), and similar values were reported for both groups; hence, no statistical correlation was reported according to the t-test (p=0.44) (Table III).

Table I. *Mean SB index and types of contractions in G1 and G2.*

	Mean SB index	Mean phasic contractions	Mean tonic contractions	Mean mixed contractions
G1	4,92 (±2,7)	9,86 (±7,55)	4,95 (±4,11)	1,49 (±1,56)
G2	4,02 (±2,39)	8,89 (±7,42)	5,15 (±4,78)	1,89 (±2,02)
VALUE	4,50(±2,61)	9,41(±7,41)	5,04 (±4,38)	1,63 (±1,78)

Table II. *T-test. Comparison of the mean values of the SB index in subjects with high/low scores (compared to the mean value) in the various psychological scales.*

Psychological scale	SB index, patients with high scores	SB index, patients with low scores	p value
STAI-1	5,4 (±3,0)	3,7 (±2,1)	0.072
STAI-2	5,3 (±2,1)	3,7 (±3,0)	0.081
COPE-social support	5,4 (±1,8)	4,2 (±3,1)	0.198
COPE- avoidance strategies	4,6 (±3.0)	5.0 (±2,0)	0.649
COPE-attitude	5,6 (±2,3)	4,0 (±2,6)	0.069
COPE- ability of managing problems	4,7 (±1,9)	4,9 (±3,0)	0.856
COPE-religion	4,3 (±2,6)	5,2 (±2,5)	0.307

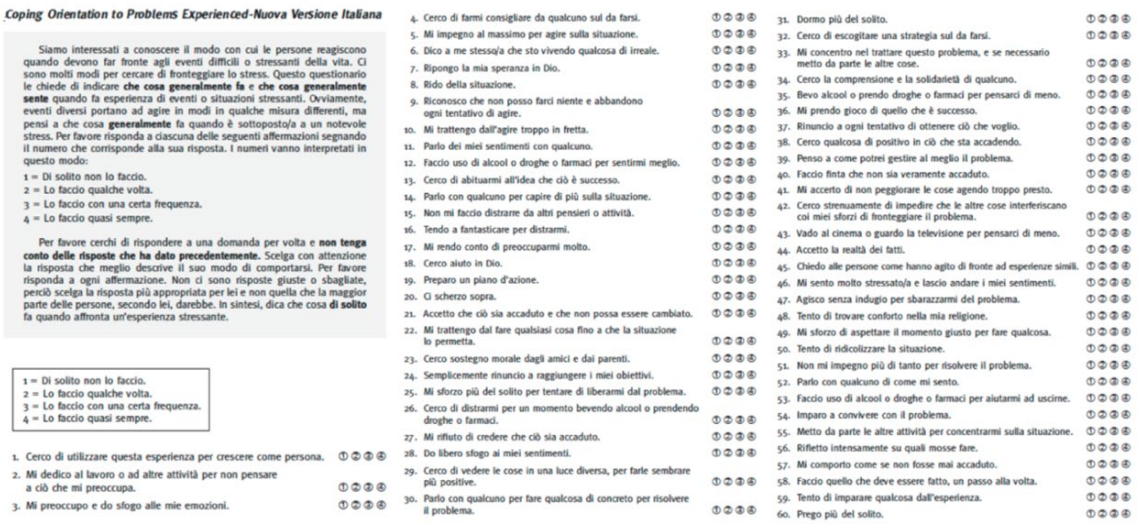
Table III. *Wear's mean scores of anterior teeth and significant value (t-test).*

Tooth	G1 mean wear	G2 mean wear	p value
13	1,91 (±1,15)	2,16 (±1,01)	0,82
12	1,23 (±0,86)	1,42 (±1,17)	0,10
11	1,23 (±0,92)	1,58 (±1,12)	0,22
21	1,27 (±0,93)	1,68 (±1,15)	0,21
22	1,18 (±0,95)	1,79 (±1,13)	0,52
23	1,91 (±1,23)	1,95 (±1,07)	0,98
33	2,32 (±1,20)	2,53 (±1,07)	0,56
32	1,59 (±1,11)	2,16 (±1,22)	0,13
31	1,82 (±1,14)	2,16 (±0,95)	0,31
41	1,82 (±1,14)	2,05 (±0,84)	0,46
42	1,91 (±1,19)	2,21 (±0,97)	0,38
43	2,23 (±1,23)	2,32 (±0,94)	0,80
Total mean value	1,38 (±0,78)	1,59 (±0,57)	0,44

Likewise, no statistically significant value (p=0.69) was found with Pearson's chi-squared test between the SB index and dental wear mean value. The last parameter considered in relation to SB was dental occlusion, which was studied through digital scans. The occlusal variables, the number of subjects, the percentage of the total and the significant values related to the SB index are also reported (Table IV). The distinction between the two groups was not considered, as it was irrelevant for statistical purposes. None of the considered occlusal variables resulted in a statistically significant correlation with the SB index.

Table IV. *Occlusal variables, number of subjects, the percentage of the total and the significant value when related to SB index*

	Number of subjects	% of the total	p value
Symmetric canine relationship	5	12	0,55
Symmetric molar relationship	37	90	0,94
Posterior cross bite	6	14	0,58
Anterior cross bite	1	4	0,67
Increased overjet	1	4	0,88
Increased overbite	7	15	0,41
Symmetric median line	21	52	0,96



Coping Orientation to Problems Experienced-Nuova Versione Italiana

Siamo interessati a conoscere il modo con cui le persone reagiscono quando devono far fronte agli eventi difficili o stressanti della vita. Ci sono molti modi per cercare di fronteggiare lo stress. Questo questionario le chiede di indicare **che cosa generalmente fa** e **che cosa generalmente sente** quando fa esperienza di eventi o situazioni stressanti. Ovviamente, eventi diversi portano ad agire in modi in qualche misura differenti, ma pensi a che cosa **generalmente** fa quando è sottoposto/a a un notevole stress. Per favore risponda a ciascuna delle seguenti affermazioni segnando il numero che corrisponde alla sua risposta. I numeri vanno interpretati in questo modo:

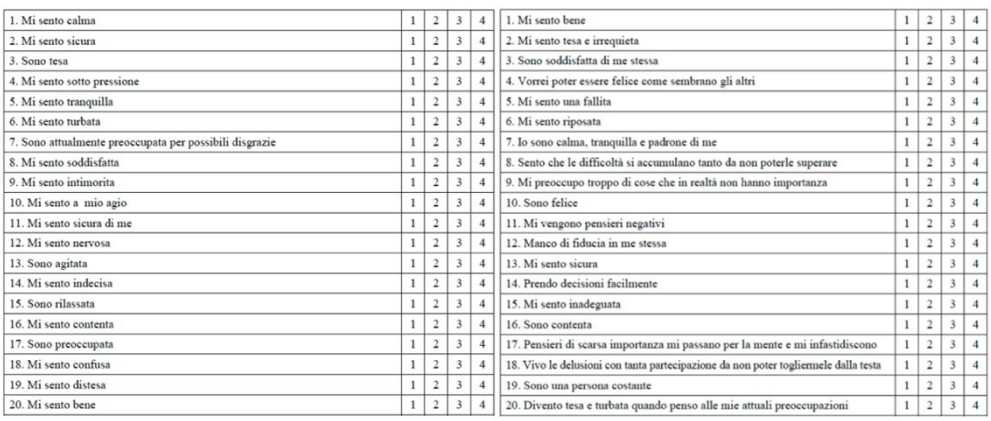
1 = Di solito non lo faccio.
2 = Lo faccio qualche volta.
3 = Lo faccio con una certa frequenza.
4 = Lo faccio quasi sempre.

Per favore cerchi di rispondere a una domanda per volta e **non tenga conto delle risposte che ha dato precedentemente.** Scelga con attenzione la risposta che meglio descrive il suo modo di comportarsi. Per favore risponda a ogni affermazione. Non ci sono risposte giuste o sbagliate, perciò scelga la risposta più appropriata per lei e non quella che la maggior parte delle persone, secondo lei, darebbe. In sintesi, dica che cosa **di solito** fa quando affronta un'esperienza stressante.

1 = Di solito non lo faccio.
2 = Lo faccio qualche volta.
3 = Lo faccio con una certa frequenza.
4 = Lo faccio quasi sempre.

1. Cerco di utilizzare questa esperienza per crescere come persona. ① ② ③ ④
2. Mi dedico al lavoro o ad altre attività per non pensare a ciò che mi preoccupa. ① ② ③ ④
3. Mi preoccupo e do sfogo alle mie emozioni. ① ② ③ ④
4. Cerco di farmi consigliare da qualcuno sul da farsi. ① ② ③ ④
5. Mi impegno al massimo per agire sulla situazione. ① ② ③ ④
6. Dico a me stessa/o che sto vivendo qualcosa di irreale. ① ② ③ ④
7. Ripongo la mia speranza in Dio. ① ② ③ ④
8. Rido della situazione. ① ② ③ ④
9. Riconosco che non posso farci niente e abbandono ogni tentativo di agire. ① ② ③ ④
10. Mi trattengo dall'agire troppo in fretta. ① ② ③ ④
11. Parlo dei miei sentimenti con qualcuno. ① ② ③ ④
12. Faccio uso di alcool o droghe o farmaci per sentirmi meglio. ① ② ③ ④
13. Cerco di abituarmi all'idea che ciò è successo. ① ② ③ ④
14. Parlo con qualcuno per capire di più sulla situazione. ① ② ③ ④
15. Non mi faccio distrarre da altri pensieri o attività. ① ② ③ ④
16. Tendo a fantasticare per distrarmi. ① ② ③ ④
17. Mi rendo conto di preoccuparmi molto. ① ② ③ ④
18. Cerco aiuto in Dio. ① ② ③ ④
19. Preparo un piano d'azione. ① ② ③ ④
20. Ci scherzo sopra. ① ② ③ ④
21. Accetto che ciò sia accaduto e che non possa essere cambiato. ① ② ③ ④
22. Mi trattengo dal fare qualsiasi cosa fino a che la situazione lo permetta. ① ② ③ ④
23. Cerco sostegno morale dagli amici e dai parenti. ① ② ③ ④
24. Semplicemente rinuncio a raggiungere i miei obiettivi. ① ② ③ ④
25. Mi sforzo più del solito per tentare di liberarmi dal problema. ① ② ③ ④
26. Cerco di distrarmi per un momento bevendo alcool o prendendo droghe o farmaci. ① ② ③ ④
27. Mi rifiuto di credere che ciò sia accaduto. ① ② ③ ④
28. Do libero sfogo ai miei sentimenti. ① ② ③ ④
29. Cerco di vedere le cose in una luce diversa, per farle sembrare più positive. ① ② ③ ④
30. Parlo con qualcuno per fare qualcosa di concreto per risolvere il problema. ① ② ③ ④
31. Dormo più del solito. ① ② ③ ④
32. Cerco di escogitare una strategia sul da farsi. ① ② ③ ④
33. Mi concentro nel trattare questo problema, e se necessario metto da parte le altre cose. ① ② ③ ④
34. Cerco la comprensione e la solidarietà di qualcuno. ① ② ③ ④
35. Bevo alcool o prendo droghe o farmaci per pensarci di meno. ① ② ③ ④
36. Mi prendo gioco di quello che è successo. ① ② ③ ④
37. Rinuncio a ogni tentativo di ottenere ciò che voglio. ① ② ③ ④
38. Cerco qualcosa di positivo in ciò che sta accadendo. ① ② ③ ④
39. Penso a come potrei gestire al meglio il problema. ① ② ③ ④
40. Faccio finta che non sia veramente accaduto. ① ② ③ ④
41. Mi accerto di non peggiorare le cose agendo troppo presto. ① ② ③ ④
42. Cerco strenuamente di impedire che le altre cose interferiscano coi miei sforzi di fronteggiare il problema. ① ② ③ ④
43. Vado al cinema o guardo la televisione per pensarci di meno. ① ② ③ ④
44. Accetto la realtà dei fatti. ① ② ③ ④
45. Chiedo alle persone come hanno agito di fronte ad esperienze simili. ① ② ③ ④
46. Mi sento molto stressato/a e lascio andare i miei sentimenti. ① ② ③ ④
47. Agisco senza indugio per sbarazzarmi del problema. ① ② ③ ④
48. Tento di trovare conforto nella mia religione. ① ② ③ ④
49. Mi sforzo di aspettare il momento giusto per fare qualcosa. ① ② ③ ④
50. Tento di ridicolizzare la situazione. ① ② ③ ④
51. Non mi impegno più di tanto per risolvere il problema. ① ② ③ ④
52. Parlo con qualcuno di come mi sento. ① ② ③ ④
53. Faccio uso di alcool o droghe o farmaci per aiutarmi ad uscirne. ① ② ③ ④
54. Imparo a convivere con il problema. ① ② ③ ④
55. Metto da parte le altre attività per concentrarmi sulla situazione. ① ② ③ ④
56. Rifletto intensamente su quali mosse fare. ① ② ③ ④
57. Mi comporto come se non fosse mai accaduto. ① ② ③ ④
58. Faccio quello che deve essere fatto, un passo alla volta. ① ② ③ ④
59. Tento di imparare qualcosa dall'esperienza. ① ② ③ ④
60. Prego più del solito. ① ② ③ ④

Fig. 1. *Coping Orientation to Problems Experienced - New Italian Version.*



1. Mi sento calma	1	2	3	4
2. Mi sento sicura	1	2	3	4
3. Sono tesa	1	2	3	4
4. Mi sento sotto pressione	1	2	3	4
5. Mi sento tranquilla	1	2	3	4
6. Mi sento turbata	1	2	3	4
7. Sono attualmente preoccupata per possibili disgrazie	1	2	3	4
8. Mi sento soddisfatta	1	2	3	4
9. Mi sento intimorita	1	2	3	4
10. Mi sento a mio agio	1	2	3	4
11. Mi sento sicura di me	1	2	3	4
12. Mi sento nervosa	1	2	3	4
13. Sono agitata	1	2	3	4
14. Mi sento indecisa	1	2	3	4
15. Sono rilassata	1	2	3	4
16. Mi sento contenta	1	2	3	4
17. Sono preoccupata	1	2	3	4
18. Mi sento confusa	1	2	3	4
19. Mi sento distesa	1	2	3	4
20. Mi sento bene	1	2	3	4

1. Mi sento bene	1	2	3	4
2. Mi sento tesa e irrequieta	1	2	3	4
3. Sono soddisfatta di me stessa	1	2	3	4
4. Vorrei poter essere felice come sembrano gli altri	1	2	3	4
5. Mi sento una fallita	1	2	3	4
6. Mi sento riposata	1	2	3	4
7. Io sono calma, tranquilla e padrone di me	1	2	3	4
8. Sento che le difficoltà si accumulano tanto da non poterle superare	1	2	3	4
9. Mi preoccupo troppo di cose che in realtà non hanno importanza	1	2	3	4
10. Sono felice	1	2	3	4
11. Mi vengono pensieri negativi	1	2	3	4
12. Manco di fiducia in me stessa	1	2	3	4
13. Mi sento sicura	1	2	3	4
14. Prendo decisioni facilmente	1	2	3	4
15. Mi sento inadeguata	1	2	3	4
16. Sono contenta	1	2	3	4
17. Pensieri di scarsa importanza mi passano per la mente e mi infastidiscono	1	2	3	4
18. Vivo le delusioni con tanta partecipazione da non poter togliermele dalla testa	1	2	3	4
19. Sono una persona costante	1	2	3	4
20. Divento tesa e turbata quando penso alle mie attuali preoccupazioni	1	2	3	4

Fig. 2. *STAI-1 (left) and STAI-2 (right).*

DISCUSSION

Bruxism is a much-debated topic in the literature; however, in the clinical field, this term is often used in a generic sense, and a diagnosis is often made relying on superficial and clinical evaluations. Few studies associate SB with psychological and personality traits using repeatable and objective diagnostics; most data have come from studies adopting a clinical and/or self-reporting diagnosis of bruxism (14). Polysomnography is considered the gold standard for diagnosing bruxism; however, access to such a complex and expensive device is limited (9, 14). In this study, a precise evaluation of SB could be made on a sufficiently broad sample through an easy-to-use holter device (10). The mean value of the SB index obtained was 4.5 (SD 2.61). This result is in line with that obtained by another research that studied a similar sample and used the same device, i.e., Bruxoff®, for the diagnosis (15). The sample was divided into two groups, dentists and laypeople, to see whether a medical profession, often associated with the burnout phenomenon (16, 17), was more correlated to SB index and an increased anxiety level. The experimental group had a higher value SB index (4.92) than the control group (4.02), but no statistically significant differences were found between them (p=0.28). Likewise, the scores of the questionnaires obtained by the two groups were very similar, and a high p-value resulted from the statistical analysis. However, this parameter could be subjected to bias since the group of non-dentists comprehended a diverse group of people with various occupations that could be more stressful than the dental profession.

Furthermore, in this study, no association was shown between the level of anxiety and coping strategies with the SB index. The role of psychosocial factors in the aetiology of bruxism is perhaps one of the most debated issues concerning this disorder, and currently, the literature is not conclusive (9). Although no valid results were obtained at a statistical level in this study, a slight association between a high SB index and high anxiety levels could suggest a partial link between SB and personality alteration. It might be possible that some personality traits, such as the anxious one, could have a greater influence on SB than others; this is corroborated by a study conducted by Manfredini et al. (18) in which the subjects that obtained a high score on anxiety traits, reported a longer duration of masseter contractions during the first hour of recording compared to subjects with low anxiety levels. For dental wear, in the past, it was considered a pathognomonic sign of bruxism (19); it was also believed that occlusal interferences induced the development of parafunctions (20). Nowadays, it is believed that the role of bruxism as a cause of wear is overestimated, while a multifactorial origin should be sought after (21). In this study, the relation between dental wear and SB index reported a non-significant statistical p-value (0.69); this finding confirms what was reported in the recent literature; thus, wear is not a valid indicator of the presence of SB (22). The role of dental occlusion in the pathogenesis of SB was reevaluated, and many studies, along with the present one, indicate the absence of a correlation between SB and occlusal features (19, 23).

CONCLUSIONS

The null hypothesis was rejected since no correlation was found between SB, psychological factors, dental wear and some occlusal variables; these results are in accordance with the most recent literature on SB. Likewise, the influence of the dental profession resulted in nil on both the SB index and the stress level. However, the weak association found with some aspects related to anxiety and personality traits, even if not sufficient to consider anxiety as a parameter correlated to SB, suggests the need for further research on this matter.

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Case report

DEEP BELLY OF TEMPORALIS OR SPHENO-MANDIBULAR MUSCLE? ANATOMICAL ASSESSMENT BY IMAGING

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ABSTRACT

The presence and the anatomical relationships of the deep belly of the temporalis muscle with adjacent structures were assessed by means of computer tomography (CT) and magnetic resonance imaging (MRI). The study group included 40 subjects (26 men and 14 women) ranging from 36 to 74 years (mean age of 56). A multislice Somatom Volume Zoom Spiral CT and 1.5-Tesla-MRI equipment were used for imaging, with a dedicated coil for facial structures; T1-weighted TSE sequences performed exams. The study volume was the same for both investigations. The deep belly of the temporalis muscle was depicted and studied on axial, sagittal, and coronal planes in all exams. The deep belly of the temporalis muscle corresponds to the spheno-mandibular muscle.

KEYWORDS: *temporalis, muscle, pain, diagnosis, CT, MRI.*

INTRODUCTION

In the last nineteen years, many authors have studied the temporalis muscle (TM) and its accessory fasciae (1-5). Some authors described the origins of the TM, such as the infratemporal crest, the frontal surface of the frontal process of the zygomatic bone, the lower surface of the zygomatic arch and the temporalis fascia insertions including the "pre-anterior belly of the TM", which inserts on the medial surface of the ramus of the mandible.

In 1995, Dunn et al. conducted an anatomic study of 25 cadavers (6). They observed that what was described as "the deep belly of the TM" was another muscle whose vascularization and innervation was different from those of the TM. This structure was therefore renamed the "sphenomandibular muscle" (SM) (7).

On its medial fascia, next to its origin, the SM muscle is innervated by branches of the buccinator nerve (fifth pair of

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cranial nerves), whereas vascularization is supplied by branches of the pterygoid artery (8) (coming from the maxillary artery) entering the SM on its medial surface, below the nerves.

In the present study, we attempt to show, by multislice CT and MRI, the position and structure of the SM correlations with adjacent structures and provide hypotheses concerning its function.

MATERIAL AND METHODS

The initial sample included 45 subjects without TMJ disease and with a stable dental occlusion subject. Patients underwent CT and MRI examinations for ENT reasons. Five subjects were excluded from the study since MR and CT imaging of TMJs showed structural changes in the joints. The remaining study group included 40 subjects (26 men and 14 women) with ages ranging from 36 to 74 years (mean, 56 years).

All patients underwent routine clinical examinations. As a result, diagnostic, treatment, and consensus for the scientific use of data were obtained from all patients. The study was performed in conformity with the Declaration of Helsinki of 2013.

A multislice Somatom Volume Zoom Spiral CT equipment (Siemens, Erlangen - Germany) was used for CT imaging. Axial scans, 3 mm in thickness, were performed parallel to the hard palate, extending from the skull base's anterior portion to the mandible's lower margin. The total scan duration was approximately 20 seconds. Coronal and sagittal images were reconstructed using Vitrea® 2.0 3-D reconstruction software (Vital Images, Fairfield, Iowa, USA). Reconstruction following planes perpendicular to the latero-lateral axis of the SM (viewed on an axial scan) was used for sagittal images. Reconstruction following planes parallel to the major axis of the SM (viewed on sagittal images) was used for coronal images. 1.5-Tesla MRI (Magnetom Vision, Siemens Germany) was used with a dedicated coil for facial structures.

Exams were performed using T1-weighted TSE sequences (500-600 TR, 12-20 TE, 160-200 FoV, two acquisitions, 256x256 matrix, slice thickness of 3 mm, and duration of each sequence of 2 min. and 30 sec.). Axial, sagittal, and coronal scans were obtained; CT and MRI study volumes were the same. All morphological features of the SM and adjacent structures were evaluated.

RESULTS

The SM was studied on axial, sagittal, and coronal planes. It proved to be a paired and symmetrical muscle originating from behind the orbit, anterio-laterally to the pyramidal process and from the anterior portion of the infratemporal surface of the greater wing of the sphenoid. It inserts on the medial surface of the coronoid process and, partially, on the mandible's ramus, at the maxillary sinus level. The upper fibres of the upper belly of the lateral pterygoid muscle (LPM) originate from the posterior surface of the pyramidal process. In contrast, inferior fibres of the upper belly of the LPM originate from aponeurosis placed between the posterior surface of the SM and the upper belly of the LPM.

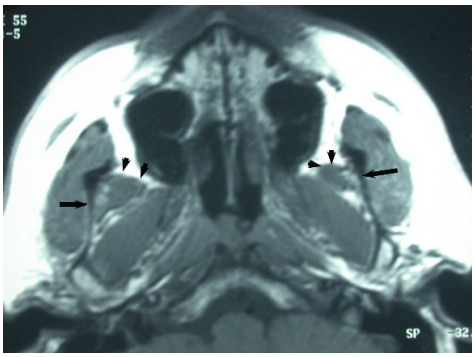

Fig. 1. *MRI axial plane. Black arrows point: deep belly of temporal muscle. Thin black arrows: mandibular insertion.*

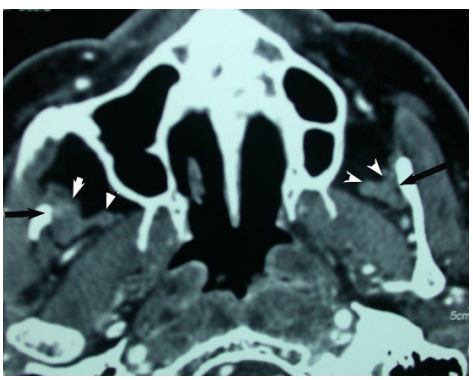

Fig. 2. *CT axial plane. White arrows point: deep belly of temporal muscle. Thin black arrows: mandibular insertion.*

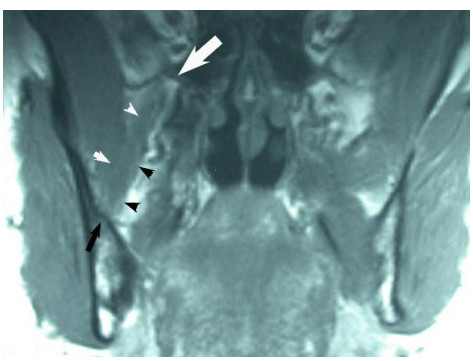

Fig. 3. *MRI coronal plane. Black and white arrows point: deep belly of temporal muscle. Thin black arrow: mandibular insertion. White arrow: insertion in the pyramidal apophysis of the sphenoid bone.*

In the axial plane (Fig. 1, 2), the SM is triangular with a lateral base and a medial apex. This triangular area is very important from an anatomical and surgical point of view; it binds the space of the infratemporal fossa where the internal infratemporal artery runs. This triangle has a very limited lateral base, formed by the ramus of the mandible at the level of the sigmoid sinus, and a medial apex, the pyramidal apophysis of the sphenoid; the anterior side is formed by the posterior border of the SM, whereas the posterior side is composed by the anterior border of the LPM.

In the coronal plane, the SM is triangular or rhomboidal (according to the width of the insertion on the pyramidal process) and inserts on the medial surface of the coronoid process of the mandible at the level of the maxillary sinus (Fig. 3, 4).

In the sagittal plane (Fig. 5, 6), the SM is ribbon-shaped vertically, with its antero-posterior thickness reducing medially. The lateral border of the SM is parallel to the medial surface of the TM, whereas the medial border is parallel to the inferior belly of the LPM. In this plane, the SM, together with the superior and inferior belly of the LPM, forms a triangle through which the buccinator nerve passes. The anterior side of this triangle is the SM, the triangle's base is the inferior belly of the LPM, and the upper belly of the LPM creates the posterosuperior side.

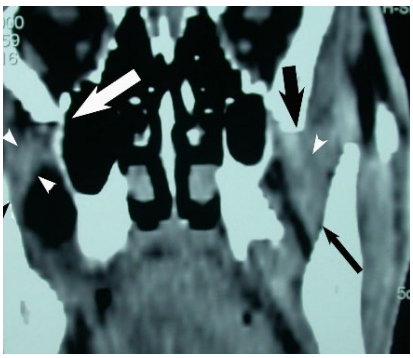

Fig. 4. *CT coronal plane. White arrows point: deep belly of temporal muscle. Thin black arrows: mandibular insertion. Black and white large arrows: insertion in the pyramidal apophysis of the sphenoid bone.*

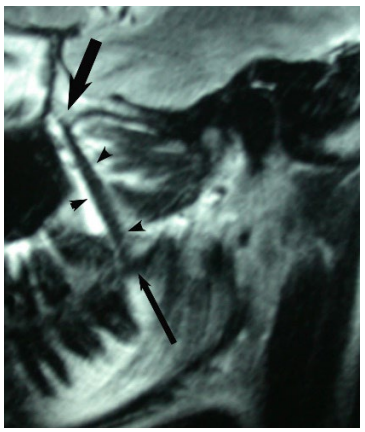

Fig. 5. *MRI parasagittal plane. Arrows point: deep belly of temporal muscle. Thin arrow: mandibular insertion. Large arrow: insertion in the pyramidal apophysis of the sphenoid bone.*

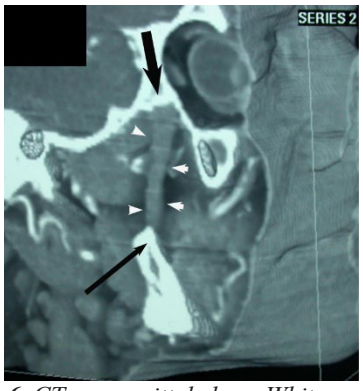

Fig. 6. *CT parasagittal plane. White arrows point: deep belly of temporal muscle. Thin black arrow: mandibular insertion. Black large arrow: insertion in the pyramidal apophysis of the sphenoid bone.*

DISCUSSION

In 1996, in their study performed on autoptic specimens, Dunn et al. (6) assumed that the SM had a vital role in the origin of pain localized behind the orbital region because of its vicinity with some nervous branches which could be compressed against the posterior maxillary wall during its contraction.

Our study shows how the origin of this muscle runs next to the posterior surface of the maxillary sinus and, in some cases, it almost touches the posterior maxillary wall, as reported by Geers et al. in 2005 (9).

The SM originates from a small apophysis of spongy bone, the pyramidal process of the sphenoid. Since this muscle is very thin, it is probably not aimed at raising the mandible during mastication; this part is played by other muscles with large bone insertions and is highly developed, unlike the SM, because of the great strength required. However, the vertical trend and the larger insertion on the medial surface of the coronoid process and the mandible's ramus suggest that SM should also have a role during mastication.

Based on morphological and structural findings, the following hypotheses can be made: 1): the structure of the SM seems ideally designed to "control" the vertical dimension of the mandible and the free interocclusal space (SM has a function on the postural control of the mandible); 2): this muscle probably acts in synergy with the homolateral lower belly of the LPM and with the posterior belly of the contralateral TM in lateral mandibular movements.

More recently, clinical evaluations have indirectly provided further evidence of the role played by this muscle (10-13).

It would be useful to remember that the intraoral palpation of the posterosuperior vestibular fornix aimed at assessing the painfulness of the LPM is almost impossible due to the presence of the SM, which is placed just

in front of the LPM. Therefore, the palpation of this region detects the presence and possible tonic-trophic alterations of the SM and not LPM.

CONCLUSIONS

In this descriptive study, the presence and the anatomical relationships of the SM with adjacent structures are assessed by CT and MR imaging. Due to its position, this muscle makes intraoral palpation of the LPM impossible.

MRI well depicts SM's anatomy. However, further studies on the microscopic anatomy of SM are required to confirm results and highlight neuromuscular spindles and neurotendinous structures. In addition, it is necessary to investigate ontogenesis and phylogenesis to better define its function in the stomatognathic system.

Authors' contribution

DM collected imaging and interpreted data; FC drafted the manuscript; MDG revised the manuscript; LB approved the final version.

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Comparative Study

COMPARATIVE ANALYSIS BETWEEN INTRAORAL SCANNERS AND EXTRAORAL SCANNER: EVALUATION OF CLINICAL ASPECTS AND PRECISION

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ABSTRACT

Nowadays, digital technology is part of our daily clinical practice. Digital models have some advantages compared to traditional plaster models, and they can be obtained with intraoral and extraoral scanners. The aim of this study is to compare four types of scanners, three of which are intraoral (3Shape Trios, 3M True Definition, Carestream CS3500), and one is extraoral (ZFX Evolution). Digital dental impressions were taken to 8 patients with every intraoral scanner tested, and a scan of traditional models was performed with the extraoral scanner to create digital models. After each scan, the time required was calculated, and the patient and the operator answered a questionnaire. Six linear measurements were detected in every digital model to investigate the scanner's accuracy, both in the upper and lower arch. The scanners have good reliability, showing no significant differences between the first and the second measurements taken by the operator (with a distance of 7 days between them). The scanners tested are very accurate since there are no significative statistical differences between the measurement, except for one parameter (distance between the lower canine and the lower first molar on the right side). The Trios scanner has a reduced scan time, followed by the True Definition. Based on the questionnaires, patients prefer the 3Shape Trios in terms of ergonomics, versatility and ease of use, while the operators prefer the 3M True Definition, thanks to its lightness, speed and versatility. The digital models obtained with the three intraoral scanners tested are all good and accurate, but there are differences in comfort and scan time.

KEYWORDS: *intraoral, scanner, extraoral scanner, digital model*

INTRODUCTION

Nowadays, digital systems are becoming part of clinical practice to obtain more predictable results and contrast

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aspects that can lead to unsuccessful achievements (1-4). For instance, with digital cameras, digital x-rays and even digital models, we can simplify complex procedures, as Maino et al. (2) developed a 3-dimensional surgical guide to provide a safe and reliable palatal miniscrew insertion (2).

Using a digital model can produce some advantages, such as electronic archiving, which does not require space, simple classification and rapid transmission of information; furthermore, the models do not break or get damaged, and the use of software to calculate specific measurements is allowed. On the other hand, traditional models need storage space, can break and cost money (5-12).

In the literature, it was said that digital models have an accuracy comparable to traditional models (13-15). In addition, it seems that patients prefer digital acquisition of the models due to the shorter time required for the dental impression (16, 17).

A digital model can be obtained by both a direct and an indirect method. The direct method consists of an intraoral scan, reducing time and materials. The scan starts from the distal part of each arch and requires continuous movements. The upper and lower arches are scanned separately and then in occlusion. The 3D model is created by superimposing multiple images. The indirect method consists in scanning the traditional model with an extraoral scan: the upper plaster cast is inserted into the scanner, followed by the lower one; then, the two parts are scanned in occlusion. LED technology is used for the light, and digital cameras record the anatomy.

Regardless of the method, the final result is a 3D digital model of the patient's mouth in .stl format. Some authors have argued that extraoral scanners are more accurate than intraoral ones (18).

The aim of this study is to do a comparative analysis of four types of scanners, three of which are intraoral and one extraoral. In particular, there are four main parts under investigation:

- Evaluation of .stl files: linear measurements obtained with the scanners are compared in order to examine if the scanners are accurate;
- Comparison of the times required for each scan;
- Evaluation of the opinion expressed by patients after each scan;
- Evaluation of the opinion expressed by operators after each scan.

MATERIALS AND METHODS

The study was performed on 8 subjects (5 males and 3 females). The inclusion criteria were the age between 14 and 65 years, the presence of all dental elements (except the third molars) or a single missing tooth, and the absence of severe malocclusions and prosthetic elements.

Digital dental impressions were taken to each patient with every intraoral scanner tested (3Shape Trios, 3M True Definition and Carestream CS3500). Titanium dioxide powder in the patient's mouth, kept as dry as possible, was required to use the 3M True Definition scanner.

In order to obtain the digital model with the extraoral ZFX scanner, traditional PVS (Aquasil Dentsply) impressions were taken using a two-step technique with putty and light material. After that, the traditional dental plaster casts (Velmix Stone type IV) were produced. The ZFX Evolution scanner was then used to scan the plaster cast and obtain a digital model.

The scanners were used and tested in a different order. Each scanner has software with correction tools that can be used after the acquisition of the scans. After each scan, both patient and the operator answered a questionnaire. The questionnaire submitted to the patients was meant to evaluate their satisfaction, and the questionnaire submitted to the operators aimed to analyse the scanners from a clinical point of view. All the answers were rendered with the VAS scale (0-10).

The patient's questionnaire was structured as follows:

- Preferred method: traditional – scanner
- Scanner speed: slow – fast
- Ergonomics and comfort: non-ergonomic – ergonomic
- Aesthetics of the scanner: non-aesthetic – aesthetic
- Discomfort caused by the powder (when 3M True Definition is used): not at all – a lot

The questionnaire for operators was structured as follows:

- Ease of the software to start the acquisition process: difficult – easy;
- Weight: heavy – light;
- Ergonomics, in particular, the possibility to access the distal surfaces of the teeth: not ergonomic – very ergonomic;
- Ease and speed of the acquisition: difficult and slow – easy and fast;
- Problems detected from the end of the acquisition to the achievement of the .stl file: yes - no:
- Aesthetics of the scanner: non-aesthetic – aesthetic.

Moreover, the time required for each scan was calculated. All the models were inserted into Orthoanalyzer software (3Shape), and 6 linear measurements were detected, both in the upper and lower arches, to evaluate the accuracy in the three dimensions of the space (x, y, z).

The 6 measurements for each arch were (15):

- 3-3: intercanine distance, using as reference points the canines' cusps;
- 6-6: intermolar distance, using as reference points the mesio-buccal cusps of the first molars;
- 3-6 right side: distance between right canine and right first molar;
- 3-6 left side: distance between left canine and first left molar;
- 3 right side: height of the right canine's clinical crown;
- 3 left side: height of the left canine's clinical crown.

Every measurement was taken twice by the same operator, with a distance of 7 days between the repetition of the measurement, to assess the operator's reliability (Fig. 1).

Statistical analysis

The SPSS-22 application (IBM SPSS Statistics, v 22.0 for Windows; IBM Corp. Released 2013. Armonk. NY. USA) was used. A first test verified the reliability of the measurements and compared the means of the first and second measurements for each value. If there is a difference between the two averages, the operator has made an error. Therefore, a 95% confidence level was selected. For both measures of each variable, the relationship between them was estimated using the intraclass correlation coefficient; when this correlation is close to unity and has a high value, the measures are similar.

Another test compared the measurements obtained in the .stl files, derived from the models obtained with the four different scanners for each patient. The mean, the median and the standard deviation were calculated. In addition, a

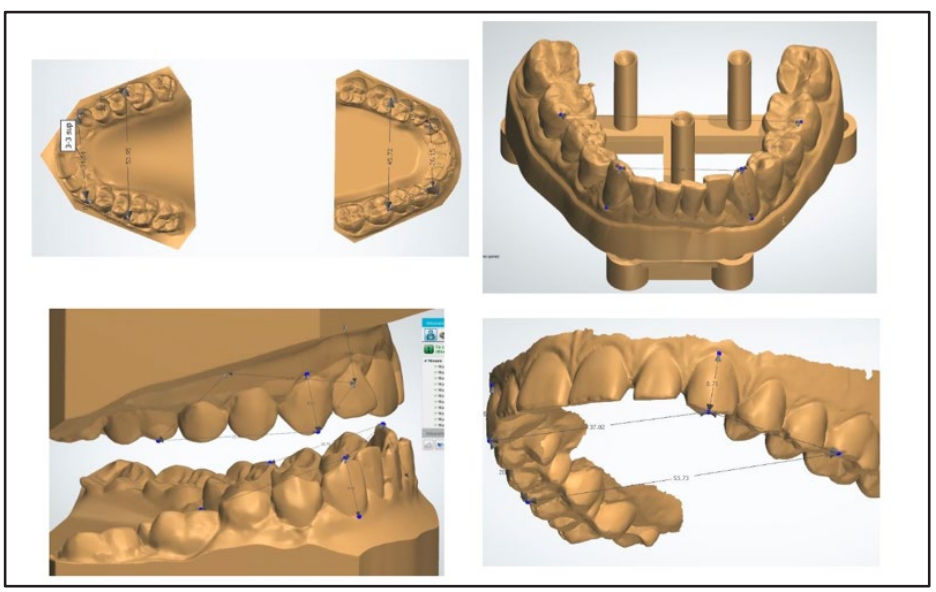

Fig. 1. *Measurements detected in every model*

Shapiro-Wilk test was performed to examine the normal distribution of the values. The other tests performed were Student's t-test, Repeated Measures Anova, Wilcoxon test and Friedman test. A significance level of 5% was chosen, which means that statistical significance is gained with $p<0.05$.

The answers from the questionnaires and the calculation of the time required for each scan were compared to calculate which scanner is more appreciated by both the patients and the operators and which works faster.

RESULTS

Intra-operator reliability

The 3Shape Trios scanner has good reliability, showing no significant differences between the first and the second measurements for none of the parameters ($p>0.05$). The measurement errors are within 0.03 mm, and the correlation coefficients range from 0.998 to 1. Similar results have been detected for the Carestream CS3500 scanner, which has very low average errors (with a maximum of 0.2 mm) and correlation coefficients between 0.999 and 1. Two of the measurements obtained with the 3M True Definition scanner were significant, but their correlation coefficients were 1 and 0.999: which means that the differences were due to a calibration error. These differences were equal to 0.05 and 0.04 mm. The other variables did not show statistically significant differences, with a high correlation coefficient (0.944 – 1); this means that intra-operator reliability with this scanner is good but not as good as the previous ones.

Accuracy analysis in .stl models

3-3 upper: the measurements are similar between the four scanners, and the values have a normal distribution ($p>0.05$ in the SW test). The means are between 34.22 and 34.30 mm, with no significant differences ($p>0.05$). Even when comparing pairs of measurements, there are no statistically significant differences.

6-6 upper: the variables are normally distributed, and the measurements are similar, varying between 50.06 and 50.14 mm, without any statistical difference.

3-6 right upper: there is a slight lack of normality due to a negative curve asymmetry, but the alternative statistical tests are similar, so this variation does not have consequences on the analysis, and the reliability is good. The means are in the range of 20.21-20.25 mm. Therefore, it is possible to conclude that this variable is measured similarly by the four scanners.

3-6 left upper: the values are normally distributed, and the means are similar, staying within a range from 19.24 to 19.29 mm, without statistically significant differences.

3 right upper: there is an adaptation of the measures to the normality model; furthermore, the values are homogeneous and vary from 9.44 to 9.49 mm. There are no statistically significant differences.

3 left upper: the measures do not differ from the normal curve model, and the averages are within the range of 9.47-9.53 mm, without any statistically significant difference.

3-3 lower: the values are normally distributed, and the means are very similar, between 24.02 and 24.20 mm, and the differences are not statistically significant.

6-6 lower: the values have a normal distribution, and any deviation from the standard curve is not statistically significant. Therefore, the means are similar, and range between 42.86 and 42.93 mm, and their differences have no statistical significance.

3-6 right-lower: the values are not normally distributed ($p<0.01$), and there is a negative asymmetry. This lack of normality does not seem to cause alterations in the comparison tests. The average value obtained with the ZFX Evolution is 20.61 mm and is lower than the other means, ranging from 2.70 to 2.78 mm. The differences are significant, with $p<0.01$ in the Friedman test but $p<0.1$ in the Anova test. Student's t-test and Wilcoxon test show that the difference between the mean obtained with the ZFX Evolution and the means obtained with the 3Shape scanner (20.78 mm) and the 3M scanner (20.78 mm) has statistical significance, with $p<0.05$ (Table I); this means that the ZFX Evolution scanner measures this variable in a different way than the other scanners.

3-6 left lower: the measurements do not differ from the standard curve model, and the means vary from 20.73 to 20.77 mm; the differences have no statistical significance.

3 right lower: No significant deviations from the standard curve, and the means are homogeneous.

3 left lower: the four values are generally distributed without statistically significant differences from the standard model. The means range from 9.88 to 9.94 mm, and the difference is not statistically significant.

When it is said that a parameter has similar means without statistically significant differences, it means that both a multivariate analysis of variance and a pairwise comparison was performed, and the differences were not statistically significant, with a p-value> 0.05; this means that these parameters were measured similarly by all scanners.

Time required for the scans

The time required for each scan was evaluated by analysing the upper arch, the lower arch, the occlusion scan and the total scan time, shown in the graph below (Fig. 2). The Trios scanner has a reduced scan time, followed by the True Definition scanner.

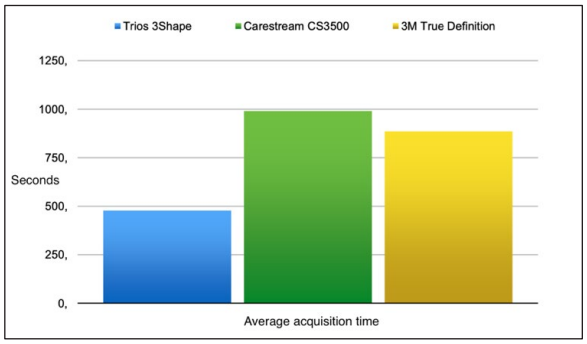

Fig. 2. *Total acquisition time.*

Opinions expressed by patients and operators

The analysis of the answers given by the patients showed that they preferred the 3Shape Trios in terms of ergonomics, versatility and ease of use. On the other hand, the answers given by the operators showed that they preferred the 3M True Definition, thanks to its lightness, speed and versatility in obtaining the .stl file.

DISCUSSION

Digital technologies are becoming part of daily clinical practice in dentistry, as they are a very useful tool for diagnosis and treatment plans. Unlike plaster models, digital models are easy to archive (5-7). This study has compared four different scanners in terms of precision, the time required and the preferences of both patients and operators. Statistically significant differences between the measurements have not been detected, except for one parameter, which was the distance between the lower canine and the lower first molar on the right side; this parameter represented a statistical weakness and, in general, it was possible to say that the four scanners analysed were very accurate.

Table I. *Differences between the values detected with the scanners: 3-6 right lower.*

Scanner	Mean	D.E.	Anova MR F	Anova MR P	Test Friedman Chi²	Test Friedman P	pairs	Student MR /t/	Student MR P	Test Wilcoxon /Z/	Test Wilcoxon P
(1) 3Shape	20.78	2.32					(1) - (2)	0.08	.939 NS	0.56	.575 NS
(2) 3M	20.78	2.41					(1) - (3)	1.33	.224 NS	1.36	.173 NS
(3) Carestream	20.70	2.31	2.73	.070 NS	11.84	.008**	(1) - (4)	2.41	.047 *	2.37	.018 *
(4) ZFX Evolution	20.61	2.31					(2) - (3)	1.30	.234 NS	1.26	.208 NS
							(2) - (4)	2.41	.047 *	2.37	.018 *
							(3) - (4)	1.22	.261 NS	1.36	.173 NS

NS = p>0.05 *= p<0.05 ** = p<0.01

The Trios scanner was the most appreciated by the patients because it is comfortable, fast and has pleasing aesthetics. The questionnaires showed that the other scanners were also appreciated, but patients argued that the Carestream CS3500 does not have pleasing aesthetics. Moreover, it should be noted that the 3M True Definition scanner requires powder in the mouth.

The operators liked the True Definition scanner more than the others. The 3Shape also received very good reviews regarding aesthetics and ease of learning how to use the software. However, the Carestream software seems less accurate in the model's optimisation because it does not cancel the errors automatically, as the other scanners do; in particular, when there is a missing tooth, errors are generated, and the total scan time is elongated. The questionnaires also showed that the patients prefer digital acquisition of dental impressions to the traditional system with alginate or PVS.

The literature has compared models obtained from digital scans with plaster models obtained from traditional dental impressions, and it appears that the two techniques can be compared in terms of accuracy (19-21). However, technology has improved over the years, and it is possible to find many studies on scanners that are no longer used today in literature.

This article provides an evaluation of current digital systems; in particular, previous scanners have shown significant differences between an intraoral acquisition and an extraoral acquisition and this study aimed to evaluate if this difference is still present.

CONCLUSIONS

Digital methods are becoming part of daily clinical practice in dentistry; digital models are a useful tool and can be obtained from a direct scan of the arches or a plaster model from a traditional dental cast.

The analysis conducted in this study shows that the digital models obtained with the three intraoral scanners tested (Trios 3Shape, Carestream CS3500 and 3M True Definition) are all good and accurate, but there are some differences in terms of comfort and scanning time. The ZFX Evolution scanner is also accurate, even though a discrepancy was found regarding the symmetry of a variable analysed. The study sample selected is small, but each model has analysed many measurements, ensuring a good reliability level. Digital systems are undergoing a rapid evolution; in the future, digital models will probably replace traditional models, guaranteeing precision, comfort and reduced time required.

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