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An innovative adhesive procedure for connecting transpalatal arches with palatal implants

Adriano Giacomo Crismani*, Thomas Bernhart**, Hans Peter Bantleon* and Gerhard Kucher***
Departments of *Orthodontics and **Oral Surgery, School of Dentistry, University of Vienna and ***Private Practice, Klagenfurt, Austria

SUMMARY The aim of this presentation is to describe an innovative adhesive procedure for connecting palatal implants with transpalatal arches (TPAs). The steps required for completing the procedure, the costs involved and the requisite time were reviewed and compared with those of two alternative procedures reported in the literature. To establish the stability and reliability of the procedure *in vitro*, tensile stress tests were performed. The results were evaluated in view of a potential loss of anchorage and compared with reported data.

The innovative adhesive procedure ensured a stable and precise connection between TPAs and palatal implants during a single visit in a chair-side time of 42 minutes. The costs incurred were €12.33. The composite-connected component parts resisted breakage up to a mean force of 3323.16 cN. Absolute stability of the TPA–palatal implant connection in terms of maximal anchorage was limited to a mean force of 408.05 cN at a wire strength of 0.036 inches.

Introduction

Anchorage is one of the most important aspects of orthodontic treatment planning. It is defined as 'resistance to unwanted tooth movement' (Profitt, 1993b). When outlining the treatment objectives for an individual and planning the necessary tooth movements, the laws of equilibrium must be considered for designing the mechanics. For every desired action there is an equal and undesired opposite reaction (Marcotte, 1990; Diedrich, 1993).

In the course of fixed orthodontic treatment, palatal implants provide maximal osseous anchorage and thus absorb the undesired reactive forces (Triaca *et al.*, 1992; Block and Hoffman, 1995; Wehrbein *et al.*, 1996; Bantleon *et al.*, 2002; Bondemark *et al.*, 2002; Maino *et al.*, 2002; Giancotti *et al.*, 2002a, b). Particularly in adults, palatal implants are a useful alternative to both extra- (headgear and Delaire mask) and intra- (Nance appliance and Jasper Jumper®) oral anchorage. In patients with complete dentitions or with extraction spaces to be closed they are necessary, because the alveolar process is not available for placing temporary implants (Roberts *et al.*, 1989, 1990; Higuchi and Slack, 1991; Glatzmaier *et al.*, 1995; Bernhart *et al.*, 2000, 2001, Henriksen *et al.*, 2003). As an added advantage they are not visible to others and therefore offer those who live a public life an acceptable solution (Shapiro and Kokich, 1988).

The benefits of orthodontic anchorage on palatal implants include easy handling, reliable stability, no need for patient co-operation and improved aesthetics of the fixed appliance (Wehrbein, 2000).

Both the standard and chair-side procedure can be used for connecting the teeth to be stabilized with a palatal implant (Crismani *et al.*, 2002). With both procedures the basic principle is that the teeth intended to act as the reactive unit are indirectly stabilized by the palatal implant. This is achieved with a sufficiently dimensioned transpalatal arch (TPA) to avoid any loss of anchorage due to the intrinsic elasticity of the system (Wehrbein *et al.*, 1999). The standard procedure was adopted from prosthodontics (Giancotti *et al.*, 2002b) and is well established, but its handling in orthodontics is cumbersome. In addition, the standard procedure is expensive due to its material intensity. Its completion takes six steps, 38 minutes of operator time and material and manufacturing costs of €159.60 (Crismani *et al.*, 2002).

The chair-side procedure was specifically developed for orthodontic use and does not involve any laboratory input. To completion it takes six steps, 55 minutes of operator time and €34.10 for material and manufacturing costs (Crismani *et al.*, 2002). The small connectors and the TPA are fixed by soldering. This implies that the composite-indexed connector–TPA construction is temporarily removed from the mouth, that a plaster support is made and that the two connections between the TPA and the small connectors are soldered.

Here an innovative adhesive procedure for connecting TPAs with palatal implants is described. It is based on the use of an adhesive technique to link the small connectors and the TPA. The procedure was evaluated for the number of steps involved, the time needed and the cost incurred and compared with the standard and the chair-side procedures. Using a special measuring set-up, the TPA–palatal implant connection was tested for its potential of tolerating the orthodontic forces to be applied to it.

Procedure, material and method

The procedure was carried out once in a patient by an orthodontist (AGC). At the time of the study, the first molars were banded and brackets had been bonded to the premolars, canines and incisors. A TPA of 0.036 inch stainless steel manufactured at a previous visit, when the teeth were banded and bracketed, was available. The time needed for the different steps of the procedure was recorded by another orthodontist (HPB) with a stopwatch and rounded to full minutes. The cost incurred for the material needed was calculated disregarding the material that would also be required for the standard and the chair-side procedure (Crismani *et al.*, 2002).

Step 1

The palatal sheaths on the molar bands are opened on the occlusal surfaces with a diamond-studded drill (8878 K, Komet® Präzisionswerkzeuge, Germany) so that the TPA can be pushed in or pulled off occlusally (Figure 1a).

Step 2

A small connector of 0.036 inch stainless steel is soldered to the implant cap.

Step 3

The cap of the palatal implant is placed and attached with its screw. The wire ends of the small connector should cross the TPA below and are bent from the distal to the mesial above it (Figure 1b).

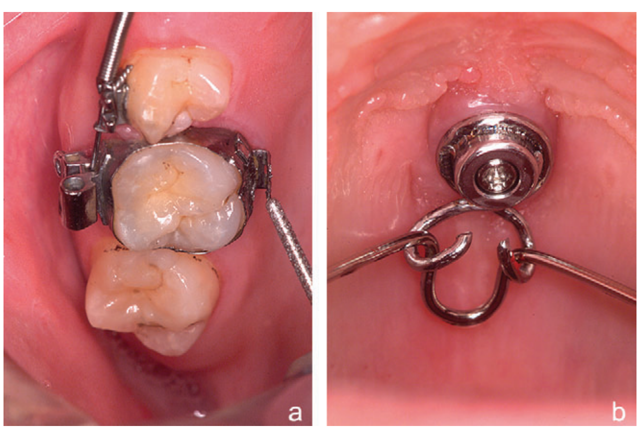

Figure 1 (a) Palatal sheaths on the molar bands opened with a diamond-studded drill. (b) Small connector and transpalatal arch *in situ*. The ends of the small connector are bent from distal to mesial around the transpalatal arch.

Step 4

The area where the small connector crosses the TPA is sandblasted.

Step 5

The TPA is attached to the tubes with a 0.010 inch stainless steel ligature and secured with composite resin (Heliosit® Orthodontic, Vivadent, Liechtenstein) in order to immobilize it for the next step (Figure 2a).

Step 6

Metal primer, sealer and light-cure paste (Light Bond®, Reliance Orthodontic Products Inc., Itasca, USA) are applied to the connections for bonding (Figure 2b and 3). The amount needed is determined using a precision scale (Delta Range PB303-S®, Mettler Toledo, Switzerland).

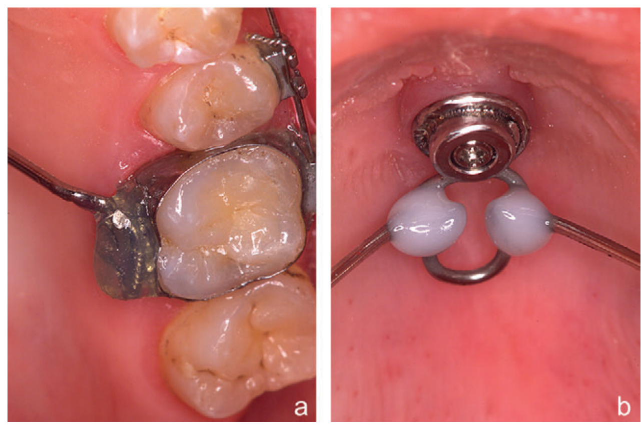

Figure 2 (a) Transpalatal arch connected to the sheaths with a 0.010 inch stainless steel ligature and Heliostat® Orthodontic. (b) The ends of the small connector are bonded to the transpalatal arch with light-cure paste (Light Bond®).

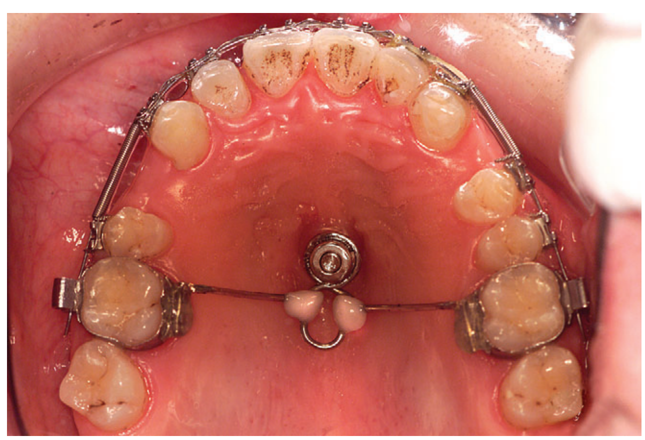

Figure 3 Occlusal view of the completed palatal implant–transpalatal arch connection.

Before carrying out the TPA–palatal implant connection an impression was taken from the maxilla and a master cast was made. On this, 10 TPA–palatal implant connections were made by an orthodontist. These connections were subjected to tensile stress tests *in vitro* on a universal testing machine (Z010; Zwick GmbH, Ulm, Germany). The Zwick machine is a stress–strain testing unit that operates in two modes, single and iterative loading. For testing the connections, the unit was set for 'strain' and 'single loading' with a steadily increasing force. Through a personal computer link the data obtained were recorded and computed.

For the stress tests, the TPA–palatal implant connections were screwed onto a T-shaped aluminium form. These forms were inserted and clamped in the holder of the Zwick testing machine. For testing, two double-twisted 0.012 inch stainless steel ligature wires were interposed between the machine and two 0.036 inch stainless steel wires soldered to the TPAs at a distance of 10 mm from their ends. The line of orthodontic force was thus at the level of the centre of resistance of the teeth. In clinical terms, this produces a translatory tooth movement (Fontenelle, 1982; Kucher *et al.*, 1993).

Results

The total chair-side time needed to connect the TPA with the palatal implant with the innovative adhesive procedure was 42 minutes. The procedure involved six steps (Table 1). The material costs totalled €12.33 (Table 2).

On exposure to a steadily increasing force in the Zwick testing machine, the TPA–palatal implant constructions, i.e. both the small connector and the TPA, were found to undergo irreversible deformation at forces above 408.05 cN (minimum 398.7 cN; maximum 416.4 cN). At a mean force of 3323.16 cN (minimum 1254.6 cN; maximum 7966.2 cN) the composite resin fractured (Table 3, Figure 4).

Discussion

Palatal implants are temporary implants for 'invisible' stable intra-oral anchorage. They are used in state-of-the-art orthodontics, if no other anchorage sites are available and patients do not accept extra-oral appliances for anchorage (Wehrbein, 2000).

If the upper molars are to be used as the anchor teeth and have been stabilized by a TPA, the TPA can be connected with the palatal implant by both the standard and the chair-side procedures (Crismani *et al.*, 2002).

With the standard procedure, the chair-side time for the different steps is relatively short, but several visits are needed to complete the TPA–palatal implant connection. The chair-side procedure can be undertaken in a single visit. The costs incurred for manufacturing are minimized, because no laboratory input and less implant material are needed (Crismani *et al.*, 2002).

The innovative adhesive procedure now described is even simpler. Like the chair-side procedure, it does not involve any laboratory work for connecting the palatal implants with TPAs. As no costs are incurred for laboratory input and the expenses for the material needed [study cast; 0.036 inch stainless steel wire; metal primer, sealer and paste (Light Bond®)] are low, the costs totalled €12.33. This is €147.27 or 92.3 per cent less than for the standard procedure and €21.77 or 63.8 per cent less than for the chair-side procedure (Table 2).

In the innovative adhesive procedure the time-consuming steps of the chair-side procedure (removing the composite-indexed small connector–TPA connection from the mouth, making a plaster support and soldering two connections between the TPA and the small connector) were replaced by a bonding technique. Orthodontists use light-cure adhesives and metal primers in daily practice for bonding brackets to metal surfaces (e.g. amalgam fillings) so that additional material costs are avoided. With the adhesive procedure,

Table 1 Time (minutes) required for each step of the innovative adhesive procedure versus both the standard and chair-side procedures.

Step	Innovative adhesive procedure	Standard procedure	Chair-side procedure
1	6	6	6
2	11	0	11
3	15	2	3
4	1	12	3
5	3	0	10
6	6	18	22
Total	42	38	55

Table 2 Material and manufacturing costs (euros) in the innovative adhesive, standard and chair-side procedures.

Costs	Innovative adhesive procedure	Standard procedure	Chair-side procedure
Study cast	10.90	10.90	10.90
Custom tray	0	18.20	0
Impression coping with screw	0	54.30	0
Master cast	0	10.90	0
Implant replica	0	14.20	0
Wire, 0.048 inch stainless steel	0	0.20	0
Laboratory work, making and soldering connector	0	50.90	0
Wire, 0.036 inch stainless steel for the small connector	0.20	0	0.20
Ultra Band-Lok®	0	0	23.0
Metal primer, sealer and paste (Light Bond®)	1.23	0	0
Total	12.33	159.60	34.10

Table 3 Results of the *in vitro* stress tests showing the forces (cN) necessary for deforming or breaking the transpalatal arch (TPA)–palatal implant connections.

	Force (cN) to deformation	Force (cN) to breakage
TPA–palatal implant connection no. 1	408.40	3274.20
TPA–palatal implant connection no. 2	416.40	7966.20
TPA–palatal implant connection no. 3	410.10	2978.40
TPA–palatal implant connection no. 4	406.70	4885.80
TPA–palatal implant connection no. 5	413.70	2274.60
TPA–palatal implant connection no. 6	406.70	4457.40
TPA–palatal implant connection no. 7	398.70	1254.60
TPA–palatal implant connection no. 8	404.00	1458.60
TPA–palatal implant connection no. 9	407.40	2254.20
TPA–palatal implant connection no. 10	408.40	2427.60
Minimum	398.70	1254.60
Maximum	416.40	7966.20
Mean	408.05	3323.16
Standard deviation	4.87	2005.70

Figure 4 Fracture of a composite connection and deformation of a transpalatal arch at the end of stress testing.

less time is needed for anchoring the teeth to the palatal implant than with the chair-side procedure. High precision and an exact fit are ensured because all work is carried out intra-orally. The exact fit of the system precludes internal stresses, which would permit undesired movements of the anchor teeth and thus promote anchorage loss. In total, no more than 42 minutes of chair-side time are needed to complete the innovative adhesive procedure. This is just 4 minutes more than the standard procedure, but 13 minutes less than the chair-side procedure (Table 1).

In vitro stress testing showed that the composite connections between the TPA and the small connector were sufficiently strong to guarantee high resistance of the entire construction. It took a mean force of 3323.16 cN for the composite resin to break. The forces measured varied between 1254.6 cN (TPA–palatal implant connection no. 7) and 7966.2 cN (TPA–palatal implant connection no. 2). These are much higher than the orthodontic forces applied to move teeth (Profitt, 1993a).

The results show that the soldering step needed for the chair-side procedure can safely be replaced by an adhesive procedure, at least with the adhesive used in this study.

The performance of the entire construction (small connectors of 0.036 inch stainless steel, TPA of 0.036 inch stainless steel) during stress testing is a point of special interest. Irreversible deformation of both the small connector and the TPA occurred at a mean force of 408.05 cN. Clinically, this force is sufficient for bodily (translatory) movements of up to four periodontally uncompromised teeth. However, en masse retraction of the upper anterior teeth (from canine to canine) requires around 500 cN (Profitt, 1993a). In terms of the results of this study, this would mean that the anchor teeth stabilized by the palatal implant are moved mesially with resultant anchorage loss.

In a prospective study, Wehrbein *et al.* (1999) also found forces of 300 and 400 cN to cause anchorage loss. They determined the extent of anchorage loss of the anchor teeth stabilized by a 0.032 × 0.032 inch stainless steel wire to a palatal implant by measuring casts and lateral cephalograms. Instability of the implant or the clamp caps proved not to be the cause of the loss of anchorage. The mesial movement of the anchor teeth was rather caused by a slight deformation of the long arms of the transpalatal bars between the implant and the anchor teeth.

In view of the results of this study and the data reported in the literature, the deformation of the TPA–palatal implant construction seen during stress testing may be prevented by using a higher-strength material for the component parts, i.e. the small connectors and the TPAs. This would, however, need adaptations or modifications of the palatal sheaths on the molar bands.

Conclusions

The innovative adhesive procedure for connecting TPAs with palatal implants is suitable for use in orthodontic practice. In a single visit it produces stable and precise anchorage within 42 minutes at a cost of €12.33. The composite-connected component parts resist breakage up to a mean force of 3323.16 cN, a force never reached in orthodontics. Absolute stability of the TPA–palatal implant connection in terms of maximal anchorage is sustained up to a mean force of 408.05 cN, if 0.036 inch wires are used. This force is sufficient for bodily movement of up to four periodontally uncompromised teeth.

Address for correspondence

Adriano Giacomo Crismani
Abteilung für Kieferorthopädie
Universitätsklinik für Zahn-, Mund- und Kieferheilkunde
Währingerstrasse 25a
A-1090 Wien
Austria
E-mail: kfo.zahnklinik@univie.ac.at

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