THE EFFECT OF INCOMPLETE SEATING OF THE IMPLANT SCREWDRIVER TIP IN THE ABUTMENT SCREW HEAD, AN IN-VITRO STUDY

By

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To my father, my daughter, Dalia, and all who made this possible

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In implant dentistry, the stripping of the abutment screw head socket often occurs during the restorative phase of treatment. Retrieving these deformed screws can be very time-consuming and costly for both the patient and the restorative dentist. In addition, the restoration, abutment and/or the implant can get damaged during the screw retrieval process. Such problem can be avoided if there is a good fit between the driver tip and the socket of the screw head during tightening or loosening of the abutment screw. This is often accomplished when the socket is free of debris and the driver is perpendicular to the abutment screw axis. There are several common conditions that could prevent full driver seating, such as, plaque accumulation, cotton pellet remnants, or restorative resin residue in the screw head.

The specific aims of this in-vitro study are to test the hypothesis that incomplete seating of the screw driver tip in the screw head socket can lead to stripping and to determine the threshold of incomplete seating when the stripping occurs in two implant systems. Also, to test the hypothesis that angulation of the screwdriver tip in the screw head socket can lead to stripping.

Twenty-five Zimmer screws (Code: MHLAS) and Twenty-five Astra tech abutment screws (Code: 24449) were used in this study. The screws were divided into two groups: the first group consisted of twenty screws of each company to study the effect of incomplete seating due to residual debris, and the second group of five screws was assigned to study the effect of angulations. All screws were tightened with the torque value recommended by the manufacturer. Each group was tightened into their correspondent mounted implant (diameter 3.7mm for Zimmer and 4.0mm for Astra). A new screwdriver was used for every five screws tested, and screwdriver tips were examined under the stereo microscope for any plastic deformations. In addition, to help understand the system, microhardness and geometries of screwdrivers and screws were studied.

Within the limitations of this in-vitro study, it was shown that incomplete seating of the screwdriver in the abutment screw head as well as angulations of the screwdriver in the head socket could potentially lead to stripping.

CHAPTER 1
INTRODUCTION

Currently, the use of implants to replace missing teeth is considered the most optimal treatment option because of its predictability and successful outcomes. Most restorative dentists have chosen implant therapy over conventional fixed or removable prosthesis because of the advantages offered by dental implants, such as preservation of adjacent teeth, preservation of bone, provision of additional support to increase masticatory function, and resistance to diseases like recurrent caries [1]. It was documented that implants could enhance the retention and stability of dental prosthesis, and improve occlusal function in patients with acquired or congenital defects [2]. Moreover, the literature shows the overall cumulative 5-year survival and success rate of root-shaped dental implants was very excellent (98.3% and 97.3% respectively) [3].

The rehabilitation of the edentulous maxilla with either implant supported fixed prosthesis or removable overdenture prosthesis is one of the most challenging procedures in implant dentistry [4]. The goal of restoring the maxilla is to restore patients' esthetics and occlusion, and several variables should be carefully evaluated and analyzed before choosing the best final prosthesis that will meet that goal. The final decision is affected by many factors such as patient preference, phonation, oral hygiene habits, economics, facial and lip support, maxillomandibular relationship, smile line, bone quality and quantity, and other factors [5]. Also, the type of final prosthesis is used as a guide to determine the number and position of implants before surgical insertion [1].

Although implant-retained or implant supported restorations have very successful outcome, one should not neglect the complications that accompany such prostheses. It was concluded in many clinical studies that screw loosening is a common complication

after insertion of fixed-detachable hybrid prostheses. It has been shown that screw fracture can occur as a result of loosening of the screw joint leading to failure of the prosthesis [6].

Stripping of the abutment screw head socket can occur if the screw is loosened and tightened more than once. Retrieving these deformed screws can be very time-consuming and costly for both the patient and the restorative dentist. In addition, the restoration, abutment and/or the implant can be damaged during the screw retrieval process. This problem can be avoided if there is a good fit between the driver tip and the socket of the screw head during tightening or loosening of the abutment screw. This is often accomplished when the socket is free of debris and the driver is aligned with the abutment screw axis. There are several common conditions that could prevent driver from complete seating, such as, plaque accumulation, cotton pellet remnants, or restorative resin residue in the socket of screw head.

Many studies have addressed clinical problems such as abutment/retaining screw fractures and screw loosening during service, but to date, there has been no published literature relating screw head stripping and residual debris in the socket of screw heads. The presence of debris in the socket of screw head could lead to two scenarios of incomplete seating between the screwdriver tip and the screw head. First, the driver tip will not be fully seated in the socket reducing the area of contact with increasing stresses on the surface of contact. Second, the driver may be seated with slight angulation to the axis of the abutment screw resulting in uneven contact between screwdriver tip and the inner surface of the socket. Both scenarios could potentially lead to stripping of the screw head.

CHAPTER 2
LITERATURE REVIEW

Implant Prosthesis as a Viable Treatment Option

Wearing conventional complete denture prosthesis is very difficult for edentulous patients especially in the mandible because of the mobility of the floor of the mouth, the thin mucosal lining of the alveolar ridge, the decreased support area, and the mobility of the mandibular jaw. Edentulous patients, who cannot function using their conventional denture, were described by Zarb as “denture cripples.” It was shown that the masticatory function of patients with implant-retained prosthesis was comparable to those with natural teeth [7]. Treatment options for the edentulous mandible could be no treatment, conventional complete dentures, implant supported fixed prosthesis, implant retained and tissue supported over-denture, implant retained and implant supported overdentures, and screw retained fixed detachable prosthesis with acrylic teeth which are also called “hybrid prosthesis” [8]. Patients who are given a fixed prosthesis reported an increase in patient satisfaction, and they had minimal post-insertion adjustments compare to patients with overdentures. However, overdentures are less expensive than fixed restorations, and still are very acceptable by patients who can’t wear conventional complete denture because they lack a good muscular control.

Furthermore, the amount of remaining bone is a viable factor when choosing between the hybrid and metal ceramic restorations. The latter option is more costly and may need a higher number of implants to be placed to support the prosthesis. On the other hand, the acrylic teeth in the hybrid prosthesis may need to be replaced in five to six years after insertion, which adds to the total cost [8]. Advantages and disadvantages of each option should be explained to the patient before making the final decision.

Prosthetic Complications In Implant Dentistry

Complications in implant dentistry can fall into following categories: implant loss, bone loss, peri-implant soft tissue complications, mechanical complications, and esthetic/phonetics complications [9]. Since this thesis is about failure of abutment screws, the author will focus only on mechanical complications. According to the review of prosthodontic literature by Goodacre [9] , the types of mechanical complications in the order of decreasing frequency were (1) overdenture loosing retention or in need of adjustment (30%), fracture of resin veneer of fixed partial dentures (22%), overdenture in need for reline (19%), overdenture clip/attachment fracture (17%), porcelain veneer fracture of fixed partial dentures (14%), overdenture fracture (12%), fracture of opposing prosthesis (12%), fracture of acrylic resin base (7%), prosthetic screw loosening (7%), abutment screw loosening (6%), prosthetic screw fracture (4%), metal framework fracture (3%), abutment screw fracture (2%), and implant fracture (1%).

Complications with single-tooth implants often involve the integrity of the dental implant-abutment screw joint. Several published studies have discussed the general guidelines for the placement and restoration of implants, and shown that single-tooth implants complications include soft tissue complications, abutment screw fracture and, most commonly, abutment screw loosening [10].

The external hexed platform design was very common in the past (Figure 2-1). The initial design was developed by Brånemark to restore fully edentulous patients. The coronal design was a 0.7-mm-tall external hexagon that did not engage the implant as an anti-rotational device. Problems occurred when the same design was used to retain single crowns because the short platform. That’s why the design was modified in

heights of 0.9, 1.0 and 1.2 mm and flat-to-flat widths of 2.0, 2.4, 2.7, 3.0, 3.3 and 3.4 mm. The expanded use of the hexagonal platform led to a large number of significant complications and many studies concluded that loosening of screws is related to the use of external hexed platform designs [11]. Jemt already reported in 1991 that for implant-retained and supported (fixed-detachable hybrid) prostheses, 31% of the retaining screws were loose at the first follow-up, and an additional 2% were loose at the second follow-up [12].

Another study reported 5% loosening of retaining screws placed in 91 patients and loose prosthetic retaining screws in 49% of treated maxillae and 21% of treated mandibles at the first annual follow-up, when Brånemark external hex implants were used [13]. Screw loosening is common with fixed-detachable hybrid prostheses, which can lead to serious complications such as screw fracture and failure of the prosthesis [6].

The exact mechanism of retaining screw loosening in fixed-detachable hybrid prosthesis is complex, because it involves fatigue cycling, oral chemical/temperature changes, and varied chewing pattern/loads. Consequently, loosening of the screw will always be a concern as the restorative dentist is making attempt to prevent it. [14]. It will be valuable for the restorative dentist to recognize the factors that facilitate the chance of screw deformation.

In the present day, root form implants present a diversity of internal connection designs. The connection can be further characterized as a slip-fit joint, where a slight space exists between the mating parts and the connection is passive, or as a friction-fit joint, where no space exists between the mating components and parts are literally forced together [15]. According to the investigators of the study, clinical experience shows

that the internal connection designs reduced the loosening incidence but has not eliminated it. However, a later study that followed 76 edentulous patients with fixed restorations over 450 implants for 15-years, reported 37 implants and 5 fixed prostheses failed caused by fractures and wear of the prosthesis, but no screw loosening [16].

Purcell *et al*. [17] investigated prosthetic complications of patients with a maxillary complete removable dental prosthesis opposing a mandibular hybrid fixed-detachable prosthesis and concluded that common complications were prosthetic tooth fracture, tooth wear, the need for relines of removable devices, and screw loosening.

External Hex Versus Internal Hex Designs

External hex implant systems were first introduced by Brånemark, and then they became widely used by clinicians. A new design with an internal hex was recently introduced to overcome the disadvantages of the previous design. It was claimed that internal hex systems have more efficient anti-rotation resistance, offer a greater tactile sense when abutments are seated, have permitted less screw flexion caused by lateral forces which decreases the chance for screw loosening [18]. It has been shown that in external hex implants, whenever occlusal forces go above the yield strength of the abutment screw, bending stress is directly applied on the abutment-implant interface. This will cause a slight deformation of the screw that could be separated at the interface and damaged [18]. However, there is no convincing evidence that the implant-abutment connection has an effect on screw loosening or that internal hex systems have any superiority over the external hex.

Mechanism of Abutment Screw System

Friction and Preload

Dental implant restorations are composed of three main components (Figure 2-2): 1) the implant body, which is the part that is integrated with the surrounding bone; 2) the abutment, the element that is fastened to the implant body by a screw to retain the restoration; and 3) the crown which replaces the clinical portion of the missing tooth [19]. Abutment screws are tightened by a torque wrench which is a practical method to control torque value [20]. When torque is applied to the screw, the screw is elongated which leads to the generation of a clamping force between the screw threads and the implant. This clamping force increases the friction between the screw threads and the screw seat inside the implant, and is called preload. The preload will hold the joint as a unit and prevent it from separating as it works against any external load applied on the joint.

When functional load is applied on the implant abutment, the screw head is compressed against the seat in the implant that reduces the elongation of the screw caused by the preload. It means that the clamping force is decreased along with reduction of the frictional forces between the threads of the implant and the screw. The functional load could be high enough to diminish the frictional force between threads so much that the screw becomes loosened [21]. Therefore, the torque applied to the abutment screw should generate enough preload that exceeds the compressive stress exerted by the occlusal forces, thus minimizes the risk of screw loosening and fracture of the prosthesis [22]. On the other hand, extremely high values of torque can cause the screw to deform plastically followed by fracture [20, 23]. To minimize screw lessening and fracture of the screw, it is necessary to keep the torque and preload delivered to the

screws at optimal levels [6]. Using a torque wrench to estimate preload value is common among restorative dentist, even though it is not the most reliable method [19].

Design of Abutment Screws to Maximize Preload

It has been found that 90 % of the torque applied during the first tightening of a screw system is to overcome friction between the engaging components leaving only 10% of the initial torque for producing preload [21]. After multiple cycles of tightening and loosening, thread friction decreases as the contacting surface being burnished and becoming smoother.

Manufacturers of implants are trying to optimize abutment screw designs in a way to maintain maximum preload and minimum input loss to friction. There are different designs of abutments and different geometries of implant/abutment interface to address joint strength, joint stability, and locational and rotational stability of the abutment-retained prosthesis [15]. The material properties of the implant components and their interaction with environmental conditions, such as change in surface friction due to the state of lubrication at mating screw and implant threaded surfaces [24].

Figure 2-3 shows a typical stress-strain curve of a material under tension. Elastic deformation of the screw under tension takes place until elastic limit (point E) is reached. After that point, plastic deformation begins. For a joint assembly like the implant shown in Figure 2-2, the preload within the implant complex or an external masticatory load can result in tensile stress within the implant. When there is no preload, the cyclic loading exerted on the implant during mastication will also be taken up by the retaining screw. In other words, the retaining screw will be cyclic loaded the elastically, as long as the load does not go beyond the elastic limit (point E). Even though the screw will return to its original form every time teeth are out of contact, the

retaining screw can still deform and fracture due to cyclic loading. If a tensile preload that is less than the proportional limit P is applied in the course of the tightening process, the retaining screw will not be subjected to the full functional load. A significant portion of the functional load is absorbed by the joint, and as a result there will be a small impact on the screw [19].

The recommended optimal preload force applied when an implant screw is fastened should be that which produces a stress level between 60% and 75% of the yield strength of the material from which the screw is made [25]. The retaining screw will fracture if the stress induced by preload equals to the ultimate strength of the material. If the stress within the retaining screw is near its yield strength, the screw will deform plastically during service and slowly loses its preload. The stress that is of most concern is the axial normal stress developed in the abutment screw shank. As described by a previous finite element analysis study [26], maximum stresses are found between the head and shank of the abutment screw and also at the root of the first threads.

Interaction between Driver Tip and Retaining Screw

It is known that when surfaces in contact slide against each other wear occurs. Wear means loss of material from surfaces and is indication of damage of the surfaces. In the case of hex driver tip and hex socket screw, wear will most likely result in unnecessary spaces between the moving components, looseness and loss of precision [27]. The process of tightening and loosening of abutment screws associated with implant restorative procedure will introduce wear between the driver tip and the inner wall of the socket. The most severe situation is the stripping of the retaining screw during loosing phase.

To investigate the causes of stripping of abutment screws, Dr. Aline Bowers of University of Florida hypothesized that stripping was the results of repeated action of tightening and loosening of the same pair of driver tip and abutment screw. The experimental protocol was to tighten and loosen abutment screw in an implant which had been fixed in an acrylic block. To maintain a constant torque throughout the study, a calibrated implant motor (Model DU 900, Biomet 3i, Palm Beach Gardens, FL, USA) was used to deliver constant torque during tightening. She used five level of torque, 5, 10 15, 20 and 30 N/cm in tightening the abutment screw. At each level of torque, the screw was tightened and loosened 20 times. There was a one min break between each process. She used 20 Astra and 25 Zimmer dental abutment screws in the study. No stripping was found in the study.

The conclusion of the study was that abutment screw of both systems can be retightened at least 20 times without fear of stripping. The study indicated that the screw head could be contaminated with debris during tightening or loosening processes, other shapes and dimensions of the screw head, or angulations of the driver when inserted in the head during tightening or loosening could complicated the process and leads to stripping.

The author of this study showed interest in the study, and focused on investigating the effect of the presence of debris in the screw head and angulations of the screwdriver during loosening and tightening as stated in the introduction.

Hypotheses

The presence of debris in the socket of screw head could lead to two scenarios of incomplete seating between the screwdriver tip and the screw head. First, the driver tip will not be fully seated in the socket reducing the area of contact with increasing

stresses on the surface of contact. Second, the driver may be seated with slight angulation to the axis of the abutment screw resulting in uneven contact between screw driver tip and the inner surface of the socket. Both scenarios could lead to stripping of the screw head. Therefore, the purpose of this in-vitro study is to test the following two hypotheses:

1. To test the hypothesis that incomplete seating of the screw driver tip in the screw head socket can lead to stripping and to determine the threshold of incomplete seating - resulting from debris remaining in the screw head- when the stripping occurs in two implant systems.

2. To test the hypothesis that angulation of the screwdriver tip in the screw head socket can lead to stripping.

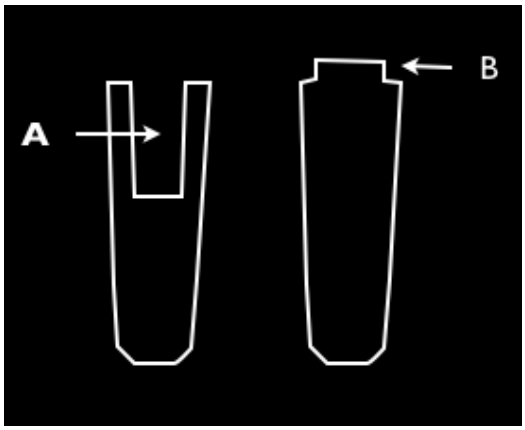

Figure 2-1. Illustration of (A) internal hex and (B) external hex implants design. (Illustration courtesy of Haya Alabhool)

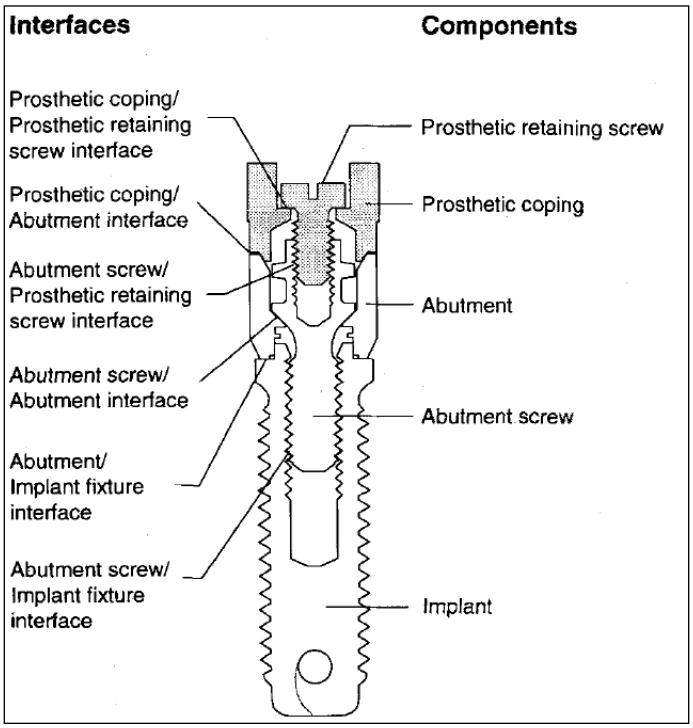

Figure 2-2. Illustration of the implant-abutment system [19]. (sourse: Jaarda MJ, Razzoog ME, Gratton DG. Geometric comparison of five interchangeable implant prosthetic retaining screws. J Prosthet Dent 1995;74(4):373-9.)

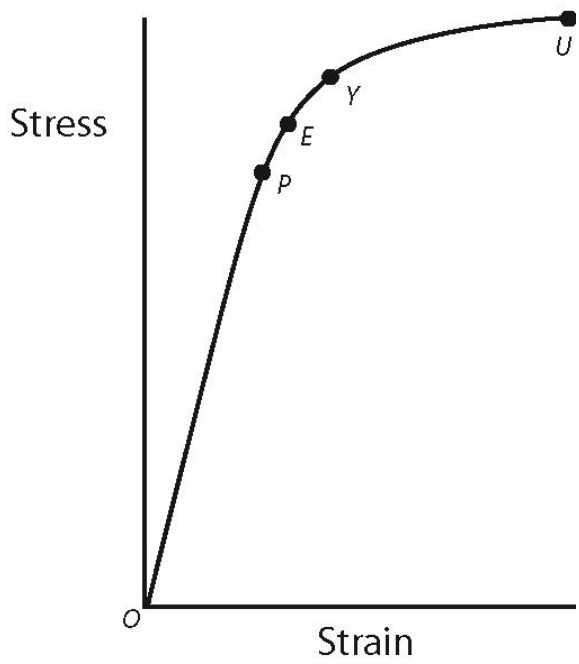

Figure 2-3. Typical tensile stress/strain diagram of screw placed under tensile load. P: proportional limit; E, elastic limit; Y, yield point; U, ultimate strength [19]. (Source: Jaarda MJ, Razzoog ME, Gratton DG. Geometric comparison of five interchangeable implant prosthetic retaining screws. J Prosthet Dent 1995;74(4):373-9.)

CHAPTER 3
METHODOLOGY

Design and Fabrication of a Device for Testing Hypotheses

To test the hypotheses, we need to immobilize the implant in a solid medium, and keep the screwdriver in a position that aligns with the implant for driving the screw. An electrical driven handpiece (Model DU 900) was used to deliver constant torque in driving screws. Two devices were constructed. The first device (Figure 3-1A) was used to mount implants in acrylic blocks. The device consists of two compartments: the mounting base (Figure 3-1A), and the guiding block (Figure 3-1B). The open space between the base and the guiding block allows visual inspection when implant is embedded in the acrylic block. The second device (Figure 3-2) also consists of two components and uses the same base (Figure 3-2A) shown in the first device. The top portion is to house the handpiece (Figure 3-2B), complete set up of the device (Figure 3-2C) and the open access (Figure 3-2D) allows operator to make sure that the driver is properly seated in the socket of the screw head. Detailed procedures of specimen fabrication are described in respective sections.

Mounting Implants in Acrylic Blocks and Their Preparation

Implant block specimens for testing the effect of incomplete seating on stripping were fabricated using a procedure modified from the process described by Martin and his colleagues [28]. The hole in the guiding block was made to fit the diameter of the screwdriver extender. Stock abutment was fixed to the respective implant root with a screw. Each screw was tightened with recommended torque. A screwdriver fitted with the extender was adapted to the socket of the screw head, and the joint area was immobilized with a heavy body PVS (Aquasil Rigid Ultra, Dentsply, York, PA, USA) to

keep the entire assembly aligned and fit together. The cavity in the center of the mounting base (Figure 3-1B) was filled up to 7/8 of the volume with freshly mixed acrylic resin (Dentsply Caulk Orthodontic Resin). The end of the extender of the implant assembly was inserted into the hole of the guiding block from underside. The guiding block with the implant assembly was fitted to the base along the four posts on the base. The implant assembly was then lowered slowly toward the acrylic resin filled cavity in the base till the acrylic resin reached the neck of the implant (Figure 3-3A). The implant block (Figure 3-4) was removed when the acrylic resin hardened.

Implant blocks for testing the second hypothesis was prepared as those for testing the first hypothesis with one exception. When the respective screwdriver was adapted to the socket of the screw, the driver was pushed off the alignment till it nudged against the rim of the stock abutment. The misaligned position represents the maximum angulation that may occur in clinical situation. Heavy body PVS was used to maintain the misalignment during the making of the implant blocks (Figure 3-3B).

Using the custom designed mounting block (Figure 3-1), four internal hex 3.7 mm X 13 mm Zimmer implants and four internal hex 4.0 mm X 11 mm Astra implants were mounted in acrylic resin for testing the first hypothesis (Figure 3-4). Each implant block was to serve as the test platform for five screws.

One implant block each was made from Zimmer and Astra for testing the second hypothesis. Each implant block was expected to serve as the test platform for five screws. Additional implant blocks would be made should the implant block had worn out before completing five tests.

Twenty hexagonal screws each from Zimmer and Astra were used to test the first hypothesis which states that incomplete seating as a result of remaining debris in the socket of the screw head can lead to stripping of the screw head. Five screws each from Zimmer and Astra were used to study the second part of the hypothesis which states that angulation of the screwdriver relative to the axis of the screw can lead to stripping. All abutment screws were tightened according to the manufacturers' recommendations (25 N/cm for Astra screws and 30 N/cm for Zimmer screw). The screw in each test specimen was tightened into its corresponding prefabricated titanium abutment, Zimmer Hex-Lock Contour and Astra TiDesign™ in the implant block.

Effect of Incomplete Seating

Preparation of Debris Loaded Screw

A material called "prop" was used to mimic the accumulation of debris in the socket in the screw head. Ideally, a more clinically relevant material like cotton pellet or resin composites would be used, but they were hard to manipulate and control. "Prop" essentially is ceramic powder that is easy to carry and to be condensed inside the very small socket in the screw head. The socket was filled in increments. After each increment, the powder was carefully condensed inside the socket with the latch driver for respective screw. To assess the quantity of the "prop" in the socket, a measuring device based on a micrometer (Model #436, Starrett, Athol, MA, USA) was constructed (Figure 3-5).

Measurement of the Debris Quantity

A metallic cylindrical cap that fits snugly to the anvil of the micrometer was machined. A 1.45 mm diameter hole that fits latch driver was drilled through the entire cylinder. The screw was tightened inside the implant in the acrylic block with the torque

recommended by the manufacturers. A small latch driver was inserted in the socket of the screw with the latch end sliding inside the metallic cap (Figure 3-6). The length registered by the micrometer represents of the baseline of the implant assembly when the screw is completely clean, and was considered the initial depth. After each increment of “prop,” the length of the assembly was measured again. The difference in length with respect to the first reading was the depth of debris in mm.

Experimental Procedure

Each screw was inserted manually into a latch driver of respective system. For screw insertion into the specimen, a calibrated implant motor (Model DU 900) was set to the desired torque and the screw was tightened into the implant (Figure 3-7). When the torque was achieved, the motor was turn off, and waited for one minute was applied before the removal of the screw. After 60 seconds the screw was loosened and completely removed from the abutment. The procedure was repeated until the head of the screw becomes stripped or up to 10 cycles if no stripping is observed. The distance between A and B was measured again after the trial to make sure the depth hasn’t changed. If the screw was tightened 10 times, and no stripping occurred, the screw was filled again with debris, and the previously described step was repeated again so we achieved multiple depths for every screw. Trial was stopped if stripping occurred or if the socket is completely filled. The number of failed screw and number of cycles at failure was recorded. A new screwdriver was used for every 5 screws and was studied after each trial using photographs and light microscopes. The results were used to determine the mean of height of debris at which stripping occurs.

The screwdriver head was qualitatively evaluated before and after each trial to check if there is any obvious sign of wear on the surface.

Effect of Improper Angulations

Preparation of Specimen Blocks

To test the effect of improper angulations, the implant was fixed in the acrylic block slightly off the perpendicular axis of the mounting base. After inserting the hex driver inside the hand-piece and the screw head using the handpiece guiding block, the hex driver was positioned in the center of the guiding hole (Figure 3-8). The amount of angulation was the degree of implant tilt made during making of the implant block. The body of the hand piece was immobilized on the guiding block with a rigid PVS impression material (Aquasil rigid Ultra, Dentsply). There is a slot on the guiding block that is designed to house the hand piece (Figure 3-2B). All screws were tightened to the manufacturer recommended values. Five screws of each company were used. This arrangement allowed us to measure the lowest depth of engagement when stripping occurred by raising the handpiece.

Experimental Procedure

First step was to tighten and loosen each screw with the screwdriver placed as deep as possible in the screw head, in the predetermined angulation. If stripping didn't occur within 10 cycles of tightening and loosening as described earlier in the effect of incomplete seating, the guiding block along with the hand piece was raised by inserting spacers of known thickness between the mounting block and the guiding block. The same testing procedure was repeated again at the new level of height. The guiding block would be raised again and tested till stripping was observed. The steps of heights used in this study were 0 mm (baseline), 0.27, 0.54, 0.93 and 1.19mm.

The number of cycles and the height of the guiding block when stripping occurred were recorded. Impressions of internal surface of the first screw head from each

company were made with heavy body PVS before and after each test at each level. These impressions were examined using photographs and under a stereo light microscope for degree of surface damage.

The results were used to establish the number of cycles before stripping of the screw head happens when angualtion of the screwdriver occurs. The pattern of surface damage can also be used to assess the potential of stripping.

Characterization of the Latch Driver Tip and the Abutment Screw

To investigate why the two groups of abutment screws behaved differently, should it occur, it is necessary to know the difference in the design and properties of material used to manufacture abutment screws and latch. Manufacturers often provide some of the information in the specification of the component but not all relevant to the study. In this study, we measured hardness of the driver tip and the head portion of the abutment screw, delineate difference in design between the two systems, and record the appearance of the drive tip and abutment screws after the tests.

Microhardness Measurement

New drivers were first stabilized on their side on a glass slide with cyanoacrylate adhesive with one flat facet set parallel to the supporting glass for indentation. New abutment screws were embedded in an epoxy resin (EpoFix, Struers A/S, Ballerup, Denmark). The epoxy resin block was ground with silicon carbide paper to expose metal with 320, 400, 600 and 1200 grit silicon carbide paper (Mark V Laboratory, East Granby, CT, USA) with running water using a lapping and polishing apparatus (Model 150;South Bay Technology, San Clemente, CA, USA). It was followed by polishing with 1 μm alpha alumina powder on alpha B cloth (Mark V Laboratory) in preparation for the microhardness indentation (Figure 3-9).

A Buhler Micro met 3 microhardness tester (Buehler Ltd, Lake Bluff, IL, USA) interfaced with a computer was used to make indentations on the metal surface. All experiments were completed with a Vicker's indenter under the same conditions: 300 g load and 15 s dwell time was used. The near square-shaped indentations were carefully observed with an optical microscope. Images of indentation were captured with a digital camera interfaced and analyzed with Omnimet 8.0 software to determine the surface hardness. Six indentations were made on each specimen.

Dimension of the Implant Components

The across-flat dimension of the hex driver tip and the outer diameter of screw head were measured with a caliper. To estimate the depth of the socket of both systems, we first measured the length of the abutment screw and the hex driver of both systems individually with the same caliper. The total length of the assembly with driver inserted in the respective socket was then measured. To examine if the hex driver of one system adapts well with screw of different system, the total length of the assembly with Zimmer driver inserted in Astra screw and vice versa were also measured.

The space between the socket and driver tip can be shown by using a fit-checking material (Fit checker, GC, Tokyo, Japan). The fit checking material was mixed and injected into the socket of screw head that immediately followed by insertion of the driver. The driver was held firmly with finger pressure till the material set. The driver was pulled out and photographs of the driver tips with fit-checking material were taken.

Appearance of the Specimens after Tests

Impressions were made for the inner surface of the first screw of each group during the improper angulations trial, however the change in the inner surface of the

socket was very minimal and the quality of available cameras and microscope was not high enough to show this change.

Hex drivers, used drivers after each experiment were examined and photographed along with new ones.

Statistical Analysis

All Data were collected for both parts of this research. For the first part, results were used to determine the mean of height of debris at which stripping occurred and the number of cycles required before stripping occurs at that height. Results obtained for both systems, Astra and Zimmer, were analyzed using the two-tail Student t-test to find if there was any statistical significant difference.

For the second part, the mean of height at which stripping happens when the screwdriver is angulated in a fixed angulation was calculated. Also, the number of cycles before stripping happened at a specific height and angulation was recorded. The results were also analyzed with two-tail Student t-test.

For the microhardness data of the driver and the abutment screw, two-tail Student t-tests were used to determine if there were differences between manufacturers, and between driver and screw.

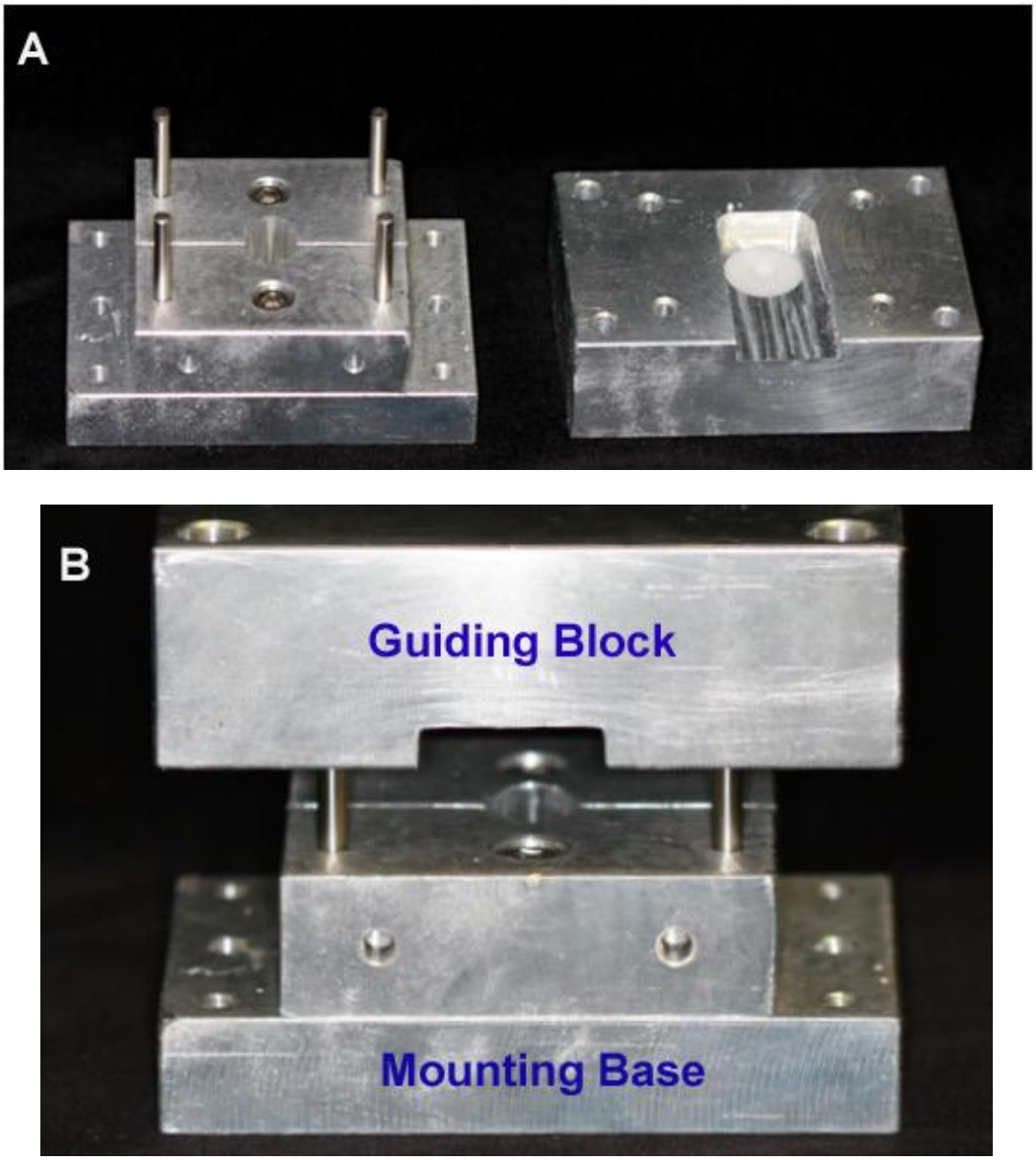

Figure 3-1. Device for mounting implant in acrylic block for testing improper seating. **A**. Mounting base block (left) and guiding block (right). **B.** The guiding block incorporated into system. The screwdriver is inserted in the screw head, which is tightened in the implant in the mounting base. (Photos courtesy of Haya alabhool)

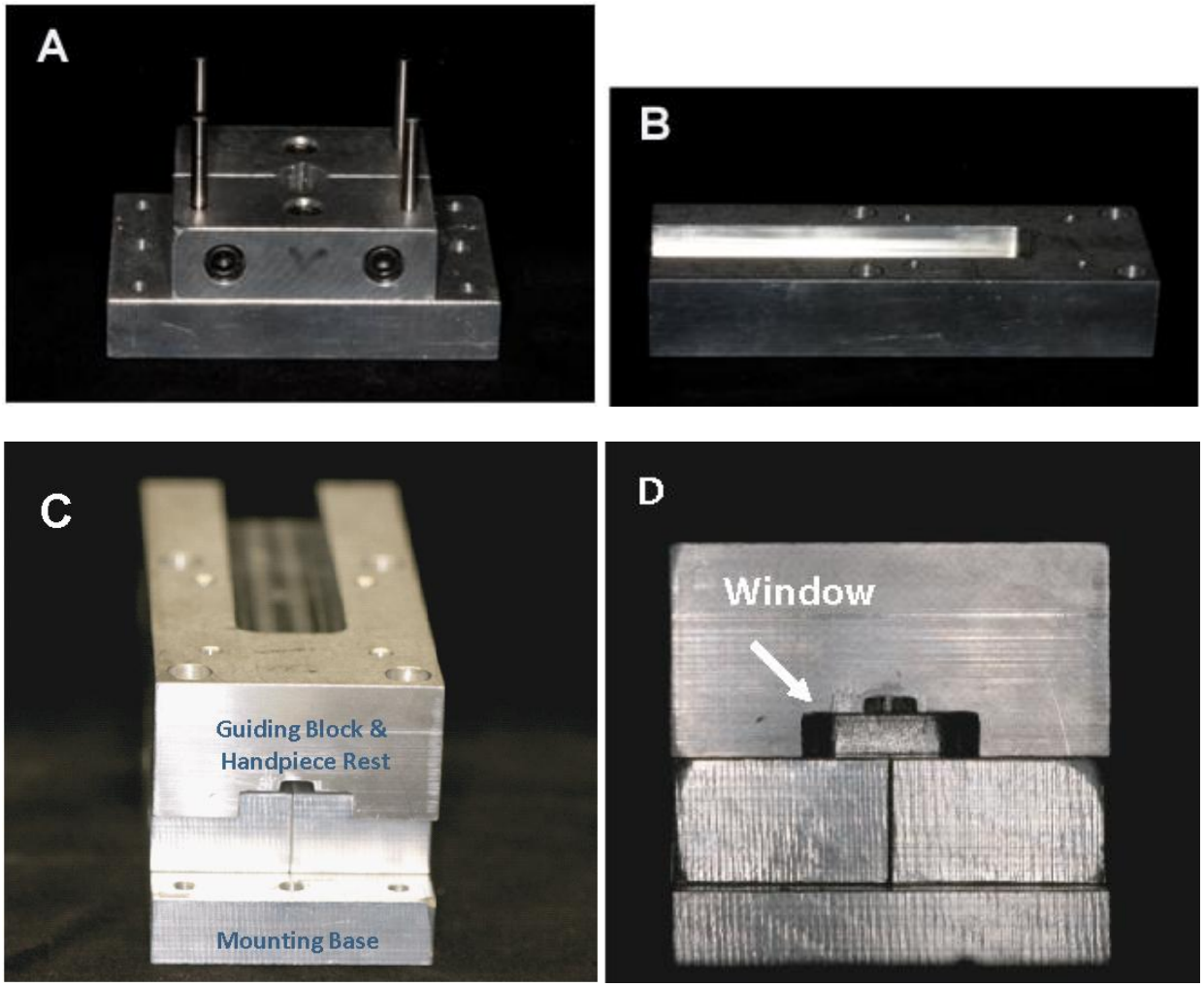

Figure 3-2. Testing device for the effect of angulation on the stripping of abutment screw. **A.** Mounting base block. **B.** The guiding block and rest for handpiece. **C.** Complete set up of the testing device. **D**. Access window for viewing the hex driver in contact with abutment screw. (Photos courtesy of Haya Alabhool)

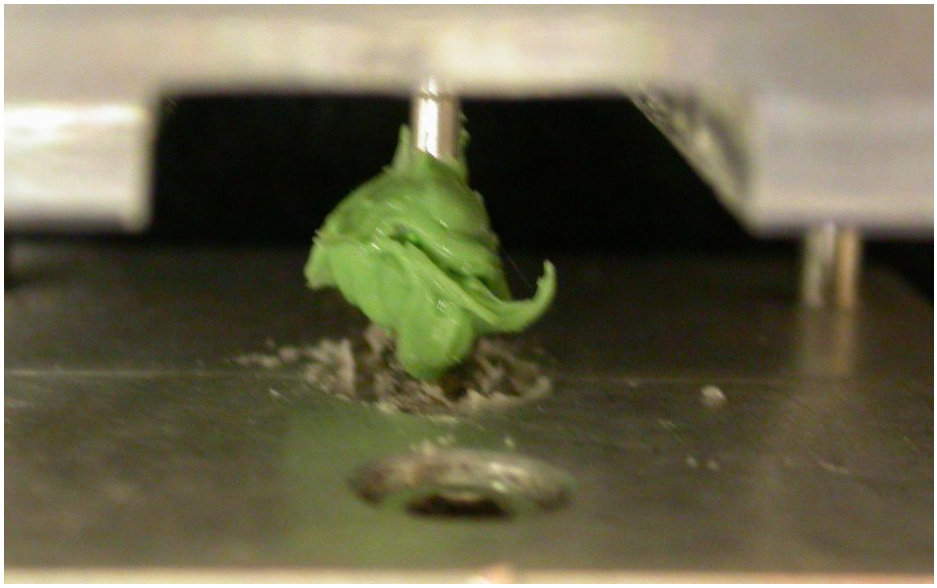

Figure 3-3. The mounting device showing implant is being lowered into acrylic resin. The hex driver and abutment screw joint is stabilized with heavy body PVS. (Photo courtesy of Haya Alabhool)

Figure 3-4. Implant specimens: (right) implant aligned with the vertical axis of the block; (left) implant seated with angulation. Hex driver was inserted and stabilized with PVS to enhance the effect of angulation. (Photo courtesy of Haya Alabhool)

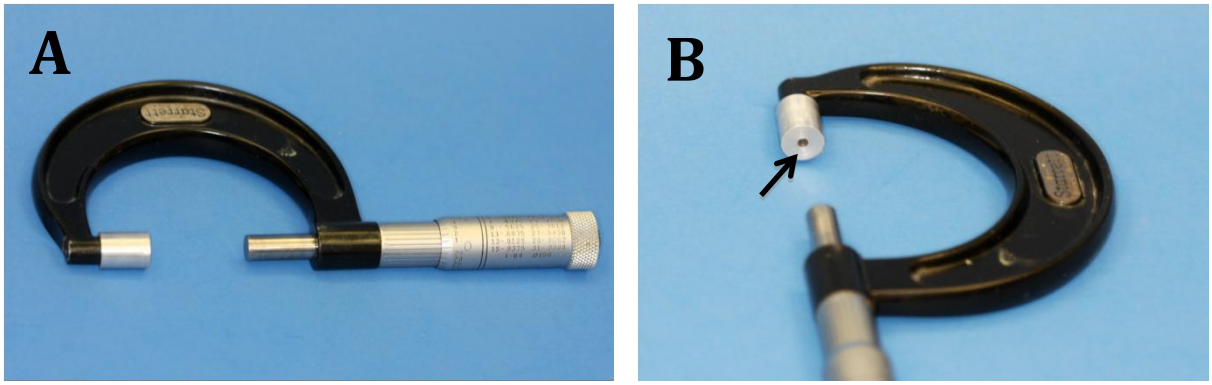

Figure 3-5. Measuring device. **A.** The caliber with metal cal; **B.** The arrow shows the hole that house the hex driver. (Photos courtesy of Haya Alabhool)

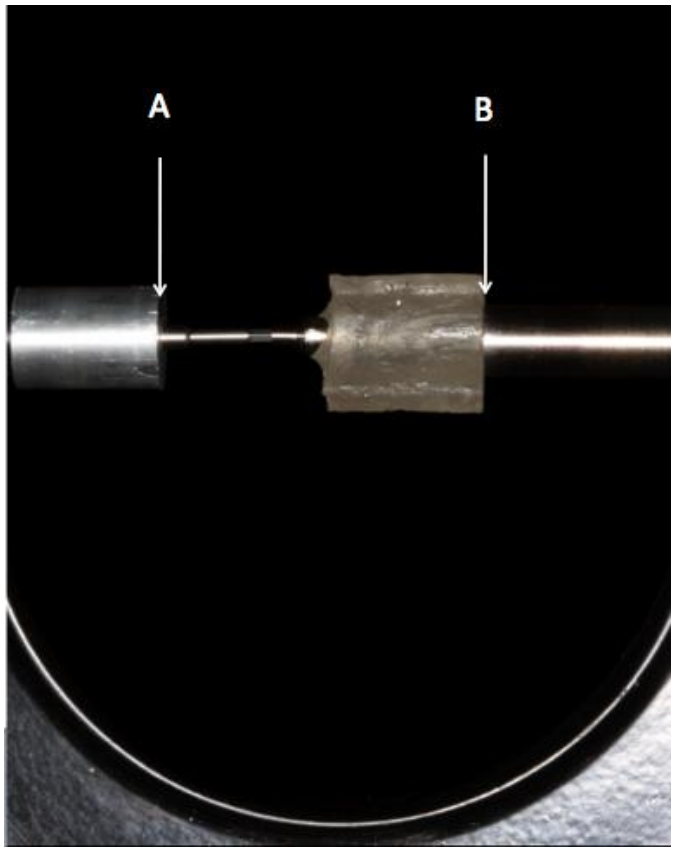

Figure 3-6. Measure the height of the test assembly for the incomplete seating experiment. The distance between A and B is the total height of the assembly. (Photo courtesy of Haya Alabhool)

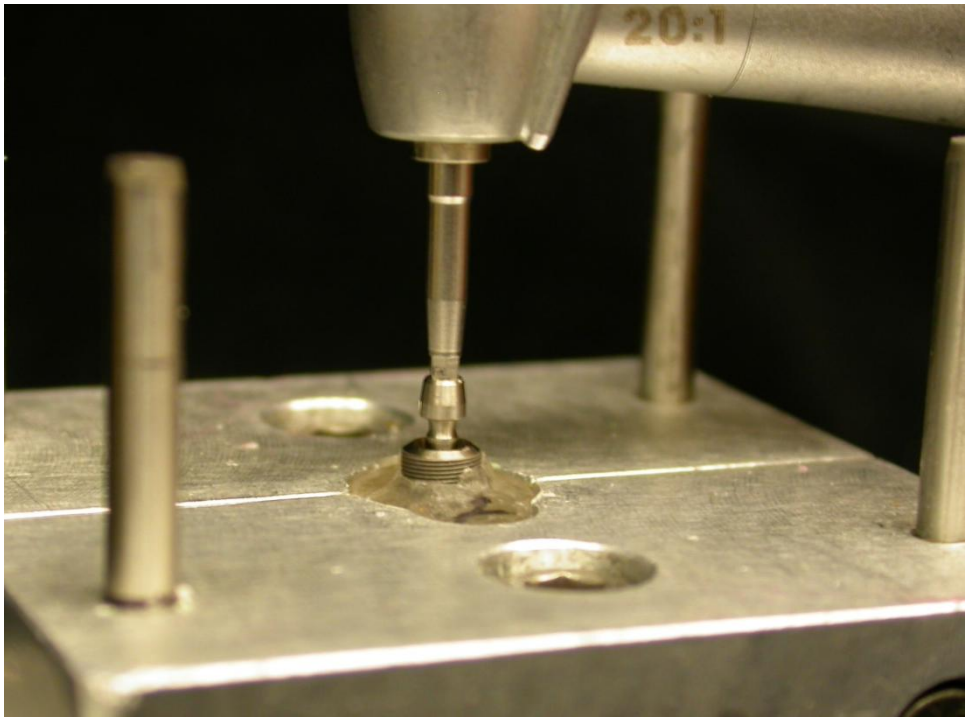

Figure 3-7. Testing of incomplete seating. (Photo courtesy of Haya Alabhool)

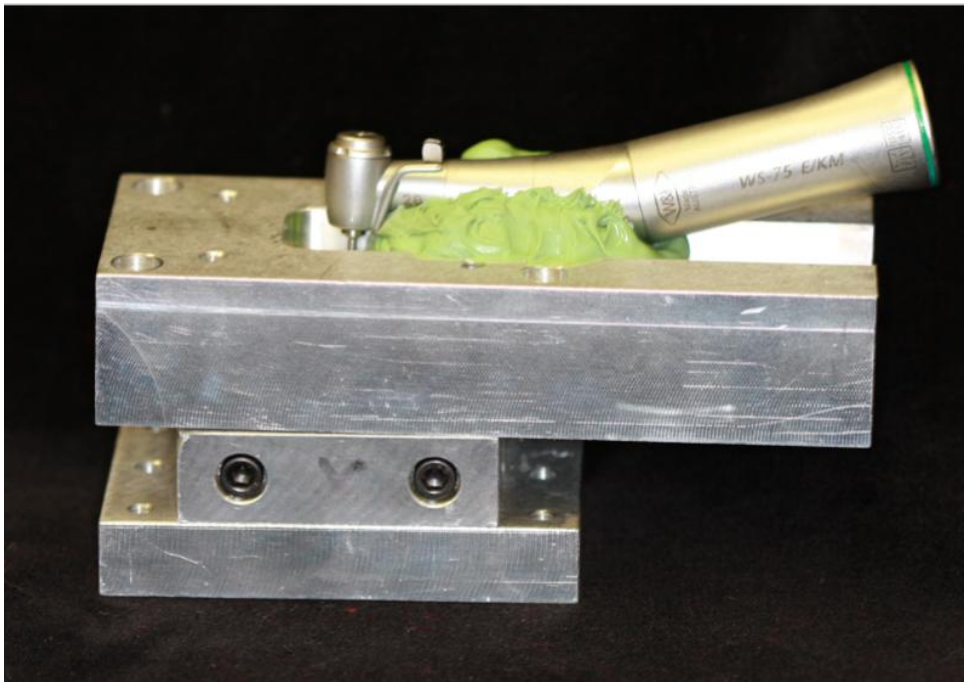

Figure 3-8. The handpiece resting on the guiding block and immobilized with a rigid PVS impression material. The guiding block can be raised with spacers to adjust the contact between the hex driver and the wall of the socket. (Photo courtesy of Haya Alabhool)

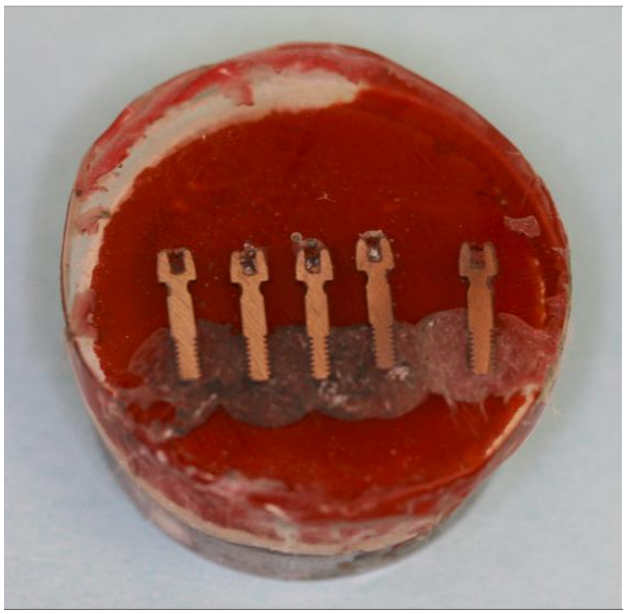

Figure 3-9. Astra abutment screws embedded in epoxy resin ready for microhardness measurement. (Photo courtesy of Haya Alabhool)

CHAPTER 4
RESULTS

Effect of Incomplete Seating

The length measured between A and B shown in Figure 3-6 before debris was packed into the socket of the screw served as the baseline of each test. The difference between the baseline length and the length after additional debris was added reflects the height of debris added in the socket (Tables 4-1 and 4-2). The highest value of height was identified and the cycle of loosening or tightening when stripping occurred was also recorded.

The results show that Astra screw heads stripped when the height of debris was between 0.79 and 1.20 mm. When stripping occurred, it was often during the first loosening. The mean of debris height at which stripping occurred was 0.98 mm (SD=0.10 mm). On the other hand, Zimmer abutment screws stripped at heights between 0.46 and 1.05 mm. Compared to Astra, Zimmer screws stripped during the first tightening procedure. Stripping occurred at a mean value of 0.92 mm (SD=0.14 mm). During testing, we often observed metal debris in the socket of the screw or on the hex driver tip even before the height of stripping was reached.

Two-tail Student t-test shows that there was statistical differences between the two systems at $p=0.028$.

Effect of Improper Angulations

As described earlier, the implant body was embedded in acrylic with a slight incline. As shown in Figure 3-8, the handpiece rests on an extended guiding block and the hex driver is fully seated in the abutment screw (not seen in the figure). Stripping of both systems did not occur when the screwdriver was completely inserted in the screw

head in spite of its angulation. Stripping finally occurred for both systems when the height of the guiding block was raised from 0.93 mm to 1.19 mm, and it always happened in the first cycle of loosening.

If a series of thinner spacer had been used before the guiding block was raised to 1.19 mm, the results might have revealed difference in the mean height of stripping occurrence. For the data obtained in this study, no statistics could be performed.

Characterization of the Hex Driver Tip and the Abutment Screw

Microhardness of the Driver Tip and the Head of Abutment Screw

Table 4-3 shows the microhardness values of the flat facet of hex driver and the polished surface of screw head of both systems. The hardness values of hex driver are 670 ± 22 Kg/cm^2 and 525 ±12 Kg/cm^2 for Astra and Zimmer, respectively, and the difference is significant by two-tail Student t-test ($p<0.001$). The hardness values are 316 ± 9 Kg/cm^2 and 320±13 Kg/cm^2 for Astra and Zimmer screws, respectively, and the two-tail Student t-test shows there is no statistically significant difference between the two systems ($p=0564$). The same test also shows that hardness of the hex driver is significantly higher than that of the screw for both systems ($p<0.001$).

Dimension of the Hex Driver and the Abutment Screw

Table 4-4 shows the dimension of the hex driver tip of both systems. The design of Zimmer driver HX 1.25D is straight with the across-flat distance of 1.24 mm and diameter of the screw head is 1.96 mm. Astra Hex CA Driver has a taper (~3° estimated from photographs) and the across-flat distance is 1.24 mm at the end and 1.29 mm at the mid section of the driver tip; the diameter of the screw head is 2.17 - 2.32 mm.

Estimation of the Depth of the Socket of the Abutment Screw

Table 4-5 shows the dimension of the driver and screw in length. Assume that the driver reached the bottom of the socket, the difference between total length and the combined length should be the depth of the socket. When the hex driver of Zimmer system was used the depth of the socket was 1.54 mm and 1.37 mm for Zimmer and Astra screw, respectively. When the Astra hex driver was used, the depth values were 1.19 mm and 1.34 mm for Zimmer and Astra screw, respectively.

By the value obtained, it appeared that the driver by Zimmer reached the bottom of both socket, but the Astra with the taper did not reach the bottom of either socket. Therefore, the depth measured with Zimmer driver should be considered the likely depth of the respective abutment screw. The results also implied that when Astra driver was used and without any debris in the socket, the flat surface of the driver tip came in full contact with the upper edge of the inner wall of the screw head. The appearance of fit check material left images of the driver pull from sockets of screw head confirmed this observation (Figure 4-1). There is a thin coating of fit check material on the tip of Zimmer driver (Figure 4-1, left) implying that there is space between driver and the abutment screw. For the Astra system, the driver came in full contact with the opening of the socket wall of the screw, separated the portion of material inside the socket from the outer portion of the fit check material. As the driver was being pulled out, the inside portion was retained in the socket and left no coating of fit check material on the tip (Figure 4-1, right)

Appearance of the Tested Specimens

Three screwdrivers from Astra and Zimmer, were examined under the microscope: one new driver, one from the incomplete seating due to debris experiment, and one

from the angulations experiment. Astra screwdriver showed no obvious sign of plastic deformation after the incomplete seating trial, while the driver used in the effect of angulation had a zone with dark deposit indicating rubbing between the driver and the wall of the socket (Figure 4-2). Zimmer driver, on the other hand, showed wear in each of the six edges of the driver after the debris test compared to the new driver (Figure 4-3A). Zimmer driver used in the effect of angulations also had worn edges that resulted from pressing against the wall of the socket, and wear was seen at each of the six edges angulation (Figure 4-3C).

Table 4-1. Results of incomplete seating of screwdriver in Astra abutment screw heads

	Astra					
Specimen #	1*	2*	3*	4*	Stripping observed	Depth of stripping
1	0.39	0.83	0.97		SL1	0.97
2	0.43	0.57	0.83	1.05	SL1	1.05
3	0.79				ST1	0.79
4	0.40	0.66	0.93		SL1	0.93
5	0.43	0.78	0.84	0.88	ST1	0.88
6	0.20	0.89			ST1	0.89
7	0.20	0.68	0.97		SL1	0.97
8	0.84	0.93			SL1	0.93
9	1.09	1.18			SL1	1.18
10	1.03				SL1	1.03
11	0.66	0.99			SL1	0.99
12	0.54	0.62	1.20		SL1	1.20
13	0.74	0.95			ST4	0.95
14	0.90				ST2	0.90
15	0.68	0.92			SL1	0.92
16	0.43	1.05			SL1	1.05
17	0.57	0.77	1.03	1.04	SL1	1.04
18	0.81	1.05			SL1	1.05
19	0.46	0.94			SL1	0.94
20	0.87	0.98			ST1	0.98
					Mean	0.98
					SD	0.10
					Max. depth	1.20
					Min. depth	0.79

Note: 1* to 4* : number of debris increment
Stripping observed: SL indicates stripping occurred during loosening; ST indicates stripping occurred during tightening; the number indicates the cycle when stripping occurred.
Depth of stripping: the highest values of the depth resulted from packing debris.

Table 4-2. Results of incomplete seating of screwdriver in Zimmer abutment screw heads

	Zimmer					
Specimen #	1*	2*	3*	4*	Stripping observed	Depth of Stripping
1	0.41	0.92			ST1	0.92
2	0.95				ST1	0.95
3	0.46				ST1	0.46
4	0.21	0.58	0.69	0.82	ST1	0.82
5	0.61	1.03			ST1	1.03
6	0.30	0.70	0.97		ST1	0.97
7	0.39	0.58	0.81		ST1	0.81
8	0.48	0.83			ST1	0.83
9	0.30	0.64	1.02		ST1	1.02
10	0.58	1.04			ST1	1.04
11	0.57	0.94			ST1	0.94
12	0.54	0.91			ST1	0.91
13	0.47	1.02			ST1	1.02
14	0.24	0.53	0.80		ST1	0.80
15	0.51	0.84			ST1	0.84
16	0.41	0.62	1.03		ST1	1.03
17	0.33	1.02			ST1	1.02
18	0.68	0.92			ST1	0.92
19	0.50	0.72	0.98		ST1	0.98
20	1.05				ST1	1.05
					Mean	0.92
					SD	0.14
					Max. depth	1.05
					Min. depth	0.46

Note: 1* to 4* : number of debris increment
Stripping observed: SL indicates stripping occurred during loosening; ST indicates stripping occurred during tightening; the number indicates the cycle when stripping occurred.
Depth of stripping: the highest values of the depth resulted from packing debris.

Table 4-3. Hardness values (in Kg/cm^2) of the latch driver and hex screw head

Replication of indent	Astra		Zimmer	
	Driver	Hex head (polished)	Driver	Hex head (polished)
1	696	303	532	324
2	685	316	518	320
3	631	314	544	299
4	675	310	519	331
5	662	330	513	314
6	668	321	524	333
Mean	670	316	525	320
SD	22	9	12	13

Table 4-4. Dimension (in mm) of the Hex driver tip and the outer diameter of the screw head

System	Astra	Zimmer
Across-flat distance of hex driver	1.24 (end) - 1.29 (at mid section)	1.24
Outer diameter of screw head	2.17-2.32	1.96

Table 4-5. Estimation of the depth (in mm) of the socket of the abutment screw

System	Zimmer		Astra	
Abutment screw (length)	8.16	8.16	8.24	8.24
Driver (length)	23.06 (Z*)	23.94 (A*)	23.06 (Z*)	23.94 (A*)
Total length (screw+driver)	31.22	32.10	31.30	32.18
Combined length	29.63	30.91	29.93	30.84
Difference	1.59	1.19	1.37	1.34

Note: Z*: hex driver for Zimmer was used; A*; hex driver of Astra was used.
Combined length: length of assembly when the driver is inserted in the socket.
Difference: total length minus combined length.

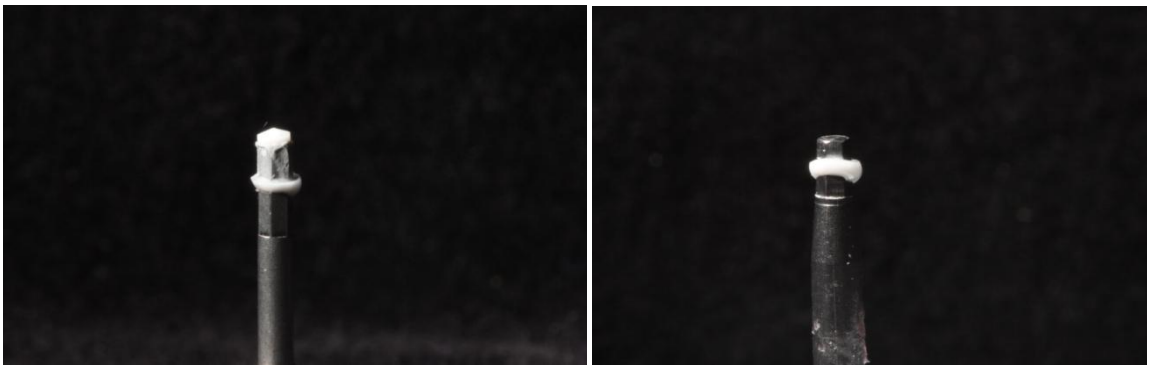

Figure 4-1. Hex driver removed from the socket filled fit check material. Zimmer driver (left)is coated with a thin layer of fit check material indicating space between the driver and the wall of the socket. Astra (right) driver is free of any material coating near the tip except chuck of material away from the tip. It implies that the flat wall of the driver came in full contact with the upper edge of the socket wall that sever the fit checker at the contact that the rest of the material is left in the socket. (Photos courtesy of Haya Alabhool)

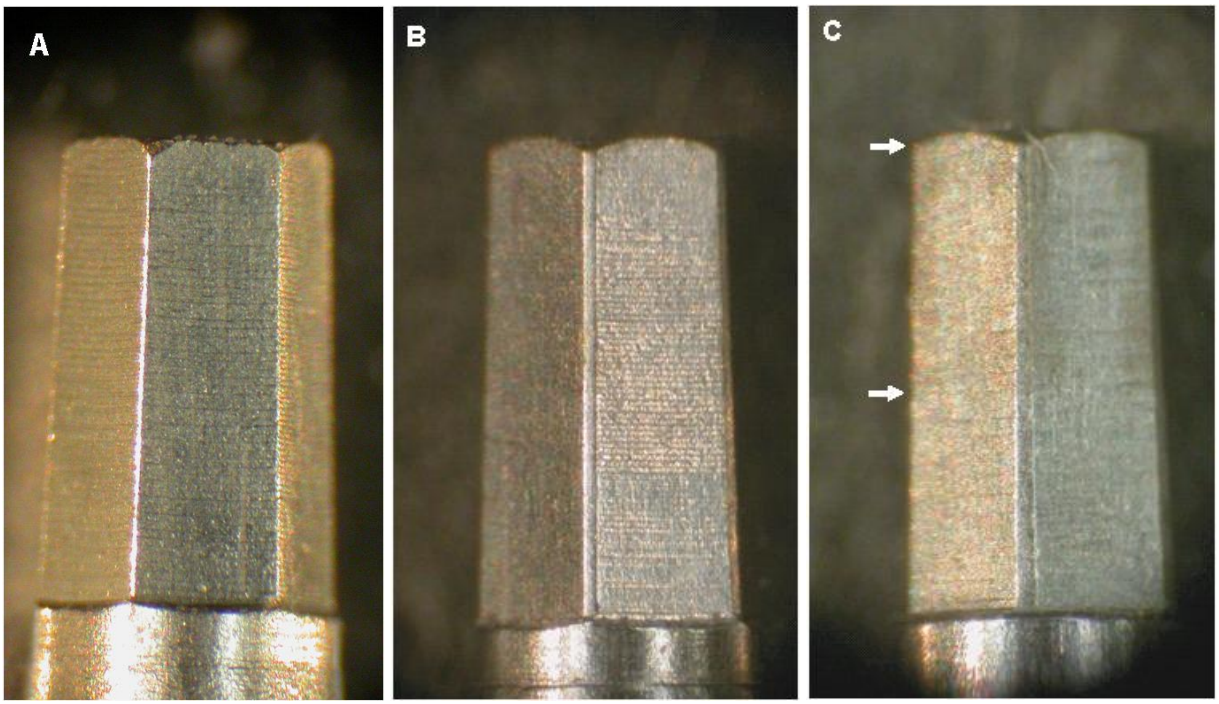

Figure 4-2. Astra drivers: (A) Driver used in the effect of debris buildup, no obvious sign of plastic deformation; (B) Brand new driver; (C) Driver used in the effect of angulation, arrows show the zone with dark deposit indicating rubbing between the driver and the wall of the socket. (Photos courtesy of Haya Alabhool)

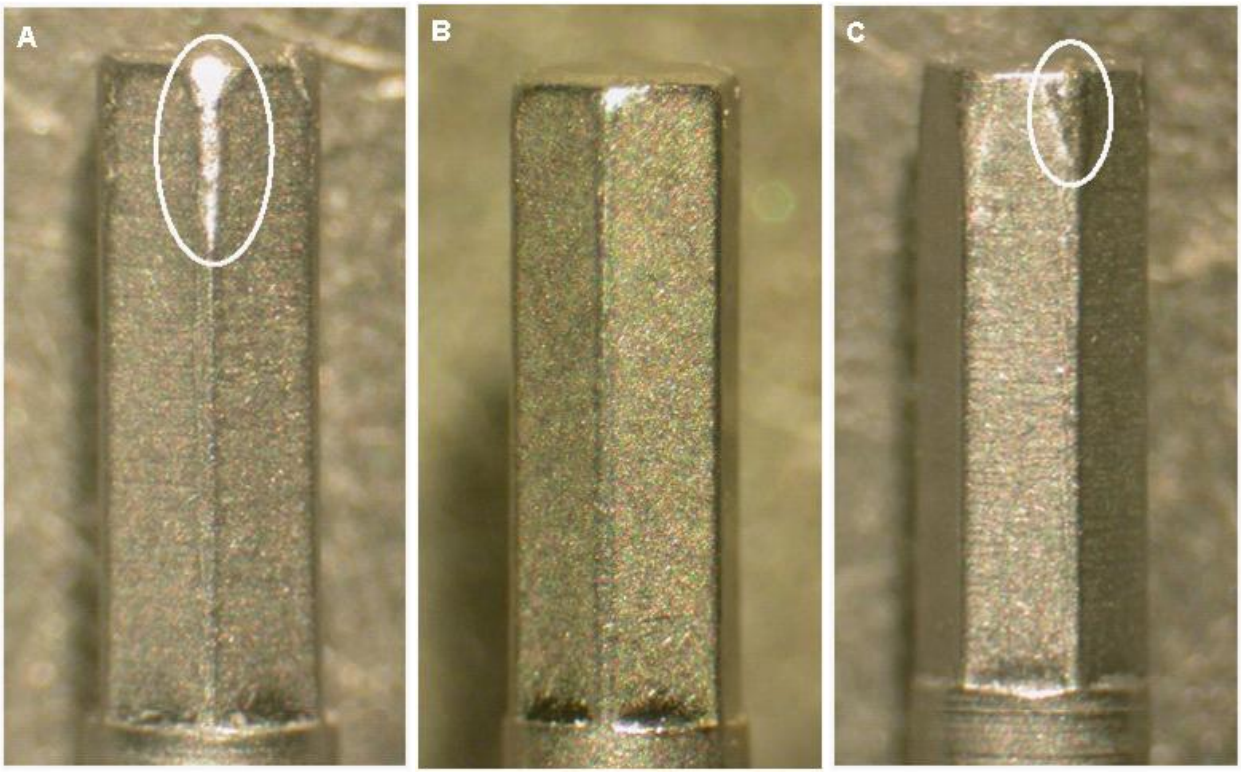

Figure 4-3. Zimmer driver: (A) The driver used in the effect of debris; area in the circle depicts the worn edge of the driver which occurred at each of the six edges. (B) New driver. (C) The driver used in the effect of angulation; area in the circle depicts the worn edge of the driver resulted from pressing against the wall of the socket, it occurred at each of the six edges angulation. (Photo courtesy of Haya Alabhool)

CHAPTER 5
DISCUSSION

Implant-retained prosthesis are more accepted now by patients and restorative dentists. These prosthesis have offered more diverse treatment options to restore edentulous and partially edentulous dental arches. One of the concerns in implant dentistry is the stripping of the abutment screw head when the dentist tries to remove the prosthesis to repair or even to clean it. Stripping may occur due to residual debris in the screw head that were not carefully cleaned by the dentist, which may lead to incomplete seating of the screwdriver, hence stripping. Debris may come either from the cotton pellet or the restorative material that is used to seal the access hole of the screw. Another reason why the screwdriver is prevented from complete seating in the screw head is angulations. If the abutment walls or prosthesis walls are too long, or in cases where implants are angulated from the long axis of the crown, direct visualization of the screw will be unattainable, and the screwdriver may be placed in the socket with an angle.

It is believed that these abnormalities would lead to stripping of the screw and premature failure of the screw. This study was to use a uniformed approach that mimics both scenarios to determine the level of abnormality when the stripping occurs.

Effect of Incomplete Seating

The first part of the hypothesis of this study was to show that incomplete seating of the screw driver tip in the screw head socket can lead to stripping, and also to determine the threshold of incomplete seating as the result of debris accumulation in the screw head when the stripping occurs in Astratech and Zimmer dental implant systems.

Difference between the Two Systems

Looking at the results of the effect of the incomplete seating, it was shown that Astra abutment screws stripped when the debris heights were between 0.79 and 1.20 mm with a mean value of 0.98 mm, while Zimmer abutment screws stripped at heights between 0.46 and 1.05 mm with a 0.92 mm mean value. The results indicated that Zimmer screws started stripping at lower heights than Astra screws. There are two possible explanations: materials used in fabricating the components and the difference in design (Figure 5-1).

Zimmer screwdriver tip was approximately 1.24 mm in diameter, and it was designed to have straight parallel walls (Figure 4-3). In the Fit checker test, it was shown that the diameter of Zimmer's screwdriver tip was smaller than its seat so uniform space was left between the screwdriver and the socket walls (Figure 5-2). Conversely, Astra screwdriver tip had angulated wall, with a diameter of 1.24 mm at the end of the tip and 1.29 mm at mid-point between tip and base of the driver (Figure 5-3). As pointed out in the results that the flat wall of Astra driver came in full contact with the upper edge of the socket wall and possibly not touch the floor of the socket.

At zero depth, we noticed that the contact between the Astra screwdriver and the screw had become tighter after 10 loosen-tighten cycles. At the beginning of the trial, the wider top of the screwdriver tip was in contact with top of the socket walls, hence the screwdriver is not inserted all the way to the floor of the socket as was confirmed by the Fit checker test. Then, as the screw was tightened and loosened, the top of the socket wall was shaved by the screwdriver and moved laterally away from the screwdriver, and the screwdriver may have been pushed further down in the socket, causing a tighter fit of the screwdriver in the screw socket (Figure 5-4). Since the hardness value of the

driver is twice as much as that of the screw (Table 4-3), it is likely that pressing driver against the screw with pressure could cause screw to plastically deform especially where the area of contact is limited.

Looking at Astra screwdriver, another observation was that the tips' designs were slightly different. One had all the six walls meeting in a sharp angle, and another had its walls meeting in a curved angle. Since either driver does not fit the sockets snugly, as the driver is turned its six sharp angles will come in contact with the socket wall and nudge into the surface. The friction between the driver and the socket wall, and the resistance of the socket wall to plastic deformation kept the driver and socket in contact and the torque applied was used to turn the screw.

Stripping of Zimmer Abutment Screw

For the abutment screw by Zimmer, as the driver was raised by the addition of simulated debris, the area of contact decreases (Figure 5-5) while the torque remains the same. It means the stress at the contact can increase to the level exceeding the yield strength of the screw. At that level of stress, plastic deformation of the socket occurred and presented no resistance to the motion of the driver, which continued to turn without touching the wall of the socket. That is when the stripping occurred. Meanwhile the amount of stress existed at the driver-screw contact could also cause the sharp corner of the driver to deform plastically.

Even though the microhardness value of the Zimmer driver is higher than that of the screw (525 Kg/cm^2 vs. 320 Kg/cm^2), there is evidence that the driver by Zimmer had deformed plastically at the corners (Figure 4-3A) as indicated by the flattening of the corner. This surface deformation would widen the clearance between the driver and socket that prevents the driver from engaging socket and transfers the torque power to

turn the screw. The result is stripping at a lower depth of debris accumulation. Based on Tables 4-2 and 4-5, we calculated that at the lowest (0.46 mm) and highest (1.05 mm) depth of stripping, the actual depth of stripping at these depths would be 1.13 mm and 0.54 mm, respectively. The latter values were obtained by subtract the lowest and highest depth values from 1.59 mm (the depth of the socket of Zimmer abutment screw listed in Table 4-5).

Stripping of Astratech Abutment Screw

Earlier discussion showed that the 3° taper of the Astratech driver created an intimate contact at the top of the socket with no debris present. Addition of debris in the socket will raise the driver as in the case of Zimmer driver. There is, however, a significant difference between the two systems. Because of the taper, the cross-section of the driver that is at the same height of the top of the socket becomes smaller as the driver is raised by the debris accumulation (Figure 5-6). It also means that the gap between the driver and the wall of the socket increases. To transfer the torque force to the shaft of the screw to turn, the six corners of the driver have to come in touch the wall of the socket. At certain gap width, when the driver is turned, its six corners may barely touch the wall of the socket and plastically deforms the area of contact overcoming the resistance by the socket. The scenario is considered striping of the abutment screw. In our experimental design of the study, we considered the screw head socket had been stripped if the screw did not turn when the driver had been turned. It is entirely possible that some of the screws in the Astra group had not been physically stripped by the driver but fail to turn because of wide gap that led to non-contact between driver and the abutment screw.

Unlike driver by Zimmer, there is no sign of plastic deformation among the Astra drivers after tests (Figure 4-2A). Having no plastic deformation on the corners of the driver means that when the driver is raised higher by the debris these corners can still come in contact with the walls of the socket. In other words, if stripping should occur, it happens at higher depth of debris accumulation.

Based on Tables 4-1 and 4-5, we calculated that at the lowest (0.79 mm) and highest (1.20 mm) depth of stripping, the actual depth of stripping at these depths would be 0.58 mm and 0.17 mm, respectively. The latter values were obtained by subtract the lowest and highest depth values from 1.37 mm (the depth of the socket of Astra abutment screw listed in Table 4-5).

Effect of Microhardenss on the Stripping

Calculations of the depth of socket wall when stripping occurred show that the remaining depth of the socket at stripping was 0.17 mm to 0.58 mm for the Astra system, and was 0.54 mm to 1.13 mm for the Zimmer system. From the design of the driver and the socket, one would expect that the Astra system to have stripped with higher values of remaining depth of the socket. The reason was that the taper of the driver would leave a greater gap between the driver and the wall of the socket as the driver was being raised higher by the debris. The results of our study showed the opposite.

Microhardness study showed that divers of both systems were made with materials of higher hardness than those of the respective abutment screws. Such selection would assure that the driver would last longer. While the hardness of the abutment screw are about the same for both systems, the hardness of driver by Astratech is harder than that of Zimmer by 27% (670 Kg/cm^2 vs. 525 Kg/cm^2;

Table 4-3). It appears that a hardness of 670 Kg/cm^2 is strong enough to resist plastic deformation in the present experimental design. It is likely that the plastic deformation exerted on the driver by Zimmer has lowered its resistance to stripping.

Reliability of the Experimental Data

It is important to point out that the reported depth of debris where stripping occurred does not necessary reflect the minimum depth of debris of stripping. In fact, the stripping should have occurred at a lower depth, if we had added debris to the socket in smaller increments. A more ideal study design would be to raise the screwdriver in smaller fixed equal increment; the approach should yield more precise values. Since stripping resulted from plastic deformation of the metal, examination of the internal walls of the socket for evidence of the plastic deformation could also help establish the depth of stripping. We made impression of the worn socket using PVS impression material and examined under light stereo microscope, but were limited by the magnification power of the scope. We also sectioned the worn screws and polished the surface for metallurgical examination but could not distinguished areas of stripping due to limitation of the microscope.

Since the debris clinicians encountered in clinical situation are often cotton pellet or composite resins, it would be more ideal if we had used these materials instead of “prop” powder to mimic the clinical situation. We investigated the issue and concluded that the size of the abutment screw was very small and using of clinical relevant material would not allow us to control the depth of debris like we could do with the powder of “prop.”

Effect of Angulations

The second part of the hypothesis was that angulation of the screw driver tip in the screw head socket can lead to stripping of the inner walls of the screw head. We have already discussed several scenarios when insertion of a screwdriver in the head of the abutment screw with angulation can happen. Logically, even if the clinician places the screwdriver with angulations, once the driver is engaged in its seat, it should be directed into place with the proper angulation. In this study we elected to investigate the situation where the screwdriver is prevented from readjusting and complete seating due to the presence of a barrier (long prosthesis) or an undercut (remaining composite).

Experimental Design

As described in the section of methodology, an abutment was first fixed in a respective implant with the respective screw, then the corresponding driver was inserted fully in the socket of the screw. With the finger pressure, the driver was forced sideway to the extreme and the joint area was stabilized with a rigid PVS impression material. An implant block was then made with the implanted seated with an angulation with a device described earlier (Figure 3-3). The design and the guiding block (Figure 3-8) used allowed us to maintain the same angulation even when the drive was being raised to simulate interference of any buildup within the abutment chamber.

We are aware that as the driver was being raised, there would be additional space for greater angulation. To take advantage of the space to extend the degree of angulation would mean one implant block for each extended angulation. Due to limited number of implants made available to us, we elected to study only one fixed angualtion for both systems.

Depth of Stripping

The results show that when the screwdriver is angulated and inserted all the way in the socket, stripping didn't occur. One might think that angulations would cause tripping early on, yet, stripping didn't occur in depths lower than 1.19mm. Since the driver was raised by adding spacers between mounting block and the guiding block, it would be more appropriate to state that stripping had occurred between 0.93 (the total height of the spacer before adding the last one) and 1.19 mm of depth. We made this note based on the fact that we had observed that "stripping" always occurred at the loosening phase of the first cycle.

One logical explanation of stripping at such a high depth would be that when the driver was angulated in our experimental design, there were at least two points of contact (Figure 5-7). One would be a corner of the driver or one edge of the driver tip nudged against the flat wall of the socket; the other one would be the one flat surface of the driver pressed against the top of the screw. Depending upon the pressure exerted in the socket of the screw, the driver might have firmly in contact with socket wall.

As the screwdriver turns, the screw will also turn with it. Because of angulation and the clearance between the driver and the socket, only some of the six corners would nudge into the wall of the socket at any given moment, and the flat surface of the driver rolled against top of the socket. Apparently the pressure exerted in the socket was high enough to keep the screw turning till the driver was raised beyond 0.93 mm from the fully seated position (Figure 5-8).

Appearance of the Driver after Tests

Driver by Zimmer shows obvious flattening at the corner (Figure 4-3C). It is an indication of high stress level during test. One would expect greater degree of plastic

deformation inside the socket where the driver touched. There is no sign of wear on the remaining part of the corners away from the driver tip. It is an indication that either the driver did not roll against the top edge of the screw at all, or some plastic deformation (too small to be observed) had occurred due to its relative low hardness.

For the Astra system, there is no sign of plastic deformation as in the study of improper seating. However, there was a zone of dark deposits on the flat surfaces of the driver extended up to 1.2 mm from the tip of the driver. Again the hardness of the Astra driver is high enough to resist plastic deformation by the pressure occurred during testing. The driver is likely to have rolled against the top edge of the socket and being a harder metal than that of the screw, some wear debris had been generated and deposited on the driver. This zone of debris deposit is identified by a pair of arrows in Figure 4-2C.

The length of the driver used in the study could have contributed to the difference in the appearance of the driver after test. The length of Astra driver used was 35 mm and the length of Zimmer driver was 23 mm. Longer driver shaft might have made the Astra driver contact with the top of the socket continuously through the entire testing period.

Reliability of the Experimental Data

The data indicate that angulations may not sound as bad we thought it could have been. However, we did observe phenomena that did not appear in the study of the effect of incomplete seating. At the end of the study of each test, when we removed the screw from the implant completely, we found metal debris in the implant and noticed slight bending of the screw shaft. Both phenomena clearly indicate that the screws have been subjected to under certain level of stress by the driver.

Clinically when the restorative dentist turns a driver which has been inserted in the socket with angulation, he may face two possible scenarios. First, the driver will simply fall out due to lack of engaging of the two components. Second, the restorative dentist applies pressure to keep the driver engaged and then turns the driver. The level of pressure needed would depend on individual case. Our study design fits the second scenario, and there is possibly no limit on the level of stress that may occur, because our device is rigid and would not allow the driver to fall out of the socket. Some modification of the device is needed to address that scenario.

In spite of the question raised in the last paragraph, it is clear that negative long-term effects of angulation not only on the screw head, but also the screw threads and possibly the thread inside the implant.

Figure 5-1. Astra abutment screw (left) and Zimmer abutment screw (right). (Photo courtesy of Haya Alabhool)

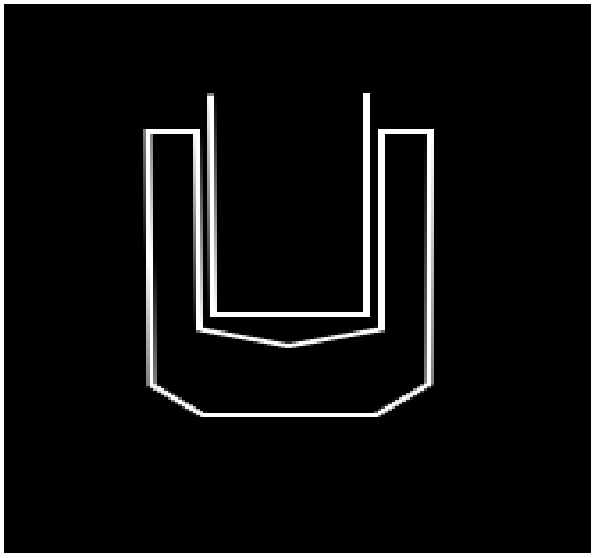

Figure 5-2. Illustration of how the straight Zimmer screwdriver fits inside the screw head leaving a uniform gap around it. (Illustration courtesy of Haya Alabhool)

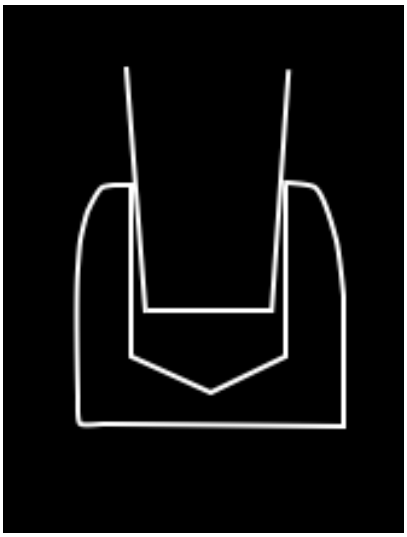

Figure 5-3. Illustration of how Astratech screwdriver fits inside the screw head. The screwdriver is in contact with the socket walls at the top of the socket only. (Illustration courtesy of Haya Alabhool)

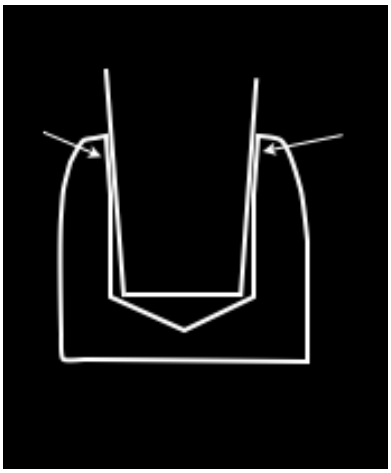

Figure 5-4. Relationship between Astratech screwdriver and abutment screw after multiple uses. The points of contact between the screwdriver and the inner wall of the socket go through plastic deformation and are shaped like a bevel, which allows the screwdriver to be seated further down the socket. (Illustration courtesy of Haya Alabhool)

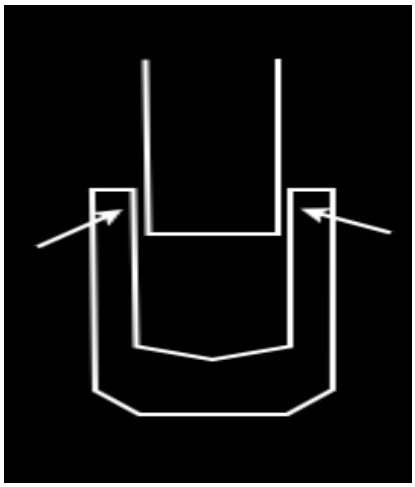

Figure 5-5. Relationship between Zimmer screwdriver and abutment screw as the driver is raised. The contact area is decreased (arrows) leading to an increase in stress and potential stripping due to plastic deformation of the socket walls. (Illustration courtesy of Haya Alabhool)

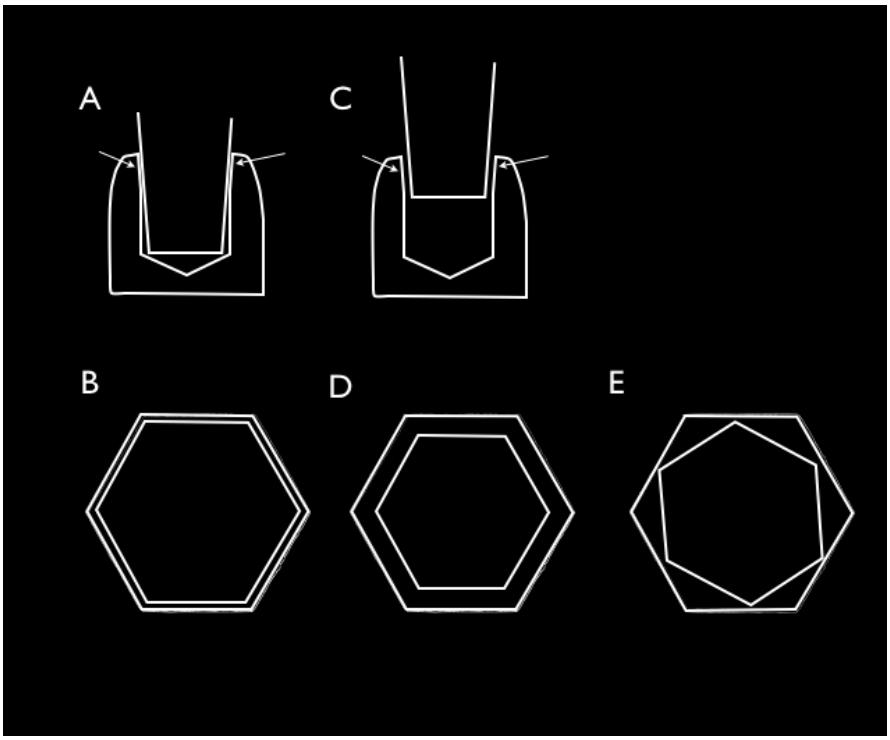

Figure 5-6. Relationship between Astratech screwdriver and abutment screw as the driver is raised. After multiple uses, the top of the socket walls are beveled permitting further seating of Astratech screwdriver down the socket (A and B). As the screwdriver is raised, the gap between the driver and the wall of the socket wall will increase (C and D). At certain gap width, when the driver is turned, its six corners could barely touch the wall of the socket and (Illustration courtesy of Haya Alabhool)plastically deforms the area of contact overcoming the resistance by the socket (E).

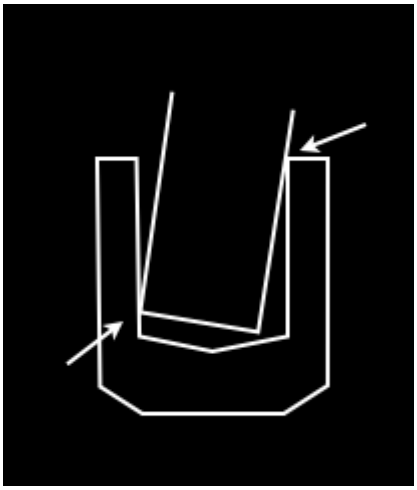

Figure 5-7. When the screwdriver is placed at lower depths in the screw socket.angulations permits at least town point contact between the screwdriver and the wall socket (arrows) (Illustration courtesy of Haya Alabhool)

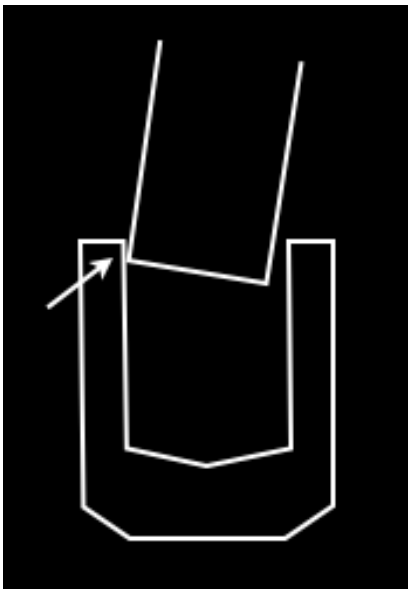

Figure 5-8. In depths higher than 0.93 mm, stripping occurred. (Illustration courtesy of Haya Alabhool)

CHAPTER 6
SUMMARY AND CONCLUSION

This in-vitro study showed that incomplete seating of the screw driver tip in the screw head socket can potentially lead to stripping of both Astra and Zimmer abutment screw heads. It also showed that angulation of the screwdriver tip in the screw head socket can potentially result in stripping.

The investigators of this study realize the limitation of the experiments, and recommend further studies to be conducted to overcome these limitations. With more advanced equipments the screws can be examined after stripping to study the stripping pattern, and determine if what occurred was actually stripping or just lack of contacts because of the previously described geometries of the screwdriver tip, especially Astra's. Also, the screwdriver tips can be examined under more advanced camera and microscope to study the effect of both debris and improper angulations on the screwdriver. For the angulations experiment, a larger number of screws can be examined, and more angulation values can be compared. In addition, the effect of angulations on the screw threads can be looked at.

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BIOGRAPHICAL SKETCH

The author, Haya Alabhool, was born in 1980 in Kuwait. She grew up in Kuwait City, Kuwait. In 1998, she enrolled at Kuwait University and graduated in 2002 with a bachelor in medical sciences. In 2005, Alabhool graduated from Kuwait University School of Dentistry, with a Bachelor of Dental Medicine degree. The author worked for the public health system of Kuwait from 2005 to 2008. In July 2008, she enrolled in the Graduate prosthodontics program at the University of Florida. After graduation with a Master of Science in dental sciences with a specialization in prosthodontics from the University of Florida in May of 2010, she plans to return to her beloved country, Kuwait, and her lovely daughter, Dalia, and work for the public health system.