Original Article

# Characterization of mini-implants used for orthodontic anchorage

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## Abstract

**Introduction:** The reduced diameter and ease of insertion of miniimplants help to minimize errors while preventing accidents that may result from surgeon error or contact between screw thread and tooth root. As diameter decreases, however, the risk of fracture increases. **Methods:** This study analysed four Brazilian commercial brands of miniimplant (INP, SIN, Conexão and Neodente) and one German brand (Mondeal) with the purpose of identifying key miniimplant features which make for good anchorage performance. The authors observed miniimplant composition and design and performed the mechanical testing of torque at fracture (in vitro study), whose values were subjected to analysis of variance (ANOVA) and Tukey's test. **Results:** Results showed that all the mini-implants tested are suitable for clinical use as reinforcement of orthodontic anchorage.

**Keywords:** Mini-implant, Skeletal anchorage.

## INTRODUCTION

Currently, skeletal anchorage systems are widespread and often used in Orthodontics as they enable satisfactory results in anchorage control with less discomfort for the patient. Since these devices can substitute other extra and intraoral resources which rely much more on patient compliance, they can easily prevent anchorage failure[5,7,13,14].

Miniimplants offer a straightforward and minimally invasive technique which precludes the use of medicines before and after miniimplant insertion. Comfortable for the patient, this anchorage alternative is highly recommended to solve severely complex orthodontic problems[1,22] or in cases where the patient presents with not enough teeth to justify the use of conventional resources. Such cases usually involve forces that may cause adverse side effects, such as asymmetric tooth movements on all spatial planes and, occasionally, can serve as an alternative to orthognathic surgery[10]. Systems in current use evolved from two different sources. The first one derived from osseointegrated dental implants, which are scientifically grounded in solid clinical[1,5,8], biomechanical[3,4] and histological[19] studies. Although smaller

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than conventional implants, orthodontic implants belong in this group, with a similarly treated surface and osseointegration capabilities. Also in this category are retromolar and palatal implants. Both are used for indirect anchorage since they are connected to the teeth, which act as anchorage units. The second system type stemmed from miniimplants and was designed specifically for orthodontic use as direct anchorage. Subsequently a new implant type was developed whose tip is similar to a bracket and can be used for direct or indirect anchorage. Unlike osseointegrated implants, these devices have a smaller diameter with a smooth surface and are designed so as to allow force to be applied immediately or soon after insertion[10].

Implants provide effective anchorage points for tooth movements even in immediate load cases[11]. They have also proved successful in cases where molar intrusion is necessary since they produce vertical force vectors without reciprocal extrusive forces affecting the remaining teeth[6,9]. Furthermore, the use of headgear or transpalatal bars as well as the inclusion of second molars to reinforce anchorage can be avoided by using implants. These are also indicated for cases requiring impacted cuspid traction[6,10] or molar uprighting[16].

Miniimplants are mostly produced from titanium alloy. They come in a wide range of designs and sizes and different commercial brands. They feature three distinctive sections, Head – area for installing orthodontic devices; Transmucosal Collar or Neck – region extending from the thread to the head (usually smooth to accommodate peri-implant tissues), and Thread – the active, cutting section[14].

The miniimplant head can have an orifice, hook or button on the tip. Implant heads in the shape of an orthodontic bracket are also available and provide the added bonus of allowing three-dimensional control as well as indirect anchorage. On this section, accessories such as springs, elastics or ligature wire can be attached for anchorage or movement, as planned[13,14].

Ideally, the transmucosal region should come in various lengths to enable placement in different sites[6]. Another key feature that should be present in this region of the miniimplant is a polished surface. The likelihood of infection in the adjacent tissues[10] is reduced as a function of how polished this implant area is.

The diameter of the threaded section varies from 1 to 2 mm and the cutting thread is an important feature which helps determine the choice of miniimplant[10]. Self-drilling miniimplants have an extremely thin and pointed apex which, more often than not, eliminates the need for any additional bone perforation procedure whereas a larger apex usually requires the site to be perforated with a bur. The latter are called self-tapping implants[20].

Miniimplant diameter should be selected according to site and available space with the aid of an intraoral radiograph. For the maxilla a smaller diameter should be selected if the miniimplant is to be inserted between tooth roots. If it needs to be inserted into trabecular bone for enhanced stability, a longer miniimplant is required. If, however, the cortical bone proves sufficient to keep it stable, a shorter miniimplant can be used. Possible insertion sites on the maxilla comprise: The area below the nasal spine, the palate, the alveolar process and the infra-zygomatic crest with the miniimplant placed at an oblique angle towards the apex. On the mandible the sites of choice for miniimplant insertion are the alveolar process, mandibular retromolar area and symphisis. If teeth are present, insertion should be performed parallel to the roots. A transcortical miniimplant can be used to promote stability in an edentulous area where trabecular bone is usually scarce[10]. The advantage of using smaller diameter miniimplants is that insertion is easier between roots, reducing the risk of root contact. Some issues have been reported regarding miniimplant use[2], among which one of the most frequent is fracture[3]. Fracture risk is closely associated with miniimplant diameter since fractures tend to occur either when miniimplant diameter is very thin or when the neck is not strong enough to sustain the tension generated at removal time[3]. In order to avoid this incident it is advisable to use tapered implants with a resistant neck and diameter compatible with bone site quality. Fracture can also occur as a result of too much force being applied by the surgeon during implantation of a self-tapping or self-drilling miniimplant. Another common problem arises from using miniimplants whose transmucosal region is poorly polished since it predisposes local tissues to infection[10]. Post-surgical oral hygiene is yet another crucial factor affecting miniimplant stability. It is of utmost importance to make the patient aware of the measures required to control dental bacteria biofilm as well as attending weekly appointments for clinical control during the first month[13].

The aim of the present study is to describe the in vitro features of orthodontic anchorage miniimplants manufactured by five different companies (SIN, INP, Conexão, Neodent and Mondeal) in terms of topography and design. The miniimplants were also subjected to a mechanical torque test up to fracture point. Hopefully the findings will help to enhance the quality of Brazilian miniimplants and make for their optimized use as orthodontic anchorage reinforcement.

## MATERIALS AND METHODS

Thirty miniimplants were analyzed while being used for orthodontic anchorage. Their specifications can be found in Table 1.

**Table 1 -** Distribution of the analyzed samples.

| Brand | Diameter (mm) | Length (mm) | Alloy | System |
|---|---|---|---|---|
| SIN | 1.4 | 8.0 | Ti-6AL-4V | Self-drilling |
| SIN | 1.6 | 8.0 | Ti-6AL-4V | Self-drilling |
| INP | 1.5 | 8.0 | Ti-6AL-4V | Self-tapping |
| Conexão | 1.5 | 8.0 | Ti-6AL-4V | Self-drilling |
| Neodente | 1.6 | 7.0 | Ti-6AL-4V | Self-drilling |
| Mondeal | 1.5 | 7.0 | Ti-6AL-4V | Self-drilling |

### Scanning Electron Microscopy (SEM)

#### Photomicrography

To observe miniimplant topography and design the samples were mounted on special aluminum bases using a double face carbon tape and observed under a Scanning Electron Microscope. A LEO 940 Model was set to high vacuum mode with 20 KV acceleration and 0.8 µA filament current. 25x, 50x, 100x and 200x photomicrographs were acquired showing images of the head, transmucosal and thread sections of all samples.

### Energy-dispersive X-ray Spectroscopy (EDX)

The metal alloy contained in the miniimplants was characterized by X-ray dispersion under the Scanning Electron Microscope. To this end the samples were cut with ISOMET and washed with ULTRAMET 2002 ultrasound equipment. After careful drying theç miniimplants were placed on the special MEV bases for content analysis.

### Measurements with a digital profile projector

The digital profile projector (Fig. 1), a PANTEC (PANAMBRA INDUSTRIAL E TÉCNICA S.A., São Paulo, Brazil) was used to obtain two key measurements for design evaluation, namely, thread depth and inter-thread distance.

### Torque test

The miniimplants were subjected to a torque[4] test where each piece was inserted into swine tibia cortical bone up to fracture point. Initially the swine tibia was attached around the bench to prevent it from moving during miniimplant insertion. A pilot hole was drilled with a surgical 1.0 mm diameter bur. Subsequently, the manual key from each original miniimplant kit was fixed to the head of the digital torque meter (LUTRON TQ - 8800, Taiwan). The screws were inserted by the same professional up to fracture point. Tests were conducted on five miniimplants of each make and the results were analyzed subsequently. The insertion torque values were obtained and submitted to analysis of variance (ANOVA) and Tukey's test as well as a descriptive statistical analysis (Tab. 4).

## RESULTS

Figure 2 shows the design of the sample mini-implants in the 6x magnification photomicrographs acquired with the Scanning Electron Microscopy (SEM); a higher magnification of the heads and threads can be observed in figures 3 and 4, respectively.

Table 2 shows the percentage of the chemical elements Aluminum (Al) and Titanium (Ti) found the samples by means of X-ray dispersion analysis (EDX).

Table 3 displays the means for inter-thread distance and thread depth of the samples.

Table 4 shows the minimum and maximum values found by the insertion torque test (N/cm) and the means of forces applied up to fracture point, standard deviation values and group statistics for the miniimplant samples.

## DISCUSSION

Orthodontic miniimplants are manufactured from Ti-6AL-4V alloy, unlike osseointegrated dental implants, which are usually manufactured from commercially pure titanium. The reason for these choices lies in the fact that miniimplants have a smaller diameter than conventional implants, requiring a material mechanically more resistant than pure titanium, such as Ti-6Al-4V alloy. This alloy is less bioactive than commercially pure titanium, thereby compromising osseointegration quality while making removal easier. Besides, miniimplant systems rely on primary (initial) mechanical stability instead of secondary stability derived from osseointegration[3,18,19]. It was noted that all researched brands displayed a similar composition (Tab. 2) whereby all miniimplants

FIGURE 1 - PANTEC Digital Profile Projector.

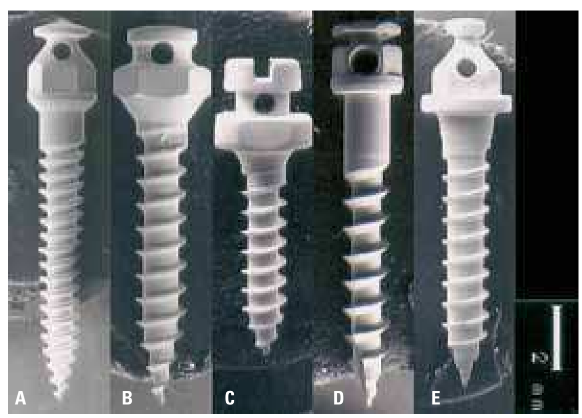


FIGURE 2 - 6x magnification photomicrograph showing miniimplant designs: Conexão (A), Neodente (B), Mondeal (C), INP (D) and SIN (E).

**Table 2 -** Elements found in the composition of the miniimplant systems assessed in this study.

| | SIN | INP | Conexão | Neodente | Mondeal |
|---|---|---|---|---|---|
| **Al (%)** | 2.60 | 2.60 | 2.51 | 2.18 | 2.50 |
| **Ti (%)** | 97.40 | 97.40 | 97.49 | 97.82 | 97.50 |

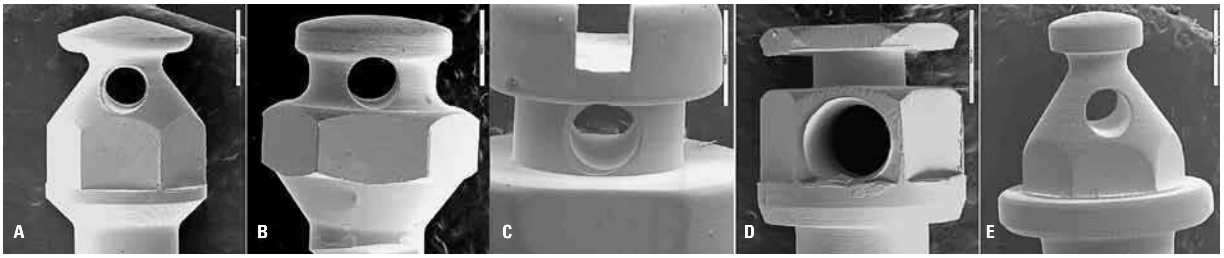


FIGURE 3 - Photomicrographs of mini-implant heads; Conexão (A), Neodente (B), Mondeal (C), INP (D) and SIN (E) at 27x magnification.

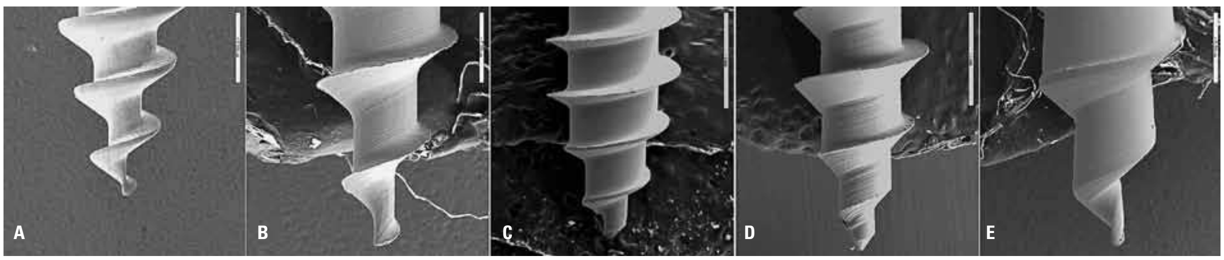


FIGURE 4 - Photomicrograph of mini-implant thread section; Conexão (A), Neodente (B), Mondeal (C), INP (D) and SIN (E) at 50x magnification.

**Table 3 -** Means for miniimplant inter-thread distances and thread depths (in mm).

| Miniimplants under studyDiameter x length (mm) | Inter-thread distance means (mm) | Thread depth means (mm) |
|---|---|---|
| SIN 1.4 x 8.0 | 0.796 | 0.186 |
| SIN 1.6 x 8.0 | 0.693 | 0.199 |
| INP 1.5 x 8.0 | 0.857 | 0.304 |
| CONEXÃO 1.5 x 8.0 | 0.498 | 0.255 |
| NEODENTE 1.6 x 7.0 | 0.734 | 0.243 |
| MONDEAL 1.5 x 7.0 | 0.654 | 0.267 |

**Table 4 -** Descriptive statistical analysis of insertion torque forces found for the miniimplant samples (N/cm2).

| groups | average | d.p. | minimum | maximum | statistics |
|---|---|---|---|---|---|
| SIN 1.4 x 8.0 | 26.34 | 3.05 | 23.1 | 30.5 | AC |
| SIN 1.6 x 8.0 | 40.0 | 1.19 | 38.5 | 41.4 | D |
| INP 1.5 x 8.0 | 22.3 | 1.99 | 20.2 | 24.6 | AB |
| CON 1.5 x 8.0 | 18.26 | 1.06 | 17.4 | 20.0 | B |
| NEO 1.6 x 7.0 | 34.8 | 2.35 | 32.3 | 38.2 | E |
| MON 1.5 x 7.0 | 28.1 | 3.38 | 24.1 | 32.9 | C |

Different letters = statistically significant difference ($p > 0.01$).

are predominantly made from titanium with a small amount of Aluminum. Vanadium did not appear on the graph given its concentration below the minimum amount detectable by EDX.

Regarding the clinical efficiency of miniimplants certain notorious flaws and issues arouse concern, mainly those linking their use to problems such as peri-implantitis and miniimplant fracture. One of the reasons for miniimplant failure is an accumulation of biofilm around the implant or a source of persistent mechanical aggression, which can cause problems such as acute or chronic inflammation and infection[17]. To avoid these setbacks special care should be taken in view of the way miniimplants are designed. A cylindrical transmucosal neck is indicated to enable a comfortable interface between miniimplant and soft tissue, and oral hygiene. The transmucosal section of miniimplants should be suitably polished to prevent biofilm from developing on the local tissues[10]. In this study the photomicrographs clearly showed that all miniimplant brands fill this requirement and both the neck and the head sections were found to be adequately polished.

Design-wise, attention should also be given to miniimplant head diameter, which should be wider than the neck to keep soft tissue from encroaching upon the miniimplant[8]. In the present study all miniimplants met this requirement. Some of the desirable features of miniimplants consist in their ease of use and a wide range of applications. It would be convenient for a mini-screw to lend itself to both direct and indirect applications, i.e. the head structure should be anatomically designed to allow for the concurrent use of elastics and orthodontic arch wire. Of all miniimplants under study only the MONDEAL brand features a slot which enables the use of orthodontic arch wires (Fig. 3). All other makes had only a button and hole for the placement of elastics and springs.

Design should ensure the prevention of irreversible tissue injuries, such as those suffered by tooth roots. For this purpose, the apical portion of the thread should be narrower and the perforation system safe enough to rule out the possibility of permanent injury to anatomical structures. This characteristic also facilitates miniimplant insertion while minimizing surgical trauma. In this investigation all mini-screws had a thin apical area (Fig. 4). Primary stability is a prerequisite for healing and is intimately related to cortical bone support. A cone-shaped thread ensures a bone condensation effect, enhancing its quality while preventing the undesirable destruction of cortical bone due to eccentric insertion or change of axis during insertion. Thus, implant stability need not rely on surgeon skill or implant insertion site [8]. Of the commercial brands under study only Mondeal, INP and Conexão featured a cylinder-shaped thread instead of tapered (Fig. 2).

The use of self-drilling or self-tapping screws – with or without a prior perforation procedure – is marked by controversy. Some authors believe self-drilling screws are more traumatic since this procedure generates physical pressure and microfractures in the adjacent bone region, which may injure the periosteum and endosteum and cause bone cell necrosis. Other professionals, however, recommend self-tapping miniimplant for they believe that the frictional heat produced by the bur during prior perforation – used for self-tapping screws – can cause more severe bone trauma. There are those who prefer to perform prior perforation with a manual instrument of high cutting capacity to minimize heat production while cooling with intense irrigation particularly the spot where the bone is thicker[8]. An in vivo test to ascertain which would be the best possible solution for this issue is beyond the scope of this study. Nevertheless, clinical studies have shown that self-drilling miniimplants enjoy a higher success rate owing to their greater primary stability compared to self-tapping miniimplants[15].

The miniimplants in this study had a 7 mm (Neodente and Mondeal) and 8 mm (SIN, INP and Conexão) length. According to LEE et al.[8], length exerts little effect on tension distribution. Thread design and diameter are more significant features in this respect. The authors assert that it is necessary to insert at least 5.0 mm of the screw length into the bone. Insertion beyond this depth, however, does not translate into an effective increase in primary stability unless a bicortical anchorage is intended. The miniimplants in this study, therefore, are in accordance with these authors' recommendations.

Regarding insertion torque up to fracture point the miniimplant systems which exhibited the highest resistance to insertion fracture were those with the largest diameter: 1.6 mm, namely, miniimplants manufactured by SIN (1.6 mm) and Neodente (Tab. 4). Our findings agree with those by ELIAS, GUIMARÃES and MULLER[3], who concluded that the smaller a screw diameter the smaller the force values required for mini-screw insertion into the bone and the insertion force required to fracture it. These authors ascribe such characteristic to the following factors: Torque is proportional to the miniimplant x bone contact area. Since the diameter of the alveolus preparation bur is smaller than the screw diameter, part of the torque is aimed at cutting and widening the hole. As diameter size increases so does the volume of material to be cut during perforation and therefore remnants from the material remain entrapped inside the alveolus thereby hindering miniimplant rotation during insertion. This observation underlines the need for greater care to be taken when using miniimplants of a smaller diameter since fracture is more likely to occur. The third best result was achieved by the Mondeal system with its 1.5 mm diameter miniimplant. The 1.4 mm SIN System achieved the fourth best result despite its smaller diameter in comparison with the INP and Conexão systems. A comparison between miniimplant brands was beyond the scope of this study. However, as can be clearly observed in table 4, certain significant differences were found in some miniimplant groups. It should also be emphasized, however, that the insertion torque force recommended in orthodontic practice, according to Motoyoshi et al.[12] is 5 to 10 N/cm$^2$, and no stronger than 15 N/cm$^2$. Therefore, all implants used in this study achieved satisfactory results in terms of insertion fracture resistance (Tab. 4).

All implants under study sustained fracture in the thread section. Measurements were made of the distances between threads and thread depths of the miniimplants from the five manufacturers (Tab. 3) and compared to the torque test results. These features proved irrelevant and no association was found between the fragility of the material in the thread section (fracture site) and the aforementioned measurements. Further studies are required to better identify and solve this problem. A lateral groove on the cortical portion of the miniimplant thread section could help to increase fracture resistance since it would prevent excessive tension from being generated onto the miniimplant's adjacent tissues where the thread section has a wider diameter[8]. None of the miniimplants used in this study featured such modification.

## CONCLUSION

After describing the topographical and design features of the miniimplants used in this study and subjecting them to a torque test it can be concluded that all miniimplants are adequate for clinical use in reinforcing orthodontic anchorage.

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