



## Experts Corner

# The past and present research at the University of Sydney's Discipline of Orthodontics

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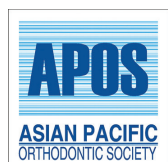
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## ABSTRACT

The University of Sydney's Discipline of Orthodontics has been actively pursuing research in the areas of root resorption, sleep apnea, magnets in orthodontics, implants, acceleration of orthodontic tooth movement (OTM), and remote monitoring (RM). Our research has shed light on many specific factors that influence orthodontically induced inflammatory root resorption (OIIRR). We also explored the effects of some of the most discussed acceleration interventions on OTM and OIIRR, such as vibration, micro-osteoperforations, piezocision, low-level laser therapy, light emitting diode, light amplification by stimulated emission of radiation, and pharmacological substances. Further, we have researched into maximizing orthopedic treatment outcomes of maxillary deficient children with use of intraoral force application with utilization of miniscrew-assisted rapid palatal expander. We are currently trialing use of RM to facilitate orthodontic services in the public dental clinics.

**Keywords:** University of Sydney, Root resorption, Sleep apnea, Magnets in orthodontics, Acceleration of orthodontic tooth movement, MARPE, Class III elastics, Remote orthodontic monitoring

## INTRODUCTION

The University of Sydney's Discipline of Orthodontics has been actively pursuing research in the area of orthodontic root resorption, sleep apnea, magnets in orthodontics, mini-implants, acceleration of orthodontic tooth movement (OTM), teleorthodontics, and remote monitoring (RM). Furthermore we have been investigating efficacy of various treatment modalities in the management of skeletal malocclusions. In this paper, the authors have divided the main areas of research, carried out over three decades, in four main domains, and they are; [Figure 1].

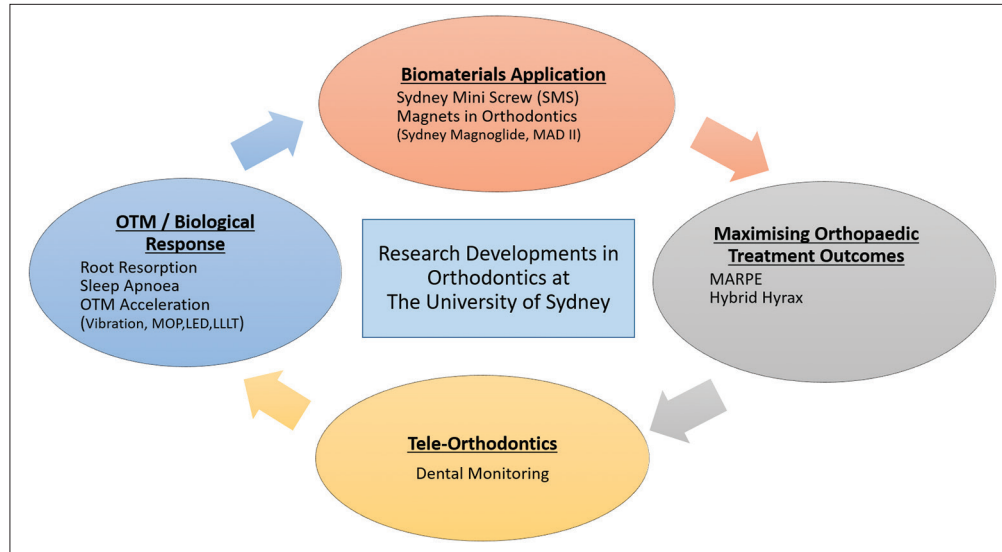
1. Orthodontically induced inflammatory root resorption (OIIRR) and OTM
2. Biomaterial applications in orthodontics
3. Maximizing orthopedic treatment outcomes
4. RM in orthodontics

## OTM AND BIOLOGICAL RESPONSES

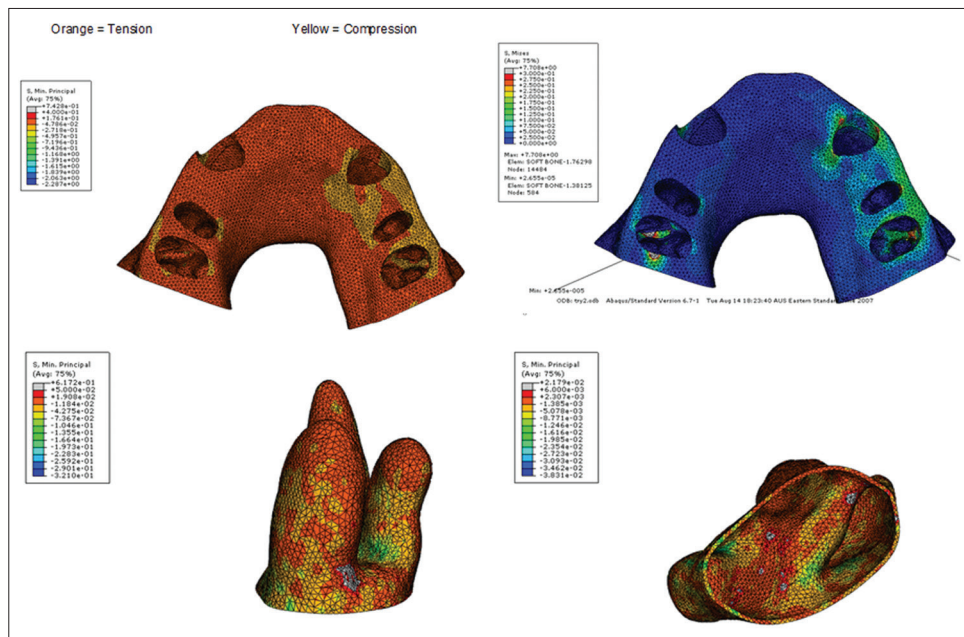
Influence of orthodontic forces on the dentoalveolar apparatus [Figure 2] and acceleration of OTM has played a key interest to OTM researchers to counter one of orthodontic treatment's major deterrents, the treatment duration. Several methods have been proposed to accelerate

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**Figure 1:** Flowchart describing the research developments in orthodontics at the University of Sydney's Department of Orthodontics.



**Figure 2:** A three-dimensional finite element model aimed to explore the biomechanical response of the periodontal ligament [first principal (tensile) and third principal (compressive) stresses] and maxillary alveolar bone (von Mises stress) under purported “heavy” (300 g) and “light” (50 g) continuous orthodontic forces. The study highlights that stress within the periodontium can occur with both heavy and light orthodontic forces.

OTM encompassing biological, mechanical, and surgical interventions aimed or targeted at enhancing the biological processes (rate of alveolar bone and PDL remodeling) that are responsible for OTM. Some of the most common interventions are; vibration, micro-osteoperforations (MOPs), piezocision, low-level laser therapy (LLLT), light emitting diode (LED), pharmacological substances, and so on, which intend to enhance cellular metabolism and

proliferation which are suggested to have the potential to accelerate OTM. Our department is actively testing the modalities of accelerated OTM to determine if there is any real benefit to using the aforementioned interventions in routine orthodontic practice.

Some of our studies on acceleration of OTM are as follows; Mistry *et al.* performed a split-mouth randomized controlled trial (RCT) to investigate the effect of LLLT on the amount

of maxillary canine distalization when applied every 4 weeks over 12 weeks, to resemble a more realistic “real-life” application frequency to go hand in hand with normal orthodontic adjustments. The gallium aluminum arsenide diode laser with a mean wavelength of  $808 \pm 5$  nm of 0.20 W and irradiance of  $1.97 \text{ W/cm}^2$  in continuous wave mode were used in this study in comparison to sham laser on the contralateral side (Thor Photomedicine, Buckinghamshire, United Kingdom). There was no difference in OTM between LLLT and control group, and also, no significant differences were noted in the rate of OTM with applying LLLT every 4 weeks at 13 J/session.<sup>[1]</sup> This was followed by our split-mouth RCT using the OrthoPulse device (Biolux Research Ltd., Vancouver, British Columbia, Canada) which is a LED-mediated photobiomodulation (PBM) device with 850 nm wavelength,  $60 \text{ mW/cm}^2$  power. The device was used at home for 5 min/d by patients. One side of the OrthoPulse device was covered by thick tape to block the light on the control side. The study concluded that daily 5 min application of LED PBM did not result in clinically meaningful differences during extraction space closure compared with no LED over the 12-week study period.

## OIIRR

OIIRR is an untoward shortcoming of OTM. In general, OIIRR is a pathological progression that is associated with the local insults of the periodontal ligament (PDL) and resorption of cementum and dentine which occurs in association with the removal of hyalinized tissue during OTM.<sup>[2-5]</sup> The University of Sydney's Orthodontic Department has carried out some of the pioneering work (published in 27 parts, so far) on OIIRR; from the initial years of OIIRR research that focussed on establishing mineral composition of human premolar cementum after the application of orthodontic forces, and effects of different types of OTM methods to modern-day acceleration of OTM applications such as LLLT, MOP, LED, and piezocision on OIIRR.<sup>[5-32]</sup> Few of our au fait advances with respect to OIIRR research are reckoned below;

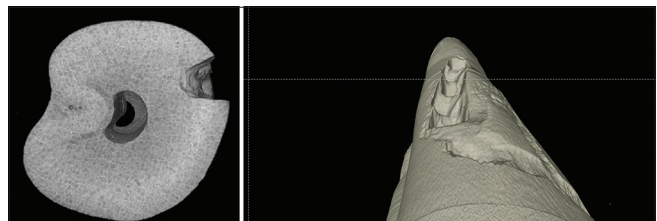
- 1) The extent of root resorption and the amount of tooth movement between continuous orthodontic force (150 g for 15 weeks) and intermittent orthodontic force (150 g for 28 days on, 7 days off) was studied using microcomputed tomography (micro-CT) scan of 50 maxillary first premolars from 25 orthodontic patients (14 boys and 11 girls; age range, 13.08–17.58 years; mean, 14.77 years). Intermittent force significantly reduced the amount of root resorption compared with continuous force.<sup>[32]</sup>
- 2) A micro-CT study was performed to assess the influence of piezocision, a flapless corticotomy procedure to accelerate OTM, on root resorption when 150 g buccal tipping forces were applied to maxillary first premolars

for a 4-week period. The study concluded that in the first 4 weeks following force application and piezocision, there was an increase in OIIRR and more importantly highlighted the risk of iatrogenic damage when piezocision is applied close to the roots<sup>[27]</sup> [Figure 3].

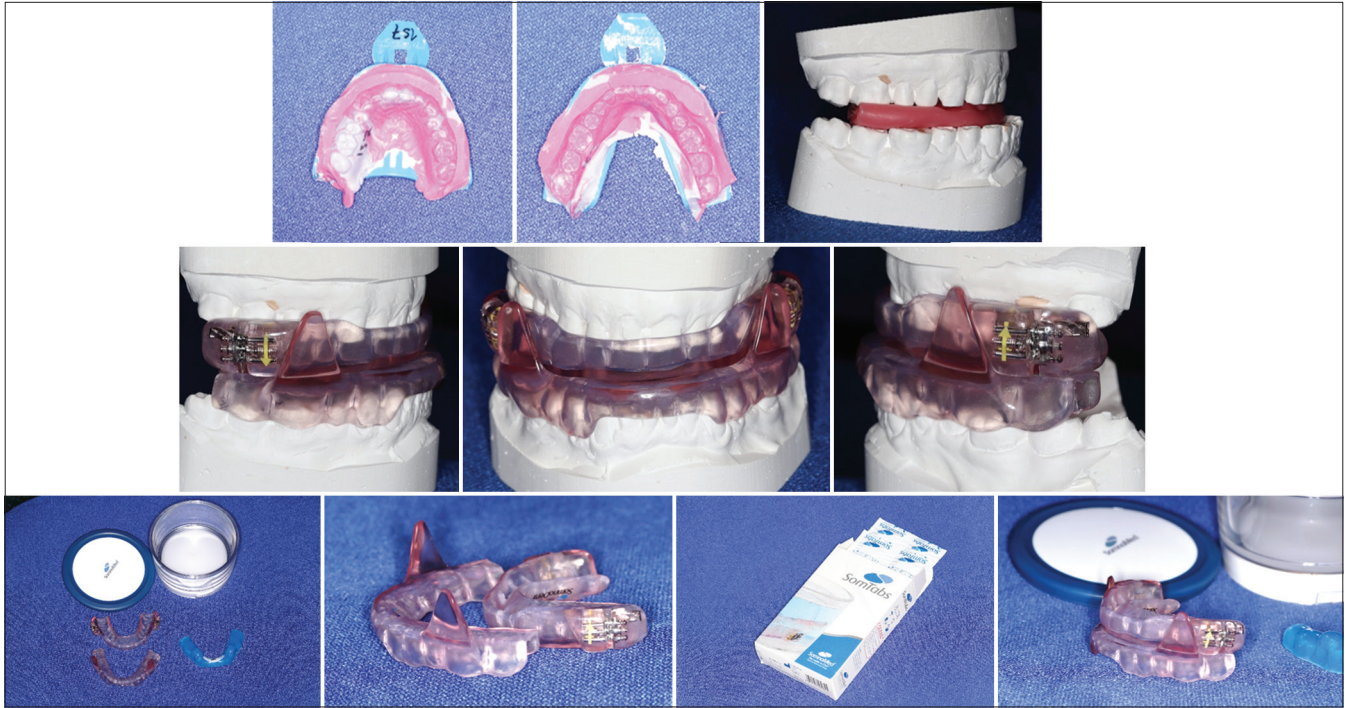
- 3) Following on from the previous study, another micro-CT study evaluated the effects of MOP on orthodontic root resorption using the Propel appliance (Propel Orthodontics, San Jose, Calif) with 5 mm MOPs on the mesial and distal aspects in the midroot region of maxillary first premolars. This trial showed that MOPs also resulted in greater orthodontic root resorption following a 28-day period.<sup>[14]</sup> Both studies suggested these results to be investigated on patients undergoing full course of orthodontic treatment.
- 4) A 2-arm-parallel split-mouth RCT studied the effect of LLLT using a continuous beam 660 nm, 75 mW aluminum-gallium-indium-phosphorus laser on the repair of OIIRR. The study concluded that there were no significant differences between LLLT and sham control groups in OIIRR repair.<sup>[22]</sup>

## OBSTRUCTIVE SLEEP APNEA (OSA)

Although continuous positive airway pressure (CPAP) remains as the main modality of treatment for OSA, mandibular advancement splints (MASs) are increasingly used in the treatment of OSA as an effective alternative to CPAP.<sup>[33-35]</sup> According to the American Academy of Sleep Medicine, MAS is recommended for mild-to-moderate OSA, and for severe OSA, when CPAP is not tolerated<sup>[36,37]</sup> There are many different designs of MAS, the custom-made 2-piece adjustable appliances being the most efficient and comfortable. Example shown in [Figures 4 and 5] (SomnoDent MAS; SomnoMed Ltd., Crows Nest, Australia). MAS's mechanism of action is through protrusion of the mandible resulting in an increase in the upper pharyngeal airway space caliber and reduced collapsibility.<sup>[33]</sup> For patients that do not tolerate CPAP and have compromised dental support for MAS, another appliance that was also studied by University of Sydney is the tongue stabilizing device (TSD). It was the prefabricated version that did not need any dental retention support whose mechanism of action is based on directing



**Figure 3:** Images showing micro-CT piezocision study showing risk of iatrogenic damage when piezocision is applied close to the roots.



**Figure 4:** A bite registration is made for the fabrication of mandibular advancement splint (MAS). The MAS, like SomnoMed (SomnoMed, SomnoDent MAS; SomnoMed Ltd, Crows Nest, Australia), is convenient to adjust as it is fitted with an adjustment screw that aids the patient to locate the best possible jaw position to control the symptoms of obstructive sleep apnea.



**Figure 5:** Mandibular advancement splints fitted in an obstructive sleep apnea patient.

the tongue forward in a protrusive position by suction mechanism, and thereby improving upper airway structure and function.<sup>[35]</sup> Our department has been actively pursuing research on dental management of OSA by collaborating with multidisciplinary teams. Some of the key findings of our OSA collaborative studies are enumerated below;

1) Our pioneering work in 2001, which was the first prospective randomized placebo-controlled crossover trial on MAS aimed to assess the efficacy of an adjustable MAS and check for predictors of success. The comparator/placebo appliance did not have any advancement of the mandible and the results showed it had no impact on

the AHI or oxygen saturation. The MAS, similar to other research studies, provided partial or complete response in 62% of the sample, complete response in 37.5%, reduced snoring frequency and intensity, and improved sleep quality and daytime sleepiness, whereas the placebo appliance did not. The following four predictors of success were identified: Neck circumference, baseline AHI, and retropalatal airway space and mandibular plane angle.<sup>[34]</sup>

2) One of our studies using magnetic resonance imaging aimed to evaluate the mechanism of action of MAS in patients with OSA by assessing their effect on upper airway structure during wakefulness. One of the key

finding of this study was that MAS improves the caliber of the upper airway by increasing the volume of the velopharynx in its lateral dimensions. Other novel findings of this study were that between responders and non-responders to MAS therapy, there were no significant differences in baseline cephalometric measurements or the volumes of the airway and soft tissue structures, but the effect of MAS on the caliber of the upper airway appeared to differ.<sup>[33]</sup>

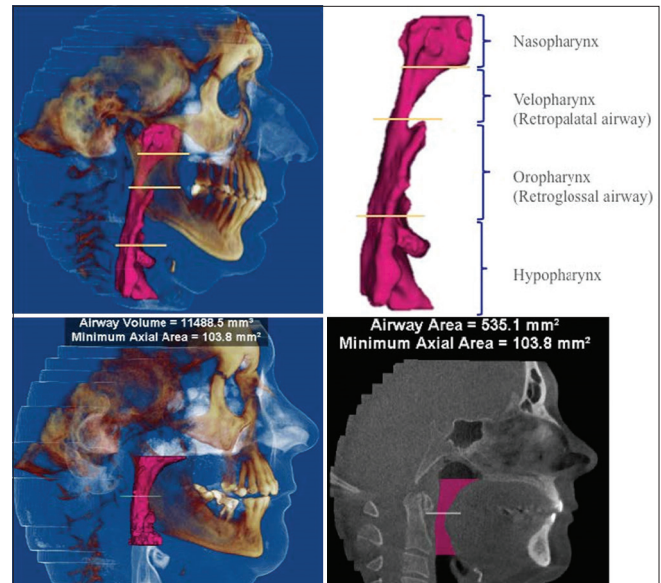
- 3) The influence of nasal airway resistance (NAR) on MAS response was studied on patients with OSA, using posterior rhinomanometry in both sitting and supine positions, with and without MAS. The study concluded that not only NAR is an important predictive factor for MAS treatment outcome but also higher levels of NAR may negatively impact on MAS treatment outcome.<sup>[38]</sup>
- 4) The differences in three-dimensional upper airway morphology and overall skeletal configuration between responders and non-responders to MAS treatment in OSA were studied. The study revealed that there are no significant differences in upper airway morphology and in anatomical structures surrounding the upper airway between responders and non-responders to MAS treatment<sup>[39]</sup> [Figure 6].

Our RCT with the crossover design, comparing the efficacy of MAS and TSD in OSA individuals, showed that both appliances reduced (AHI) and improved sleep pattern.<sup>[35]</sup> Results also highlighted that there were higher complete response rate, overall acceptance, and compliance with MAS suggest, suggesting it to be a superior treatment for OSA. Nevertheless in patients that do not have enough periodontal support and that tolerate TSD, it is still a viable treatment option.

## BIOMATERIALS APPLICATIONS IN ORTHODONTICS

### Sydney miniscrew (SMS)

Orthodontic miniscrew (MS) failure rate is reported to be as high as 50% in some studies,<sup>[40]</sup> mainly due to lack of initial or primary stability. To counter failure rate and to promote primary stability of MSs, we designed and developed the SMS (SMS, Patent number: PCT2009014) which can be used with injectable bone graft substitutes (iBGS) in patients lacking the cortical bone thickness [Figure 7]. The SMS, a hollow cylindrical screw with lateral exit holes, was introduced with the aim of addressing the failure rates and improving the efficacy in application of MS in orthodontics. Bakopoulou *et al.* showed, in a rabbit model, that a combination of SMS and iBGS increased the primary stability.<sup>[41,42]</sup> iBGS is a composite of calcium sulfate (CaSO<sub>4</sub>)



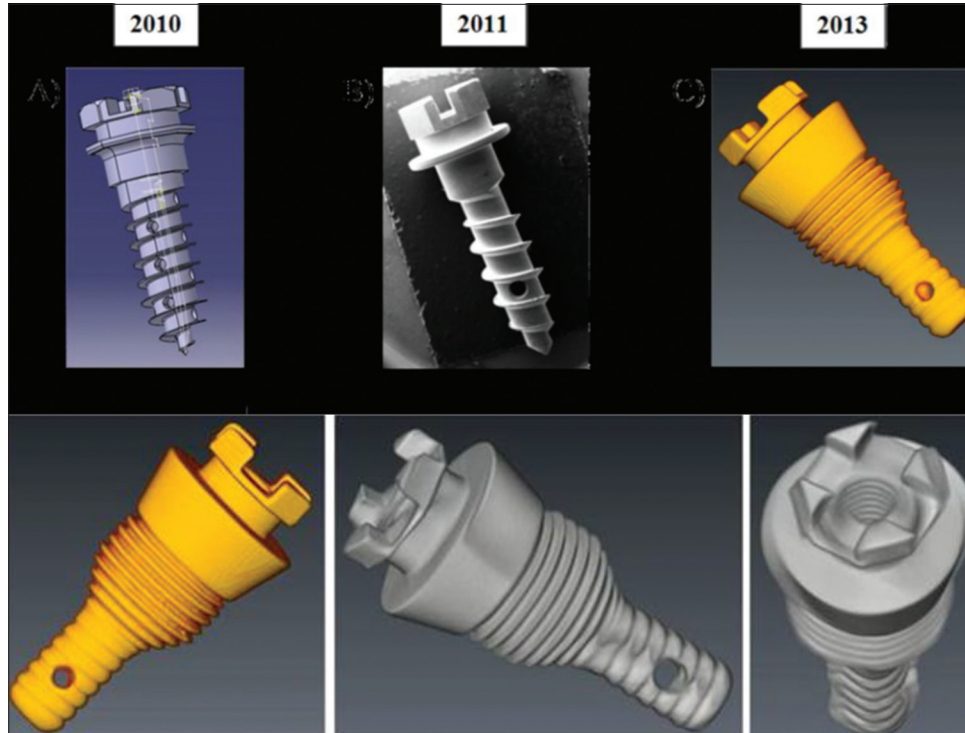
**Figure 6:** Cone beam CT images of pharyngeal airway space studied in the responders and non-responders to mandibular advancement splints treatment.

and dicalcium phosphate dihydrate (CaSO<sub>4</sub>-DCPD) forming a matrix (CaSO<sub>4</sub>-DCPD) with a distributed phase of  $\beta$ -tricalcium phosphate ( $\beta$ -TCP) granules in glycolic acid. The histomorphological and micro-CT showed uniform integration of SMS-iBGS with bone tissues. Furthermore, the study, through microtomography and histological analysis, revealed insights of biological integration between the hollow SMS and osseous structures of the alveolar bone.<sup>[41]</sup>

### Magnets in orthodontics

In orthodontics, rare earth magnets, such as samarium-cobalt (SmCo<sub>5</sub>) and neodymium-iron-boron (Nd<sub>2</sub>Fe<sub>14</sub>B), have been applied successfully in both research and clinical practice, as the magnets have the ability to push, pull, or rotate a tooth or move the skeletal structures without the need for the magnet to be in direct contact with specific area of interest.<sup>[43-45]</sup> The University of Sydney's contribution in regard to application of rare earth magnets in orthodontics is diverse, some of them are;

- 1) Magnetic Activator Device II (MAD II), a removable functional magnetic appliance, introduced by Darendeliler and Joho, was designed for severe Class II problems with repulsive posterior and attractive anterior magnets.<sup>[46]</sup> Adding magnets to the functional orthopedic treatment espouse several advantages, such as; (1) provide active functioning on a full time basis, (2) less bulky and cause lesser muscle fatigue as opposed to the conventional functional appliance, (3) delivers continuous force delivery system in comparison to conventional method's intermittent rigid



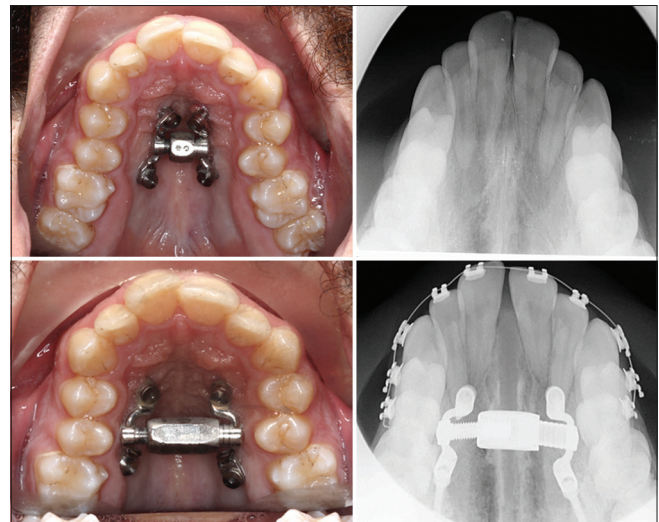
**Figure 7:** The Sydney Mini Screw (SMS, Patent number: PCT2009014). The initial implant design introduced in 2010, the SMS has seen several refinements with the current design having a dispersion capacity of an injectable bone graft.

propulsion, and (4) offers better and faster adaptation for patients.<sup>[46,47]</sup>

- 2) Sydney Magnoglide is a refined design to its predecessor MAD II. A fixed compliance-free minimal obstructive design having buccal placement of magnets encased in nickel and copper coated with a Signum metal bond (Heraeus, Hanau, Germany) to enhance acrylic resin retention. Moreover, the cobalt-chromium alloy framework allows removal of blocks in toto post-treatment. Phelan *et al.* conducted a prospective study in Class II division I malocclusion to evaluate the skeletal and dental outcomes of Sydney Magnoglide with untreated Class II controls. The study concluded that the appliance brings favorable skeletal mandibular changes with limited breakages and easy, chair-side repair.<sup>[48]</sup>

## MAXIMIZING ORTHOPEDIC TREATMENT OUTCOMES

Incorporation of newer modalities of treatment and protocols has always been a highlight of our department. We would like to maximize the outcomes of orthopedic treatment of our patients that are especially suffering from a small maxilla by utilizing miniscrew-assisted rapid palatal expander (MARPE) [Figure 8] and alternating rapid maxillary expansion and constriction (Alt-RAMEC) protocol when needed, as well as intraoral



**Figure 8:** Miniscrew-assisted rapid palatal expander could be an alternate for those individuals that do not prefer surgical intervention or is contraindicated for the correction of constricted maxillary arch.

force application methods in the management of maxillary retrusive children. MARPE when used in conjunction with Alt-RAMEC protocol (9 weeks) in the management of Class III malocclusion together with miniscrew supported lower lingual arch and heavy Class III elastics has shown to very effectively correct Class III in patients that are even at the later stages of

their growth in significantly shorter time without the need to use face mask [Figure 9].<sup>[49]</sup> These results were also evaluated 4 years post-treatment and results remained stable indicating long-term success with this treatment modality without the need for face-mask.<sup>[50]</sup>

## TELEORTHODONTICS AND RM IN ORTHODONTICS

Incorporation of teleorthodontics into routine care of patients is inevitable, as sooner or later, technology-driven health care will be omnipresent. RM, a part of teleorthodontics, is steadfastly allowing clinicians to distantly monitor patients with virtual consultations and management. RM is proposed to be a valuable adjunct in supplanting the chairside appointment time, especially, for the following reasons; (1) ability to do RM of sequential clear aligner therapy as well as compliance and oral hygiene, (2) decreased non-essential clinic visits thereby, not only

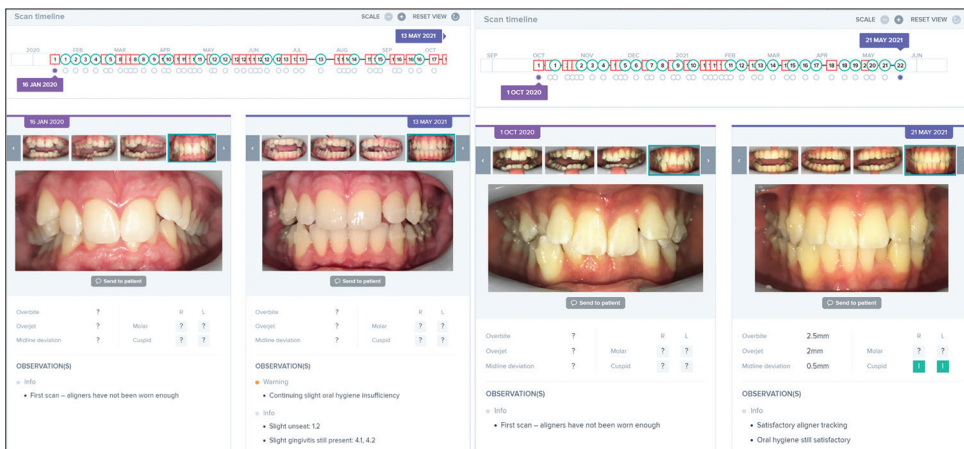
enhancing dedicated chairside time for conventional treatment but also curb on the financial burden incurred from the clinic visits, especially for distantly placed patients that cannot frequently attend clinics.<sup>[51-53]</sup>

Dental monitoring (DM) (Paris, France) is one such artificial intelligence (AI)-assisted application designed for RM of dental treatment and management. The DM system (AI motion tracking algorithm) consists of three integrated platforms: A patient app, an analysis platform, and a Doctor Dashboard. DM calculates and quantifies 3-dimensional (3D) tooth movements through photographs or videos that patients capture using a smartphone camera. The aforementioned information amalgamated with AI-generated parameters of individual patient's treatment progress are communicated to the orthodontist through a web-based Doctor Dashboard [Figure 10].

At the University of Sydney, we are [Figure 10] checking the applicability of this system in utilizing the dental workforce in



**Figure 9:** Intraoral images showing miniscrew-assisted rapid palatal expander with alternating rapid maxillary expansion and constriction protocol (9 weeks) used in conjunction with heavy Class III elastics in the management of Class III malocclusion.



**Figure 10:** Dental monitoring (Paris, France) utilizes artificial intelligence application designed for remote monitoring of dental treatment and management.

the public system, to reduce the extensively long waiting times to get orthodontic treatment and its financial benefits if any.

## CONCLUSION

An outline of some of the main research interests at the University of Sydney Discipline of Orthodontics is provided. Our research on acceleration of OTM methods most importantly identified risks related to piezocision that if applied close to the roots it may cause iatrogenic damage and should be used carefully. MOP and piezocision were shown to result in greater root resorption after 4 weeks, and the studies conducted on LLLT study showed that there were no significant differences between LLLT and sham control groups in OIRR repair. Further, protocols utilizing MARPE, Alt-RAMEC, and heavy Class III elastics through miniscrew supported lower lingual arch show promising results in short and long term management of skeletal class III patients, eliminating the need for face mask in non-compliant patients. With more research on, teleorthodontics along with technologies used for 3D diagnosis and management, 3D intra-extra oral scans and 3D printed appliances may become an integral part of routine orthodontics in the future.

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## Declaration of patient consent

The authors certify that they have obtained all appropriate patient consents.

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Nil.

## Conflicts of interest

There are no conflicts of interest.

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